Decarbonised Energy Systems Roadmapping for Ireland

Report 2: December 2025

NEXSYS

1. Executive Summary

Introduction: The Strategic Imperative of Net Zero for Ireland

The global and national imperative for the energy transition has never been more pressing. 2024 was a year of unprecedented global temperatures, exceeding the 1.5°C threshold established in the Paris Agreement. Ireland has not been immune to these shifts, recording a greater number of significant storms as the local climate becomes warmer and wetter.

In this context, Ireland's existing plan to reach net zero represents not just an environmental necessity, but a feasible strategic pathway to 2050. While total final energy consumption and fossil fuel use have recently increased, Ireland's energy-related emissions fell for the third consecutive year in 2024. This demonstrates that the decoupling of economic activity from emissions is underway. The challenge now is to accelerate this progress. The ambition contained in the Climate Action Plan 2025 is grounded in achievable technological pathways, provided that policy implementation shifts from target-setting to urgent, material delivery.

The 2025 NexSys Roadmap seeks to contribute to this decarbonisation pathway by offering an up to date summary of the NexSys programme's research contextualised around the current decarbonisation and sustainability policy challenges which Ireland now faces. For ease of reference, the Roadmap is presented with 4 key chapters, each focusing on a collection of thematically interrelated NexSys research; Energy Systems, Renewable Energy, Energy and the Built Environment and Transport. Key policy insights drawn from NexSys research from each of these chapters have been summarised in an annex at the end of this Roadmap Report

Energy Systems: Three Pillars of Transition

This Roadmap identifies three interdependent pillars that underpin the feasibility of the net-zero energy system, Electrification of Demand, Decarbonisation of Supply and Grid Infrastructure Upgrades. Integrating these pillars requires a "whole of system" approach. For instance, increased demand side electrification provides opportunities for the demand-side flexibility needed to balance the system with higher levels of wind and solar power. Green hydrogen also helps supply-side flexibility and supports difficult to decarbonise sectors such as transport.

Electrification of Demand: Decarbonisation relies heavily on electrifying heat and transport, which currently account for over 75% of energy-related emissions. While progress has been slower than targeted, with EV uptake and heat pump installations currently tracking behind 2030 goals, this Roadmap emphasises that overall targets remain technically viable if deployment rates are accelerated. Research on behavioural attitudes to clean energy technologies indicate a general willingness to invest in retrofitting and heating upgrades, but cautions that this may not necessarily translate into actual adoption without more targeted policy measures. In terms of EV uptake policies such as the ban on the sale of internal combustion engine cars in 2035 is shown to have a very decisive impact.

It is also important to emphasise that the adoption of clean energy technologies provides new opportunities for consumers to participate in system flexibility. Dynamic or Time of Use electricity tariffs in combination with sufficient flexible demand can lead to reduced energy bills. For example flexible EV charging and Vehicle to Home/Grid technology can potentially lead to electricity bill savings of 20-30% while also benefiting the grid.
The recent adoption of a Private Wires Policy framework is an interesting development with potential opportunities for enabling more self supply for industry and large energy users. However at this early stage and without the full enabling legislation it is difficult to assess the impact.

A central message of the 2025 Roadmap is the critical need to kick-start emerging technologies now to ensure they are available at scale when needed in the 2030s. The report highlights Green Hydrogen as a prime example of where immediate action is required to reap future benefits. While electricity will do the heavy lifting for decarbonisation, green hydrogen or its derivatives may be useful for hard-to-abate sectors like heavy transport, high-grade industrial heat, and dispatchable power generation. However, there is a risk that Ireland could miss the opportunity to develop an indigenous hydrogen industry. If infrastructure for hydrogen production is not initiated immediately, Ireland may become reliant on imports, undermining energy security.

Decarbonisation of Supply: Decarbonising Ireland's electricity supply will require a mix of variable renewable generation, storage, and clean dispatchable power plants. Decarbonisation of the wider energy system will furthermore require a significant supply of clean fuels.

The continued buildout of renewable generation is critical to decarbonisation efforts. The pace of addition of onshore wind has significantly slowed in recent years, to the point where it is now very unlikely that the 2030 target of 9 GW will be achieved. In contrast the pace of addition of PV has been quite rapid and if this pace of growth is maintained then it is conceivable that the target of 8 GW PV might be achieved. Progress on build-out of offshore wind to date has been very slow and it is highly unlikely that the 2030 target of 5 GW will be met. Considering the longer term targets for renewable capacity needed for the net-zero electricity system, as proposed in EirGrid's Tomorrow's Energy Scenarios, these are achievable, but will require a significant focus on speeding up delivery and maintaining policy certainty for developers.

The need to speed delivery is particularly acute for offshore wind which remains a cornerstone of Ireland's decarbonisation strategy. Offshore wind is not only central to supplying electrical demand, but will also be critical to delivering on a green hydrogen strategy. However, delivery risks are high due to planning delays and supply chain constraints. A lack of marshalling port capacity has been identified as a critical barrier that could stall the rollout even after planning issues are resolved.

Dispatchable generation will remain a critical part of the electricity system. In the medium term there are very few economically feasible options other than gas fired plants. In the longer term these should transition to clean alternatives with biomethane, green hydrogen, or carbon capture and storage being options. However, considering the limited potential for indigenous biomethane and the immaturity of other technologies there is still considerable uncertainty about how this transition will proceed. Nuclear in the form of Small Modular Reactors is also a possibility, but deliverability has got to be questioned considering the legislative changes needed and the difficulty around public acceptance.

Grid Infrastructure Upgrades: The grid must be reinforced to transport renewable generation to demand centres and to facilitate the electrification of demand. With a significant increase in planned investment in grid infrastructure by 2030, Ireland is taking significant steps to address the network constraints that currently cause renewable dispatch down. Other critical infrastructure upgrades include the buildout of sufficient public charging stations to cater for private and heavy duty vehicles, and the transition of the gas network to facilitate the transport of biomethane and hydrogen.

Built Environment: Electrification & Heating

The residential sector accounts for roughly a quarter of energy consumption, making the built environment a key focus for decarbonisation.

Retrofitting & Electrification: The CAP 2025 targets include retrofitting 500,000 homes to a B2 BER standard and installing 600,000 heat pumps. Progress against these targets has been slow and current trajectories indicate that these targets will be missed by a considerable margin. There is an urgent need for policies to reduce upfront costs and de-risk retrofitting (for example, expanded grants, low-interest financing, or tax incentives). Gaining a deeper understanding of behavioural factors and understanding why households adopt technologies is necessary in addition to financial incentives.

District Heating: There is significant untapped potential in district heating, with the SEAI heat study indicating that over 50% of buildings would be suitable for connection to a district heating system. The CAP25 has a target of 2.7 TWh of heat delivered by 2030. Practical implementation is already underway through the Tallaght District Heating Scheme and the developing Dublin District Heating System. While high capital costs and regulatory uncertainty have historically slowed progress, the Heat Networks and Miscellaneous Provisions Bill 2024 and new dedicated funding—including a €5 million pre-construction fund and up to €100 million in planned capital support—provide a clearer pathway for infrastructure rollout. Integrating large energy users, such as data centres, into district heating networks could turn a challenge (high energy demand) into a solution (waste heat utilisation). By integrating with the renewable-led power grid, district heating can also offer essential flexibility, shifting consumption to periods of high renewable output.

Building Energy Flexibility: In general buildings offer significant potential for implementing demand side flexibility. Research from NexSys has been investigating the concept of transforming buildings into "active nodes" that generate, store, and trade energy. A particularly interesting opportunity lies in Peer-to-Peer (P2P) trading, which allows communities to exchange power directly, enhancing efficiency and lowering costs. However, scaling such models requires overcoming regulatory hurdles, data-sharing restrictions, and technical standardization issues.

Water-Energy Nexus: The connection between water conservation and energy savings is an often-overlooked "win-win." Water and wastewater utilities account for a large share of municipalities' electricity use, while water-related energy consumption represents 20% of Irish residential buildings' energy demand. Reducing water usage directly reduces the energy required for treatment and heating, offering a low-hanging fruit for efficiency.

Energy Poverty: The energy consumption of buildings has a profound impact on the wellbeing of building residents, and is felt most acutely by those at risk of or experiencing energy poverty. Using data from the Growing Up in Ireland survey, a NexSys investigation of the impacts of residential energy and transport poverty on children and young people is the first to establish a link between these forms of poverty and mental health.

Transport: Alternative Fuels & Modal Shift

Transport remains the largest share of energy consumption in Ireland (43.4%), with 94% of this demand still met by fossil fuels.

Electrification of Private Transport: While EV targets are challenging and progress is behind targets, the technology is mature and adoption is increasing. However, to achieve full private fleet electrification the policy direction must remain clear. The roadmap suggests that a ban on Internal Combustion Engine (ICE) vehicle sales by 2035 is necessary to meet long-term emission goals, as current adoption rates (including hybrids) are insufficient.

Heavy Goods & Freight: The heavy goods vehicle sector remains heavily reliant on diesel, with only a very small number of battery electric good vehicles being adopted and these are disproportionately concentrated in the smaller, lighter commercial classes. These largest tonnage sectors present the greatest challenge for transition and may require alternative solutions beyond electrification. The nationwide rollout of high-power charging infrastructure suitable for commercial vehicles is urgent. Investments need to be focused on supporting improved Depot Charging to offset high installation costs which often require expensive grid upgrades. For the heavy goods vehicle (HGV) sector, operators may prefer hydrogen for long-distance, heavy-load operations where batteries are constrained. Life cycle assessments indicate that green hydrogen is the least environmentally harmful option for this sector, reinforcing the need for the hydrogen demonstrators outlined in the Energy Systems chapter.

Aviation: The energy demand for international aviation increased by 12.9% in 2023. The ReFuelEU Aviation Initiative introduced as part of the 'Fit for 55' package mandates a proportion of all jet fuel used within the EU aviation sector to be sustainable aviation fuel (SAF), with the level increasing every five years. By 2050, 70% of all jet fuel will need to be SAF. and at least half of all SAF (or 35% of all jet fuel) will need to be synthetic. NexSys findings identify the critical need for green hydrogen and a mix of other sustainable fuels for decarbonising this sector. However, in all cases the costs are substantial and fiscal support is required for achieving the 2030 and 2050 targets.

Transport Poverty: NexSys research highlights that transport poverty in Ireland creates a "double energy vulnerability," where low-income households struggle with both home energy and transit costs. Rural residents are especially at risk, facing three times the likelihood of transport poverty compared to Dubliners, often resulting in "forced car ownership" or social isolation. Vulnerable groups, including children and the elderly, suffer educational and mental health disadvantages due to poor connectivity. Addressing this requires official national indicators, improved data collection, and targeted investments. Recommended actions include expanding school bus eligibility, increasing active travel infrastructure, and extending Local Link services to bridge spatial inequalities.

Conclusion: Feasibility and Delivery

Ireland's plan for a net-zero energy system, while ambitious, is grounded in physical and engineering reality. It is true that some of the pathways are more clear than others and some rely on technologies which are currently immature and hence expensive. Many of the technologies required to achieve the 2030 and 2050 targets; renewable generation, electrification, and grid flexibility are largely established or in advanced development. Others such as green hydrogen and other clean fuels require further trialling, demonstration and support to mainstream them, but this support needs to happen now in order to be ready for the net-zero system. The feasibility of much of the plan relies on the speed of implementation and the gap between ambition and outcome is not technological but operational. By urgently advancing grid upgrades, encouraging dynamic demand management, and investing in demonstrators and infrastructure for hydrogen and ORE, Ireland can convert its ambitious plan into a functioning, decarbonised energy system. The research presented in this Roadmap suggests that the path to success is clear and within Ireland's capability to deliver.

2. National & International Context

The global energy landscape is experiencing rapid changes, underscored by both unprecedented momentum toward renewable sources and increasing demand in some regions and sectors. Geopolitical shifts, technology costs and financing are contributing to regional variations in predictions to 2030. For example, the IEA found that global renewables could more than double by 2030, with 80% of new clean energy capacity expected to come from solar power.[1] Renewable energy outpaced coal in the first half of 2025 for the first time, with fossil fuel generation falling in China and India, but growing in the EU and the USA.[2]

Ireland's energy-related emissions reduced for the third consecutive year in 2024, including reductions in both the electricity and transport sectors' emissions. However, total final energy consumption and overall use of fossil fuels have increased.[3] Current EPA projections using both existing and additional measures suggest that Ireland will miss its greenhouse gas emissions reduction target by a considerable amount.[4] Some uncertainty in the offshore wind sector is evident globally.[5] Ireland's offshore wind ambitions also continue to face significant challenges, some outlined further in this report.

At the same time, the realities of human-induced climate change are being felt globally, regionally and nationally. 2024 was a year of unprecedented and record-breaking global temperatures and corresponding human and environmental impacts.[6] The year's average temperature exceeded the scientifically informed threshold in the Paris Agreement of 1.5°C above the pre-industrial level, a level that may "significantly reduce the risks and impacts of climate change".[7] Europe saw its hottest year on record, with extreme weather events across the region.[8] A record number of named storms in Ireland's storm season were recorded, as Ireland's climate has become warmer and wetter.[9]

In the context of this challenging and ambiguous outlook, Ireland's transition to a just, decarbonised and electrified energy system requires urgent and material action.

---

[1] International Energy Agency. "Renewables 2025: Analysis and Forecasts to 2030." *www.IEA.org*, IEA, 2025, iea.blob.core.windows.net/assets/76ad6eac-2aa6-4c55-9a55-b8dc0dba9f9e/Renewables2025.pdf.

[2] Wiatros-Motyka, Małgorzata, and Kostantsa Rangelova. *Global Electricity Mid-Year Insights 2025*. EMBER, 7 Oct. 2025, ember-energy.org/app/uploads/2025/10/Global-Electricity-Mid-Year-Insights-2025-PDF.pdf.

[3] "National Energy Balance." *Sustainable Energy Authority of Ireland*, Sept. 2025, www.seai.ie/data-and-insights/seai-statistics/key-publications/national-energy-balance.

[4] Environmental Protection Agency. "Indicators / Targets." *EPA*, May 2025, www.epa.ie/our-services/monitoring--assessment/climate-change/ghg/indicators--targets.

[5] International Energy Agency. "Wind." *www.IEA.org*, IEA, 2025 https://www.iea.org/energy-system/renewables/wind

[6] Copernicus Climate Change Service. "Global Climate Highlights 2024." *Copernicus*, Jan. 2025, climate.copernicus.eu/global-climate-highlights-2024.

[7] UNFCCC. "The Paris Agreement to the United Nations Framework Convention on Climate Change." United Nations, 2015, https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

[8] Copernicus Climate Change Service. "Global Climate Highlights 2024." *Copernicus*, Jan. 2025, climate.copernicus.eu/global-climate-highlights-2024.

[9] *Storm Names - Met Éireann - the Irish Meteorological Service*. www.met.ie/forecasts/storm-names.

3. Overview of Key Policy Changes

Since the previous iteration of the NexSys Roadmap,[10] Ireland's energy and climate policies have been updated and reshaped in a number of key areas, underpinned by and interlinked with the updated 2025 Climate Action Plan. These policies are presented as essential steps towards achieving Ireland's legally binding 2030 carbon budgets and the 2050 climate-neutrality target.

However, while Government policy emphasises ambition and delivery, independent analysis and Government progress reporting suggests a more complex reality.[11,12] The policies collectively reflect a shift towards tighter demand management, new pathways for investment, and stronger consumer participation in flexibility, but there are risks around deliverability, cost allocation, distributional fairness, and legal complexity.

A critical reading is essential to distinguish between stated goals and credible outcomes, and to assess whether these changes can realistically position Ireland on track to meet its climate commitments.

Climate Action Plan 2025

The 2025 update to Ireland's Climate Action Plan restates Ireland's ambition to halve emissions by 2030 and reach climate neutrality by 2050, with renewed sectoral actions for electricity decarbonisation, grid reinforcement, electrification and demand measures.[13]

A headline target of at least 5 GW of offshore renewable energy (ORE) has been retained, despite slow progress in delivery of ORESS-1 projects, including the cancellation of the 450 MW Sceirde Rocks wind farm.[14]

A critical delivery gap remains. Independent bodies warn the Plan remains optimistic unless legally binding, funded, and implemented measures are prioritised. The Irish Fiscal Advisory Council and Climate Change Advisory Council estimate Ireland could face very large EU compliance costs (roughly €8–€26bn) if policies aren't delivered and have repeatedly

---

[10] NexSys. "NexSys Roadmap: Report 1." *.nexsys-energy.ie*, 2024, www.nexsys-energy.ie/nexsysresearch/nexsysroadmap.

[11] Irish Fiscal Advisory Council. "A Colossal Missed Opportunity: Ireland's Climate Action and the Potential Costs of Missing Targets." *www.fiscalcouncil.ie*, Irish Fiscal Advisory Council, Mar. 2025, www.fiscalcouncil.ie/a-colossal-missed-opportunity.

[12] Department of the Taoiseach. "First Progress Report of Climate Action Plan 2025 Published." *gov.ie*, 22 July 2025, www.gov.ie/en/department-of-the-taoiseach/press-releases/first-progress-report-of-climate-action-plan-2025-published.

[13] Department of Climate, Energy and the Environment. "Climate Action Plan 2025." *gov.ie*, 3 Sept. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2025.

[14] Fuinneamh Sceirde Teoranta. "Statement on Sceirde Rocks Windfarm." *Sceirde Rocks Windfarm*, 28 Apr. 2025, www.sceirderockswindfarm.ie/blog/2025/04/28/statement-on-sceirde-rocks-windfarm.

highlighted weaknesses in policy delivery.[15] Government progress reporting shows only partial delivery of near-term actions. The first progress report of Climate Action Plan 2025 flagged only some actions completed on time, which is consistent with past gaps between plans and outcomes.

On the demand side, the electricity system faces real limits: concentration of new, large electricity demands (notably data-centres) already consumes a rising share of Irish electricity and threatens to crowd out domestic and low-carbon uses unless demand is shaped. Data centre demand is already very considerable and is rising (approx. 21% of electricity in recent years).[16] The National Energy Demand Strategy (NEDS) will be critical in managing this demand, but further detail may be needed in relation to how much additional demand proposed flexibility measures will enable the system to absorb.

CRU Large Energy Users Connections Policy

In February 2025 the Commission for the Regulation of Utilities (CRU) published its proposed decision paper on the Large Energy Users connection policy and invited feedback from interested parties. A final decision on the policy was issued in December 2025.[17]

The decision tightens the pathway to grid connections for large energy users (especially data centres). This includes more strict technical and locational conditions, stronger assessment of climate compatibility, and an emphasis on onsite and nearby dispatchable resources, storage or demand flexibility matching their import capacity which should also be available to participate in wholesale electricity markets. Data centres above a certain minimum size are also required to meet at least 80% of their annual demand with additional renewable generation.

Through this decision, the CRU is explicitly using its connections policy to reconcile grid capacity with Ireland's climate targets. A significant part of this energy usage is related to cooling requirements of data centres, and NexSys research is exploring how these large energy users can potentially integrate into national district heating objectives.

Private Wires Policy Statement

On the 15th of July 2025, the Government adopted a Private Wires Policy Statement which provides a framework to allow private parties to build, own and operate private electricity lines ("private wires") connecting generation, storage and loads directly.[18]

[15] Halpin, Padraic. "Laggard Ireland May Face 26 Billion Euro EU Climate Bill, Watchdogs Warn." *Reuters*, Thomson Reuters, 4 Mar. 2025, www.reuters.com/sustainability/climate-energy/laggard-ireland-may-face-26-billion-euro-eu-climate-bill-watchdogs-warn-2025-03-04.

[16] CSO. *Data Centres Metered Electricity Consumption 2023 - Central Statistics Office*. 23 July 2024, www.cso.ie/en/releasesandpublications/ep/p-dcmec/datacentresmeteredelectricityconsumption2023/keyfindings.

[17] *Review of Large Energy Users Connection Policy | CRU.ie*. 12 Dec. 2025, www.cru.ie/publications/28573.

[18] Department of Climate, Energy and the Environment. "Private Wires Policy Statement." *gov.ie*, 15 July 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/private-wires-policy-statement.

The Policy Statement provides an overall framework for private wires. Formal introduction of private wires will require full enabling legislation, which is currently being drafted and is due for publication in Q4 of 2025.[19] Practical implementation of private wires will require planning and network codes, licensing, technical standards and coordination between DCEE, CRU, EirGrid / ESB Networks and local planning authorities.

The stated aim of the policy is to unlock private investment in infrastructure, accelerate renewable energy sources (RES) rollout, facilitate EV charging, and enable more self-supply opportunities for large energy users. However, concerns have been raised that with the proliferation of data centres in Ireland, private wires risk creating a parallel grid network for large energy users, undermining funding for the national grid and locking in additional demand for fossil fuel generation, particularly at times of low RES generation.[20] [21] NexSys researchers have examined these issues in more detail as part of this Roadmap.

Dynamic Electricity Pricing

On the 26th of September 2024, the CRU published a decision paper on dynamic electricity tariffs, whereby half-hourly prices for electricity customers follow wholesale market conditions and are changed accordingly.[22] In April 2025, the CRU extended the timeline for suppliers to introduce standard dynamic price contracts while systems and consumer protections are prepared. Suppliers will now be obliged to offer a standard dynamic price contract from the 1st of June 2026.

The overarching policy objective underlying dynamic pricing is to use price signals to shift demand away from high-price peak periods and make better use of variable RES-E. However, analysis from NexSys researchers suggests that peak demand is relatively inflexible, even under a dynamic price contract. Furthermore, Ireland's opt-in approach for customers availing of dynamic pricing means uptake of dynamic pricing may be slow, thereby reducing any potential impact on demand response. Additional measures such as appliance automation and bill protection may be necessary to realise the potential of dynamic pricing to support greater demand flexibility. The role of automated flexible EV charging and Vehicle to X technology in providing price sensitive flexibility is analysed later in this report.

---

[19] House of the Oireachtas. *Energy Policy: Parliamentary Question [49010/25]*. 26 Nov. 2025, www.oireachtas.ie/en/debates/question/2025-09-18/95/?highlight%5B0%5D=49010&highlight%5B1%5D=25.

[20] Friends of the Earth. "Friends of the Earth Raises Concerns Over Government's Private Wires Policy and Risk of a Two-Tier Energy System | Friends of the Earth." *Friends of the Earth*, 6 June 2022, www.friendsoftheearth.ie/news/friends-of-the-earth-raises-concerns-over-governments-privat.

[21] Irish Congress Of Trade Unions. "Why 'Private Wires' Policy Could Cost Taxpayer Billions in EU Penalties and Increase Electricity Charges." *The Irish Congress of Trade Unions*, 25 July 2025, www.ictu.ie/blog/why-private-wires-policy-could-cost-taxpayer-billions-eu-penalties-and-increase-electricity.

[22] Commission for Regulation of Utilities. "Dynamic Electricity Price Tariffs." *CRU.ie*, 2025, www.cru.ie/publications/28339.

In addition to this, care should be taken around dynamic pricing's potential to further benefit those who have the most capacity to shift their demand due to their household's ability to invest in relatively expensive appliances such as batteries and solar PV - this creates distributional effects whereby those who are least impacted by energy price increases are further able to reduce their bills, while those in or at risk of energy poverty are left further behind.

Offshore Renewable Energy (ORE): DMAP & Industrial Strategy Implementation

In September 2025, the Government published the National Designated Maritime Area Plan (DMAP) for Offshore Renewable Energy (ORE) Proposal.[23] The Proposal sets out how the planned National Designated Maritime Area Plan (DMAP) for offshore renewable energy (ORE) is to be developed.

ORE is central to Ireland's electricity decarbonisation ambitions, but delivery constraints (consenting, grid export capacity, supply chain, finance, environmental assessment and co-use of sea space) make these targets high-risk. The DMAPs and auction frameworks are necessary first steps, but they do not guarantee completion of projects in line with targets, and delivery on past auction outcomes for offshore wind (ORESS-1) shows procuring projects on schedule has been harder than expected. NexSys researchers have identified that a lack of marshalling ports represents a critical barrier to the proposed rollout of ORE in Ireland.[24] This will become more apparent if current planning delays in ORESS-1 are resolved and these projects move to the delivery phase.[25]

---

[23] Department of Climate, Energy and the Environment. "National Designated Maritime Area Plan (DMAP) for Offshore Renewable Energy." *gov.ie*, 12 Sept. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/national-designated-maritime-area-plan-dmap-for-offshore-renewable-energy.

[24] Carton, James G., et al. "Missing the Boat: Port Infrastructure as a Critical Barrier to Offshore Wind Energy Development in Ireland." *nexsys-energy.ie*, University College Dublin, Oct. 2025, www.nexsys-energy.ie/t4media/NexSys_Policy_Brief__ORE_Port_Infrastructure.pdf.

[25] Wind Energy Ireland. "Offshore Wind Action Plan: How Ireland Can Accelerate Offshore Wind Delivery." *windenergyireland.com*, Wind Energy Ireland, May 2025, windenergyireland.com/images/files/web-offshore-wind-strategy-may-2025-12-page-a4-260525-am.pdf.

4. Energy Systems

Introduction

There are three critical, interdependent pillars for achieving a net-zero energy system. The first is the electrification of energy demand, particularly in heating and transport, which currently depend heavily on fossil fuels; Chapters 6 and 7 of this Roadmap focus on these sectors and the technical and societal changes required. Second is the decarbonisation of electricity supply using a mix of variable renewable generation, storage technologies and clean dispatchable plants, with key elements of renewable supply covered in Chapter 5. The third pillar is upgrading the electricity grid so that renewable generation can be reliably transported to centres of demand, ensuring a stable supply of electricity across the country at all times. This chapter examines the measures to integrate these three elements—demand electrification, clean electricity supply, and grid reinforcement— within the overall energy system.

Electrification of Energy Demand

Energy system emissions reductions heavily relies on electrification of the heating and transport sectors, as they are almost entirely based on fossil fuels and make up 33.3 and 43.6% respectively of energy-related CO2 equivalent emissions in Ireland[26]. In addition to emissions reductions, the electrification of demand has wider benefits in terms of improving energy efficiency, resulting in overall energy demand reductions.

Figure 4.1 shows one example of the overall energy demand in Ireland in various sectors and how it might evolve to meet high targets for electrification by 2050. In the figure, the energy demand for each sector is divided into demand which is provided by electricity and demand which is provided by other fuels (e.g. hydrogen, biofuels, biomass, etc.). This illustrative example assumes almost full electrification of residential heating demand, full electrification of private vehicle demand, electrification of the low grade heating portion of industrial heating demand and includes aviation demand in transport. Although such projections are subject to a large degree of uncertainty and different scenarios can be proposed based on different assumptions, there are some important general points to be made.

The move to electrification of heating and transport achieves very significant overall energy efficiency improvements with total demand in these sectors decreasing as electrification increases. In terms of total energy requirements these efficiency improvements will be partially offset by overall increased demand from a growing population and economy.

There will remain significant portions of energy demand which will have to be supplied by means other than direct electrification. These include medium and high grade industrial heating demand, heavy duty transport demand and aviation fuels. For decarbonisation of the industrial heating demand the initial emphasis is on use of biomass, biomethane and

[26] Sustainable Energy Authority of Ireland, "Energy in Ireland 2025 Report", www.seai.ie/sites/default/files/publications/Energy-in-Ireland-2025.pdf

improvements in energy efficiency with green hydrogen a possibility in the longer term. For heavy duty transport viable decarbonisation options include biofuels, battery electric and hydrogen fueled. Battery electrification is gaining ground globally and looks set to dominate, although there are still significant concerns around availability of charging infrastructure.[27] With the development of green hydrogen supply and infrastructure, fuel cell EVs might also emerge as a solution. For aviation fuels, ReFuelEU requires that by 2050 at least half of all sustainable aviation fuel be synthetic, or derived from renewable hydrogen and captured CO2 which equates to 35% of all jet fuel being synthetic. This points to a very high demand for green fuels across all of these sectors all of which may be difficult to supply from indigenous sources.

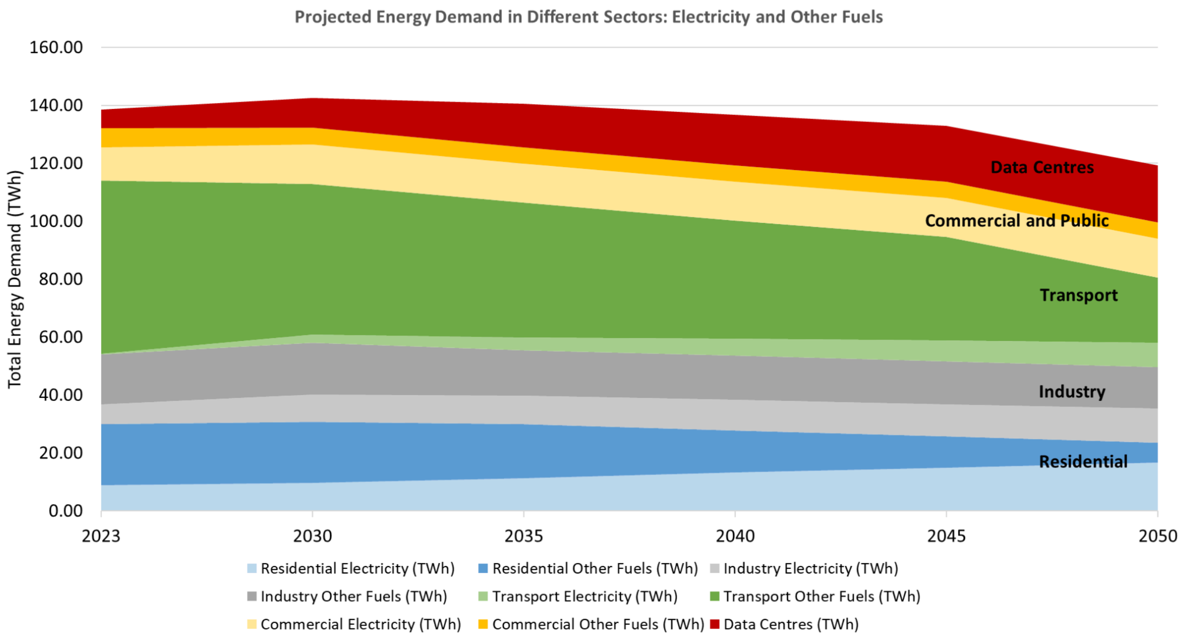

Figure 4.1: Example of projections for total energy demand by sector split into demand supplied by electricity and demand supplied by other fuels.

The above projections assume that electrification targets in the heating and transport sectors will be met. To date progress towards achieving near term targets for electrification has been slow.

The CAP 2024 target for private car fleet electrification is 30% of the total passenger car fleet and 845,000 private EVs by 2030. The interim 2025 target of 195,000 EVs (both BEV and PHEV) was slightly exceeded by November 2025; however, approximately 45% of these are plug-in hybrid vehicles (PHEV). In recent studies it was found that, under real world driving conditions, emissions from PHEVs are only somewhat lower (approximately 19%) than the

[27] Department of Enterprise, Trade and Employment. "Roadmap for the Decarbonisation of Industrial Heat." *enterprise.gov.ie*, DETE | Government of Ireland, June 2024, enterprise.gov.ie/en/publications/publication-files/roadmap-for-the-decarbonisation-of-industrial-heat.pdf.

emissions from a diesel or petrol car.[28] Therefore, although PHEVs are popular and growing in numbers, they cannot be considered in the same category as BEVs as regards emissions reductions. With EVs (battery EVs) currently accounting for approximately 14% of total annual private vehicle registrations the 2030 target of 845,000 private EVs is very unlikely to be achieved. The detailed modelling of passenger transport described later in the *Passenger Transport Modelling and Projections* section of the Transport chapter suggests that only the introduction of a ban on ICE and Hybrid vehicle sales in 2035 will have the impact needed to increase BEV usage and significantly reduce passenger vehicle emissions by 2050.

A key performance indicator of the Climate Action Plan 2024 also includes the installation of up to 280,000 heat pumps in new dwellings and 400,000 in existing dwellings by 2030.[29] From 2019, a cumulative total of 14,194 heat pumps had been retrofitted in existing households up to across Ireland by the end of 2024, supported by different Government-funded programmes.[30] It is clear that 2030 targets for electrification of heating and transport are now also very unlikely to be met. The *Uptake of Clean Energy Technologies* section below discusses research carried out in NexSys which attempts to better understand the determinants of take up of clean energy technologies.

Flexibility from the demand side is an important tool in facilitating supply-demand balancing which becomes increasingly challenging when more of the supply comes from variable renewable generation. The Climate Action Plan has the target of achieving 20-30% flexibility in the demand side by 2030. The introduction of *Dynamic Pricing* discussed later in this chapter is seen as a tool to encourage flexibility from the demand side. However this flexibility will not be realised unless there are sufficient electrical loads which can be shifted in time preferably in an automated manner. EV charging is one such load which could be used in different ways through vehicle to everything (V2X) technologies, to provide flexibility and NexSys research on this is discussed further in the *Vehicle to Grid Technology* section below.

As mentioned earlier in relation to **Figure 4.1** there is a very significant role for clean fuels to serve energy demand in medium/high grade industrial heating, heavy duty transport and sustainable aviation fuels. Green hydrogen is one of the fuels often discussed as a candidate to fulfill this demand side role. Additionally it may provide a fuel for clean dispatchable power generation. However, there is still a high level of uncertainty surrounding the production and demand volumes, costs and timings for green hydrogen. For example EirGrid's Tomorrows Energy Scenarios envisages hydrogen electrolyser capacities between 4.4 and 9.8 GW for green hydrogen in the All-Island system by 2050.[31] The national hydrogen strategy suggests a domestic demand for hydrogen between 4.6 and 39 TWh by 2050 with this very wide range

[28] Transport Environment. "Smoke Screen: The Growing PHEV Emissions Scandal." *transportenvironment.org*, T&E, 24 Oct. 2025, www.transportenvironment.org/articles/smoke-screen-the-growing-phev-emissions-scandal.

[29] Department of Climate, Energy and the Environment. "Climate Action Plan 2024." *gov.ie*, 12 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2024.

[30] Sustainable Energy Authority of Ireland. "National Retrofit Plan: Full Year Report 2024." *seai.ie*, SEAI, Apr. 2025, www.seai.ie/sites/default/files/publications/SEAI-Retrofit-Full-Year-Report-2024.pdf.

[31] EirGrid and SONI. "Tomorrow's Energy Scenarios 2023: Final Report." *eirgrid.ie*, EirGrid, 2024, cms.eirgrid.ie/sites/default/files/publications/TES-2023-Final-Full-Report.pdf.

again reflecting the high degree of uncertainty.[32] NexSys researchers have been investigating the role of *Green Hydrogen* in the Irish energy system and this work is discussed later in this chapter.

Grid Infrastructure Development

The development of the grid is critical for decarbonisation of the energy system. If the grid capacity and infrastructure is not sufficiently developed the renewable generation cannot be delivered to the demand centres, leading to wasted renewable energy (dispatch down) and delayed electrification of heating and transport sectors. Dispatch down of renewable generation due to network constraints is already a feature of the system with some regions of the country being more impacted than others. For example, dispatch down of wind in the North-West region was as high as 19% in 2024 with the majority being due to network constraints. For Northern Ireland the most recent SONI reports indicate 17.5% wind energy was dispatched down while 13.0% of solar was dispatched down, primarily due to grid constraints.

On the positive side there are significant grid development plans in place to address such issues, with the CRU recently approving an investment of €13.8bn for the Price Review 6 period from 2026 to 2030. This represents an 80% increase on the funding allowed under the previous price review. The investment is envisaged to address increased network and generation capacity, building of new offshore wind infrastructure, upgrading the network to support the electrification of heating and transport and improvements in grid resilience. Both EirGrid and ESB Networks have defined plans for the required network upgrades. There is always the risk however that timelines for delivery of some of the major projects may be affected by planning delays. Northern Ireland Electricity Networks have also responded to constraints in its most recent RP7 Price Control (2025-2031) with a £2.3Bn investment in electricity infrastructure. The building of privately owned grid infrastructure, i.e. private wires is another interesting emerging aspect of grid development and this is further discussed in the *Private Wires* section below.

Another critical consideration for electrification of transport is the provision of charging infrastructure. Zero Emissions Vehicles Ireland (ZEVI) has put forward a plan for the development of charging infrastructure covering both light duty vehicles and heavy duty vehicles on the main road networks in the country.[33] These plans are also being driven by European regulations through the Alternative Fuels Infrastructure Regulation (AFIR). AFIR establishes mandatory minimum alternative fuels infrastructure targets and obligations, to ensure that adequate recharging and refuelling infrastructure is in place across EU Member States.

The gas network infrastructure will also remain critical to the overall energy system decarbonisation efforts. As **Figure 4.1** above highlights, there will remain a significant energy

---

[32] Department of the Environment, Climate and Communications. *National Hydrogen Strategy*. DECC | Government of Ireland, July 2023, assets.gov.ie/static/documents/national-hydrogen-strategy.pdf.

[33] Zero Emission Vehicles Ireland, "National Road Network EV Charging Plan 2024-2030", https://www.zevi.ie/sites/default/files/2024-10/NR-Plan-English.pdf.

demand which may not be amenable to direct electrification. Gas Networks Ireland's roadmap for the network targets a network which will carry 100% renewable gas by 2045, made up of 30% biomethane and 70% green hydrogen with a separate national hydrogen network and a smaller regional network for biomethane.[34]

Uptake of Clean Energy Technologies

With residential sector accounting for about one quarter of total energy consumption and roughly 15% of the consequent carbon emissions, some of the key energy and climate policy priorities include promoting adoption of Clean Energy Technologies (CETs) in Irish homes that use electricity rather than fossil fuel combustion.[35] [36] In line with the EU and national level binding carbon emission targets, policymakers in Ireland are pursuing an ambitious plan for adoption of CETs in Irish homes through a range of grant schemes and monetary incentives.

In 2024, the adoption rate for the country as a whole appears to have slowed down for solar PVs and heat pumps, when compared with the previous year. Further, the adoption numbers across counties shows an inconsistent pattern, underlining the need for careful reflection and remedial policy measures. Mac Uidhir et al.[37] simulated two key policy targets for rapid diffusion of electric vehicles and significant deep retrofitting of residential buildings and found that unprecedented technology diffusion rates will be required to match Ireland's Climate Action Plan targets.

A key government objective in the delivery of climate targets focuses on societal behaviours towards environmental sustainability and citizens' engagement in sustainable investments in CETs (EVs, solar PVs and batteries, and heat pumps).[38] [39] [40] [41] Evidence suggests that there is a

---

[34] Gas Networks Ireland. "Pathway to a Net Zero Carbon Network." *gasnetworks.ie*, GNI, 2024, www.gasnetworks.ie/sites/default/files/docs/renewable/Pathway-to-a-Net-Zero-Carbon-Network.pdf.

[35] Sustainable Energy Authority of Ireland. "Residential Energy Statistics in Ireland." *seai.ie*, 2025, www.seai.ie/data-and-insights/seai-statistics/residential. These figures reflect measures installed under National home retrofit programmes, Community energy grants scheme, National home energy upgrade scheme and Solar PV scheme excluding Warmer home scheme.

[36] Department of Climate, Energy and the Environment. "Climate Action Plan 2024." *gov.ie*, DECC, 12 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2024.

[37] Mac Uidhir, Tomás, et al. "Achieving the unprecedented: Modelling diffusion pathways for ambitious climate policy targets." *Energy and Climate Change* 3 (2022): 100073.

[38] Ivanova, Diana, et al. "Quantifying the potential for climate change mitigation of consumption options." *Environmental Research Letters* 15.9 (2020): 093001.

[39] Meles, Tensay Hadush, and Lisa Ryan. "Adoption of Renewable Home Heating Systems: An Agent-Based Model of Heat Pumps in Ireland." Renewable and Sustainable Energy Reviews 169 (November 2022): 112853. https://doi.org/10.1016/j.rser.2022.112853.

[40] Psarra, Ifigenia, Ethemcan Turhan, and Fatemeh Ghassemialiabadi. "Zero carbon, some nuisance: Exploring the viewpoints of heat pump owners and their neighbors in Groningen, Netherlands." *Energy Sources, Part B: Economics, Planning, and Policy* 19.1 (2024): 2421924.

[41] Snape, J. Richard, Peter John Boait, and R. M. Rylatt. "Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling." *Energy Policy* 85 (2015): 32-38.

difference between what people intend to do or think and what they actually do in practice.[42] [43] [44] In the context of residential households, it is often seen that energy consumers do not invest in efficient products and technologies in their daily lives despite apparent benefits.[45] [46] [47] [48] Among the three technologies, the role of heat pumps is less understood by the general public in comparison to the high awareness and visibility of solar PV panels or electric vehicles.

Despite the rich and growing volume of literature in the past two decades, the field of clean energy technology adoption remains fragmented and difficult to navigate systematically due to conceptual pluralities, multiple explanations and inconsistent taxonomies. From a climate policy perspective, it is not only important to understand what are the observed market and non-market barriers in terms of households' willingness to pay for or intention to invest in CETs but also to identify the intrinsic factors underlying those drivers and barriers in the first place.[49] [50] [51]

UCD researchers have surveyed Irish households on their preferences for CETs in 2018 and 2024.[52] The survey of households showed very heterogeneous preferences for CETs between households based on a range of factors such as demographics, socioeconomic status, and building characteristics. NexSys researchers have analysed the potential role of behavioural factors and socio-demographic profiles in comparing the stated adoption preferences of CETs with their actual adoption by Irish households. They also examine the impact of policy measures and technology costs on adoption rates. Another study[53] of Irish homeowners draws

---

[42] Brown, Marilyn A., and Benjamin K. Sovacool. “Theorizing the Behavioral Dimension of Energy Consumption: Energy Efficiency and the Value-Action Gap.” *Oxford Handbook of Energy and Society*, 2018, doi.org/10.1093/oxfordhb/9780190633851.013.0011.

[43] Frederiks, Elisha R., Karen Stenner, and Elizabeth V. Hobman. "The socio-demographic and psychological predictors of residential energy consumption: A comprehensive review." *Energies* 8.1 (2015): 573-609.

[44] Kollmuss, Anja, and Julian Agyeman. "Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?." *Environmental education research* 8.3 (2002): 239-260.

[45] Kumar, Pranay, et al. "Reflections on Energy Efficiency Policies in Sustainable Transition: Bedrock, Gamechanger, or More of the Same?." *Environmental Policy and Governance* (2025).

[46] Abrardi, Laura. "Behavioral barriers and the energy efficiency gap: a survey of the literature." *Journal of Industrial and Business Economics* 46.1 (2019): 25-43.

[47] Gerarden, Todd D., Richard G. Newell, and Robert N. Stavins. "Assessing the energy-efficiency gap." *Journal of economic literature* 55.4 (2017): 1486-1525.

[48] Jaffe, Adam B., and Robert N. Stavins. "The energy-efficiency gap What does it mean?." *Energy policy* 22.10 (1994): 804-810.

[49] Sherren, Kate, Ellen Chappell, and John Parkins. "Strategies for integrating quantitative methods into critical social acceptance research." *A critical approach to the social acceptance of renewable energy infrastructures: Going beyond green growth and sustainability*. Cham: Springer International Publishing, 2021. 23-42.

[50] Mukherjee, Sanghamitra Chattopadhyay, and Lisa Ryan. "Factors influencing early battery electric vehicle adoption in Ireland." *Renewable and Sustainable Energy Reviews* 118 (2020): 109504.

[51] Claudy, Marius C., et al. "Consumer awareness in the adoption of microgeneration technologies: An empirical investigation in the Republic of Ireland." *Renewable and Sustainable Energy Reviews* 14.7 (2010): 2154-2160.

[52] Kumar, Pranay, et al. “What moves the needle? Exploring heterogeneities in adoption of clean energy technologies in Irish households” (Working paper to be published in UCD Centre for Economic Research), 2026.

[53] La Monaca, Sarah, and Lisa Ryan. "Solar PV where the sun doesn’t shine: Estimating the economic impacts of support schemes for residential PV with detailed net demand profiling." *Energy Policy* 108 (2017): 731-741.

from experiences of solar PV panel deployment across jurisdictions to suggest special and targeted policy measures for different groups, including low-income households.

In **Figure 4.2**, the results of the survey for household preferences on heating system upgrades and building energy retrofits are shown. The graph demonstrates that householders are willing to pay more for building energy retrofits with higher bill savings. Also, even with the same energy savings, households appear to be more willing to invest in building retrofit & heating upgrades or building retrofits than just an upgrade to their heating system alone. When we examine the results for building retrofits & heating system upgrades, households appear to act rationally, stating that they would be willing to invest more than double for a 70% energy bill savings than a 30% energy bill savings.

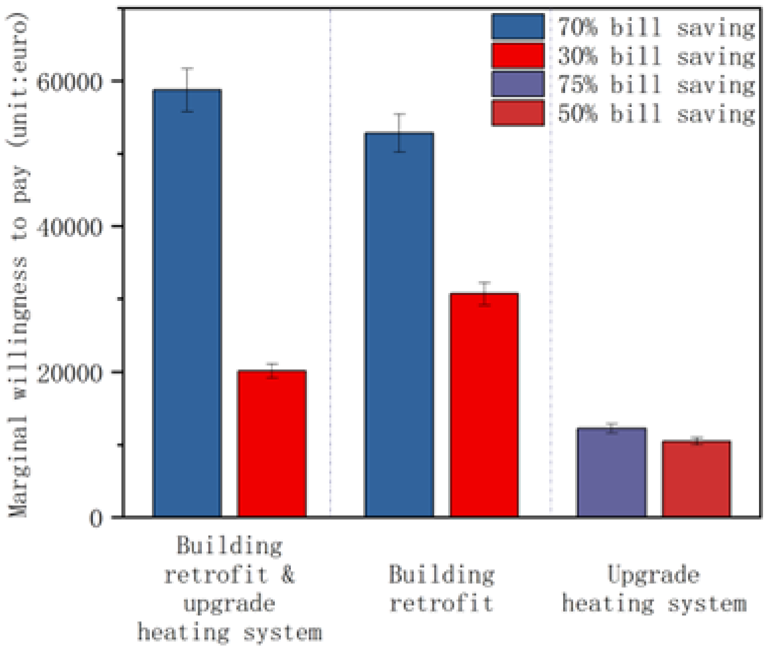

Figure 4.2: Marginal willingness to pay for energy bill savings[54]

Early results suggest a significant association between the latent behavioural factors, such as neighbourhood (peer) effects, progressive attitudes towards innovative technologies and future preferences as significant factors in influencing adoption preferences. However, it also cautions that they do not translate into actual adoption, requiring more nuanced and targeted policy measures. Further, the perceptions of inconvenience and discomfort appear to be acting in the opposite direction to the generally favourable progressive attitudes and sustainability concerns.

Using a mix of the survey and historical data from Irish homes, UCD researchers[55] have developed an agent-based model to understand and forecast the adoption decision mechanism

[54] Na Li, Ryan, L. Wheatley, J., Kumar, P., "Household Preference Heterogeneity for Home Energy Transition Based on Interpretable Machine Learning Over Time", International Association for Energy Economics, 2025.

[55] Meles, Tensay Hadush, and Lisa Ryan. "Adoption of renewable home heating systems: An agent-based model of heat pumps in Ireland." *Renewable and Sustainable Energy Reviews* 169 (2022): 112853.

of CETs heat pumps, solar PV and EVs. The model estimates decisions on uptake including variables in recognised possible factors under four broad categories as economic, socio-demographic, psychological, and social network to simulate different adoption scenarios based on extant policies up to the year 2030. **Figure 4.3** shows the projections for different powertrain technologies in private cars out to 2030.

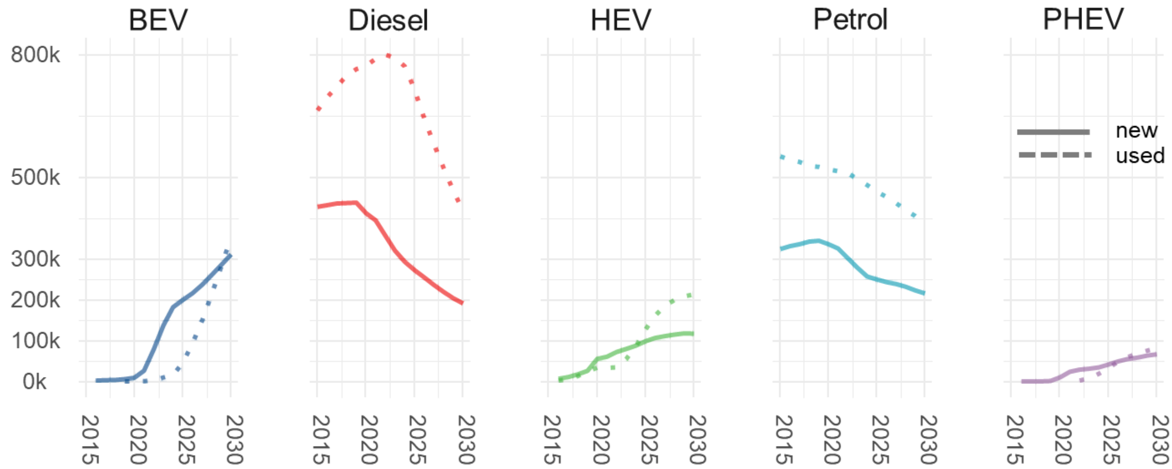

Figure 4.3: Adoption of vehicle powertrain technologies in Ireland to 2030

The model estimated approximately 250,000 battery and plug-in hybrid electric vehicles in 2025, which compares with the 196,000 vehicles on the road reported by the Department of Transport in October 2025. The model assumptions included low electricity prices and high grants, both of which reversed in the period. A significant fall in fossil fuel, petrol and diesel, combustion vehicles is predicted with current policy measures both for new and second-hand cars by 2030. At the same time, the number of battery electric vehicles on the road rises dramatically, and the number of HEV and PHEV vehicles also increases, albeit at a lower rate.

The policy implications of this research are significant. Modelling provides insights on whether current policy will deliver the uptake of heat pumps, EVs, and solar PV systems. Our forecasts, which can be considered optimistic as they include generous grants and low electricity prices, indicate that the 2030 EV target (845,000 electric private cars) will be undershot by approximately 450,000 vehicles. Understanding who is likely and not to adopt clean technologies can guide policy design. More targeted policies ensure better value for money and higher impact. For example, private cars in rural Ireland drive higher mileage due to the sparse population and lack of public transport. Rural areas could be prioritised for higher financial incentives for EVs than urban areas. Similarly households with heating systems based on oil and/or solid fuels and high energy demand could be targeted for heating system grants.

Dynamic Electricity Pricing

By June 2026, Ireland's five largest retail electricity suppliers, Bord Gáis Energy, Electric Ireland, Energia, PrePay Power/Yuno and SSE Airtricity, will be obligated by the Commission for Regulation of Utilities (CRU)[56] to offer dynamic price contracts to customers. This

[56] Commission for Regulation of Utilities. "Dynamic Electricity Price Tariffs." *CRU.ie*, 2025, www.cru.ie/publications/28339.

obligation is on foot of legislation enacted in 2022[57] based on EU policy. In these plans, a portion of the base unit rate will change every half hour based on the wholesale market price of electricity.

The wholesale electricity price varies throughout the day depending on the generation mix and the quantity produced to meet variable demand. Despite this, many residential consumers are charged a constant unit rate, meaning they are not incentivised to reduce consumption at times of high demand. An increasing reliance on intermittent energy sources such as wind and solar will exacerbate the inefficiency of flat price plans. Ireland's 2024 Climate Action Plan[58] included dynamic electricity pricing in a strategy to shift demand to times of abundant renewable supply.

A recent NexSys Policy Paper summarises what research has told us so far about dynamic electricity pricing, including potential benefits and outstanding challenges in its implementation.[59] Some of the main findings from previous literature are summarised in **Table 4.1** below.

Table 4.1: Research findings on electricity demand response to dynamic and TOU pricing

Study	**Setting**	**Price design**	**Finding**
Allcott[60]	US	Dynamic	Total demand reduction
Dutta & Mitra[61]	Mainly US	Dynamic	Low demand response, but higher with automation technology
Bollinger & Hartmann[62]	US	Dynamic	Peak demand reductions only with automation

[57] Office of the Attorney General. "S.I. No. 20/2022 - European Union (Internal Market in Electricity) Regulations 2022." *Houses of the Oireachtas Service*, www.irishstatutebook.ie/eli/2022/si/20/made/en/print.

[58] Department of Climate, Energy and the Environment. "Climate Action Plan 2024." *gov.ie*, DECC, 12 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2024.

[59] Mac Domhnaill, Ciarán, et al. "Don't look back in anger: Making Dynamic Electricity Pricing Work for Ireland." *nexsys-energy.ie*, University College Dublin, Oct. 2025, www.nexsys-energy.ie/t4media/NexSys_Policy_Paper__Dynamic_Electricity_Pricing_.pdf.

[60] Allcott, Hunt. "Rethinking real-time electricity pricing." *Resource and energy economics* 33.4 (2011): 820-842.

[61] Dutta, Goutam, and Krishnendranath Mitra. "A literature review on dynamic pricing of electricity." *Journal of the Operational Research Society* 68.10 (2017): 1131-1145.

[62] Bollinger, Bryan K., and Wesley R. Hartmann. "Information vs. automation and implications for dynamic pricing." *Management Science* 66.1 (2020): 290-314.

Study	Setting	Price design	Finding
Newsham & Bowker[63]	US	TOU, dynamic and others	Peak demand reduction of 5% with pricing alone; 30% with pricing and automation
Faruqui & Sergici[64]	US, France, Australia, Canada	TOU	Peak demand reduction of 3-6%
Kim et al.[65]	Korea	TOU	Peak demand reduction
Enrich et al.[66]	Spain	TOU (for network charges)	Peak demand reduction of 1-9%
Bernard et al.[67]	UK	TOU	Peak demand reduction of 50% among heat pump owners
Di Cosmo et al.;[68] Di Cosmo & O'Hora[69]	Ireland	TOU	Peak demand reduction, greater with in-house display
Faruqui et al.[70]	Canada	TOU	5.5% peak demand reduction with in-house display
Harding & Lamarche[71]	US	TOU	Peak demand reductions, greatest with automation

[63] Newsham, Guy R., and Brent G. Bowker. "The effect of utility time-varying pricing and load control strategies on residential summer peak electricity use: A review." *Energy policy* 38.7 (2010): 3289-3296.

[64] Faruqui, Ahmad, and Sanem Sergici. "Household response to dynamic pricing of electricity: a survey of 15 experiments." *Journal of Regulatory Economics* 38.2 (2010): 193-225.

[65] Kim, Jihyo, Soomin Lee, and Heesun Jang. "Lessons from residential electricity demand analysis on the time of use pricing experiment in South Korea." *Energy Economics* 113 (2022): 106224

[66] Enrich, Jacint, et al. "Measuring the impact of time-of-use pricing on electricity consumption: Evidence from Spain." *Journal of Environmental Economics and Management* 123 (2024): 102901.

[67] Bernard, Louise, et al. *Decarbonizing Heat: The Impact of Heat Pumps and a Time-of-Use Heat Pump Tariff on Energy Demand*. No. w33036. National Bureau of Economic Research, 2024.

[68] Di Cosmo, Valeria, Sean Lyons, and Anne Nolan. "Estimating the impact of time-of-use pricing on Irish electricity demand." *The Energy Journal* 35.2 (2014): 117-136.

[69] Di Cosmo, Valeria, and Denis O'Hora. "Nudging electricity consumption using TOU pricing and feedback: evidence from Irish households." *Journal of Economic Psychology* 61 (2017): 1-14.

[70] Faruqui, Ahmad, Sanem Sergici, and Ahmed Sharif. "The impact of informational feedback on energy consumption—A survey of the experimental evidence." *Energy* 35.4 (2010): 1598-1608.

[71] Harding, Matthew, and Carlos Lamarche. "Empowering consumers through data and smart technology: experimental evidence on the consequences of time-of-use electricity pricing policies." *Journal of Policy Analysis and Management* 35.4 (2016): 906-931.

Policy Considerations

Based on that research the following recommendations will encourage uptake and maximise the potential benefits to consumers and the energy system:

1. Roll out automation capabilities in tandem with dynamic pricing. Dynamic pricing is most effective at reducing peak consumption when coupled with technologies that consumers can configure to automatically switch some appliances off when the price becomes high. Providing better feedback on usage, for example using in-house displays or mobile applications, can also improve the effectiveness of dynamic pricing.

2. Explore options for mitigating potential distributional effects. Flexible consumers who can shift more of their consumption to off-peak hours will benefit most from dynamic pricing. EVs, batteries and HVAC appliances increase this flexibility. Higher-income consumers tend to have more of these devices and are therefore more flexible.

3. Help consumers understand different price plans through communications campaigns. Electricity price plans are complex and identifying the best plan based on individual consumption is a difficult task for most consumers. Web-based comparison tools that offer personalised cost estimates, such as the UCD Energy Cost Calculator, can help consumers choose their most suitable plan, and access to supplier price data will be important in facilitating such tools.

4. Offer bill protection for a phase-in period. Price uncertainty is higher in a dynamic price plan. Suppliers could offer a guarantee that bills will not exceed a certain level for a phase-in period, allowing consumers to try a dynamic price plan without risk to determine whether it is suitable. Linked to this, restricting early termination fees for a phase-in period would help encourage uptake of dynamic price plans.

5. Analyse smart meter data to investigate the effect of dynamic pricing on electricity consumption. It will be important to robustly and securely analyse smart meter data to determine whether they are effective in reducing peak demand. The impact on consumer bills should also be carefully assessed for any impact on energy poverty.

Vehicle to Grid Technology

Targets for electrification of transport will significantly increase electricity demand, however, there is a large degree of flexibility in residential EV charging demand. Charging can readily be shifted in time, especially during the nighttime, as long as user preferences, such as ensuring a full battery in the morning or always keeping the level above a threshold, are satisfied. EV charging is also an excellent candidate for providing an automated demand shifting in response to dynamic or time of use electricity prices.

Moreover, under high EV penetration scenarios, the sum of the energy stored in all of the EV batteries is very significant. For example, the energy stored in the batteries of 1 million EVs could be more than 20 times the energy storage capacity of the Turlough Hill pumped hydro energy storage plant. Cars also tend to remain parked for 90-95% of the time so there is ample scope to use the energy storage capability of EVs to support the power grid while also satisfying users' travel needs.

International studies[72] suggest that implementing flexible charging optimised to reduce emissions could lower emissions associated with EV charging by up 18% across a year compared to a baseline uncontrolled (EV charges as soon as it plugs in) charging scenario. A recent study for a 2045 scenario in California[73] suggests that use of flexible charging could achieve 1% system cost savings in a year, while allowing energy stored in EVs to be returned to the grid at certain times could achieve up to 5% system cost savings. These savings arise from a reduction in grid infrastructure buildout which would otherwise be needed to meet the charging demand and from avoiding buildout of thermal generation and other alternative storage assets.

Flexible EV charging combined with variable electricity tariffs can also result in very significant energy bill savings for EV/home owners. Under variable tariff structures, either fixed time of use (TOU) or dynamic hourly (due to be introduced in 2026), consumers can reduce their electricity bills by shifting electricity usage from higher price times to lower prices times. The graph in **Figure 4.4** shows the percentage savings in annual electricity bills for an average EV/home owner in Ireland resulting from the use of flexible charging (V1G), vehicle to home (V2H) and vehicle to grid (V2G) charging approaches, under different variable tariff structures. Under a typical existing 3-Tier TOU tariff, an EV owner can save somewhere in the region of 30% on their electricity bills by using V1G charging, with the possibility of saving up to a further 10% by implementing V2H. Savings under existing 4-Tier TOU tariffs are very significant and would provide large incentives for implementing V2H or V2G charging. However, the widespread use of this type of tariff would concentrate the EV charging in a few nighttime hours, thus creating a new nighttime demand peak which exceeds current evening demand peaks under high EV uptake. This type of tariff structure is not recommended under high EV penetration scenarios.

Under hourly dynamic tariffs the savings are somewhat less in the range of 20-30%, with higher savings achieved when the variable component of the electricity price is higher. The use of V2G does not result in significant extra savings for the consumer under the assumed pricing as the electricity price paid for exporting to the grid rarely exceeds the lowest import prices.

[72] Bronski, Pete. "New Report Finds Emission-Optimized Charging Can Make Electric Vehicles Nearly 20 Percent Cleaner Annually." *WattTime*, 20 Jan. 2024, watttime.org/news-and-insights/new-report-finds-emission-optimized-charging-can-make-electric-vehicles-nearly-20-percent-cleaner-annually/?utm_source=chatgpt.com.

[73] Houston, Samantha, et al. "Harnessing the Power of Electric Vehicles." *Union of Concerned Scientists*, 16 June 2025, www.ucs.org/resources/harnessing-power-electric-vehicles.

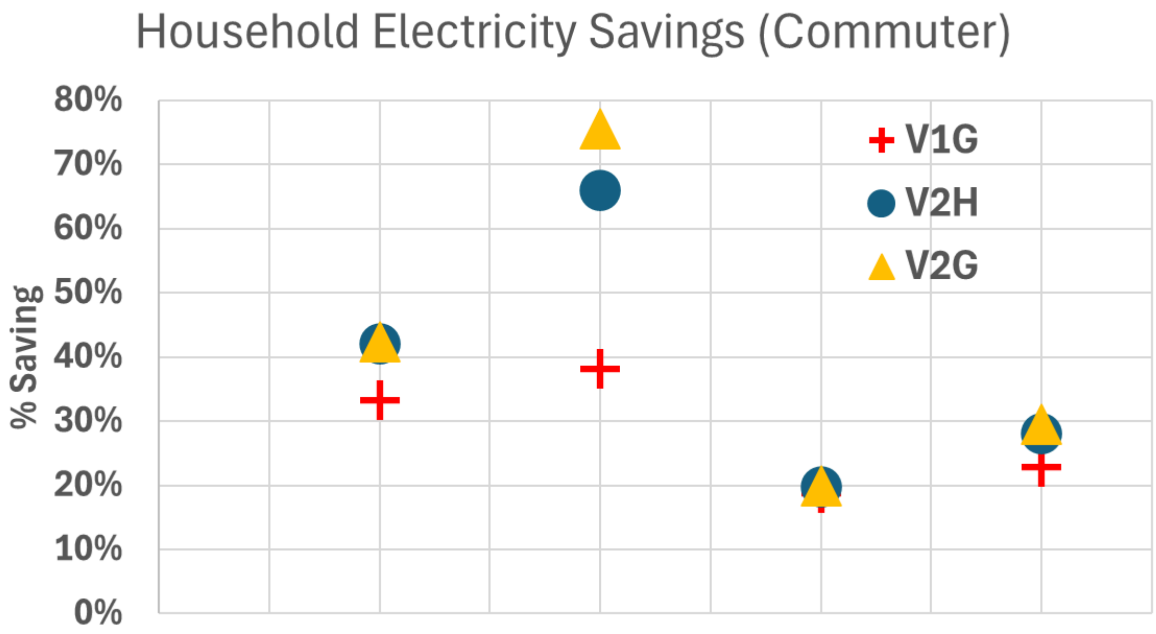

Figure 4.4: Percentage savings in electricity bills using flexible charging techniques under different electricity tariffs relative to uncontrolled charging under a flat tariff structure. The charging schemes are: V1G - flexible unidirectional charging, V2H - the EV battery can also be used to cover household energy usage, V2G - the EV battery can also sell energy to the grid. The tariff structures are: 3-Tier TOU – a static Day/Night/Peak, 4-Tier TOU – a static Day/Night/Peak with extra low rate from 2 am to 6 am, Standard Dynamic – prices can vary every 30 mins, High Dynamic – prices can vary every 30 mins with higher variability.

Policy Considerations

Policy considerations arising from this work include:

1. The adoption of automated home energy management systems should be promoted and supported. The case for cost savings for the consumer using flexible charging is strong.
2. Price responsive V1G EV charging should be implemented as a default charging strategy as there is clear value for the consumer and for the system.
3. Recognising that dynamic tariffs alone may not unlock the potential of V2G as the consumer incentive for going from V1G or V2H to V2G is not strong, additional incentives for customers to make this change should be considered.
4. To exploit the potential of V2G there will need to be viable business models for aggregators. This requires the establishment of flexibility markets which allow participation by aggregation of small assets.
5. V2G may be most effective as a tool to mitigate local network congestion problems therefore the development of appropriate local flexibility markets is needed.

6. Home energy management systems making use of flexible EV charging would benefit from the establishment of standard. Therefore the promotion of standards to ensure interoperability between different vendor equipment and data sharing between systems is important. This includes clarifying the grid connection arrangements and standards for vehicle to grid.

Private Wires

Private wire networks are locally confined systems linking generation, storage, and consumers without using the public grid and are gaining traction in Ireland's energy strategy as part of the move towards decarbonisation and decentralisation. In contrast to traditional flows through ESB Networks and EirGrid, private wires encompass privately owned electricity lines or networks that directly connect renewable generators such as wind and solar parks to one or multiple users. Often bypassing parts of the public grid, this model is particularly appealing to sectors such as data centres faced with ambitious growth plans, slow grid connection processes and grid constraints. While seen by some as innovative and necessary, the real benefits and alignment of private wires with Ireland's climate and system planning goals remain subjects of debate during these early stages of policy development in Ireland.[74]

Use Cases and Rationale

There is a range of use cases for private wires, including industrial campuses, research institutions, data centres, and cooperative community projects. Proposed to support localised energy management, microgrids, and self-sufficient systems, yet in practice, most private networks still maintain connections to the public grid for backup and balancing, so true "islanding" is rare. A noteworthy example is UCD's private wire network, which illustrates how campuses can integrate local generation and supply within a defined area, and is often referenced as a significant operational private wire system in Ireland. Industrial and commercial users are deploying private wires for cost savings and decarbonisation, such as rural cooperatives linking solar arrays to dairy processors, and EV fleet operators connecting solar resources to charging sites, reducing grid peaks and emissions. Corporate PPAs supported by private wires potentially offer financial predictability and stronger sustainability credentials than short term or wholesale market purchases, as they guarantee a long term linkage to renewable generation. However, trials in Wales and other parts of the UK indicate the benefits are highly context-dependent, with limited added value when the existing public grid already sufficiently supports generation and flexibility services.[75]

---

[74] Department of Climate, Energy and the Environment. "Private Wires Policy Statement." *gov.ie/DCEE*, DCEE | Government of Ireland, July 2025, assets.gov.ie/static/documents/Private_Wires_Policy_Statement.pdf.

[75] Forshaw, Jane. "Best Practice Note on Private Wires." *gov.wales*, Welsh Government Energy Service, Mar. 2022, www.gov.wales/sites/default/files/publications/2022-04/welsh-government-energy-service-private-wire-best-practice-guide.pdf.

Decarbonisation and Energy Source Integrity

Aligning private wire networks with Ireland's Climate Action Plan requires consistent decarbonisation standards across both private and public systems, particularly in the context of rising demand from some sectors and lower reductions in energy-related emissions than required.[76] The Government stated an ambition that the objective of "any change is to accelerate decarbonisation, and promote the deployment of electricity infrastructure, renewable generation and storage." Transparency about fuel mixes is critical since some behind-the-meter generation still depends heavily on gas engines and turbines, complicating accurate carbon accounting. While emerging technologies like small modular reactors and hydrogen are not yet commercially available, battery storage is advancing rapidly and could be integral to private wire designs. Ensuring that private networks meet equivalent emissions, renewables, and efficiency requirements as the public grid is essential to prevent carbon leakage and avoid perverse incentives that could undermine Ireland's clean energy goals.

Grid Integration and Regulatory Challenges

A key policy issue is how to fairly allocate grid upgrade costs when financially capable users, like data centres or industrial sites, build private networks. While private wires can facilitate substantial on-site or linked generation, they still rely on the public grid for reliability, as outages affecting private networks mean users typically fall back on the main national grid. Typical outage rates for private supply (estimated around 8%) highlight the continued necessity of backup from the main grid. International experience exposes governance risks, such as unclear billing and weak consumer protections seen in UK residential private wire cases, underscoring the need for strong regulatory oversight.

Private wire networks and their associated generation resources also present a risk of duplicate and excess generation being installed. Internationally, utility companies are seeking access to on site generation in specific circumstances. This approach is mentioned in recent proposals from Ireland's Commission for Regulation of Utilities (CRU), which require large energy users and new data centres to provide their own dispatchable onsite or nearby generation or storage, matching their maximum import capacity, and integrated with the wholesale market. This holds the potential to minimise overall short term dispatchable generation requirements and extends to private wires networks and their connection to the public grid (if any). Of note here is recent legislation in Texas which mandates new requirements of behind the meter on site generation and in Ireland the CRU's recent decision on the Large Energy Users Connection Policy.[77] [78]

Private Wires and a Just Transition

Ireland's formal Just Transition infrastructure is at an early stage of development.[79] Key policy development and implementation components for climate related developments include

---

[76] Sustainable Energy Authority of Ireland. "National Energy Balance." *seai.ie*, 8 Sept. 2025, www.seai.ie/data-and-insights/seai-statistics/key-publications/national-energy-balance.

[77] Aslam, Waleed, and Robin Hytowitz. "Texas SB6 Explained: Addressing Large Load Impacts." *epri.com*, 2025, www.epri.com/research/products/3002033410.

[78] The Commission for Regulation of Utilities. "Review of Large Energy Users Connection Policy." *cru.ie*, Apr. 2025, consult.cru.ie/en/consultation/review-large-energy-users-connection-policy.

[79] Just Transition Commission of Ireland. "Terms of Reference - Just Transition Commission." *https://justtransitioncommission.ie*, Just Transition Commission | Government of Ireland, justtransitioncommission.ie/docs/Just-Transition-Commission-Terms-of-Reference.pdf.

inclusion and justice for communities impacted. For private wires, relevant policy considerations have been identified at a national (electricity grid as a crucial piece of infrastructure) and local (consent of local communities).[80] Design of private wires policy and implementation measures may consider concepts of spatial, procedural and distributive justice within or beyond these policy components, in keeping with the Just Transition principle that 'existing inequalities are not exacerbated' and the UN SDG principle of 'Leave No One Behind'.[81] [82] [83] These may link to existing mechanisms and stakeholders, and be informed by just transition indicators in practice across spatial issues, participation, engagement, equity and other issues.[84]

Policy Considerations

1. **Equity and Fair Cost Sharing:** Ensure private wire users contribute transparently to grid maintenance via levies or fees, preventing not only cost shifting to residential consumers but also avoiding opportunity costs, such as communities losing access to potentially cheaper, greener electricity. This will help preserve public trust and ensure that infrastructure resources are allocated efficiently and fairly across all electricity consumers.
2. **Regulatory Clarity and Innovation**: Establish clear licensing and approval criteria that align private wires with national energy and climate goals, while encouraging innovative projects like rural cooperatives, industrial decarbonization, and campus models.
3. **Environmental and Social Oversight:** Integrate comprehensive environmental impact assessments, including water usage and resource impacts, especially for data centres and generation facilities, into planning and regulation.
4. **Carbon Transparency and Reporting:** Require full disclosure of carbon emissions and annual performance reporting for all private generation and storage assets to ensure accountability.
5. **Just and Adaptive Policy Framework:** Utilise pilot projects, regulatory sandboxes, active stakeholder engagement, and ongoing policy reviews to maintain responsiveness to technological advances and evolving energy profiles and demand.

[80] Department of Climate, Energy and the Environment. "Private Wires Policy Statement." *gov.ie/DCEE*, DCEE | Government of Ireland, July 2025, assets.gov.ie/static/documents/Private_Wires_Policy_Statement.pdf.

[81] Banerjee, Aparajita, and Geertje Schuitema. "Spatial justice as a prerequisite for a just transition in rural areas? The case study from the Irish peatlands." *Environment and Planning C: Politics and Space* 41.6 (2023): 1096-1112.

[82] Just Transition Commission of Ireland. "Introductory Report of the Just Transition Commission of Ireland 2025." *justtransitioncommission.ie*, Just Transition Commission | Government of Ireland, June 2025, justtransitioncommission.ie/docs/Introductory%20Report%20of%20the%20Just%20Transition%20Commission%20of%20Ireland%202025.pdf.

[83] Department of Climate, Energy and the Environment. "National Implementation Plan for the Sustainable Development Goals 2022-2024." *gov.ie*, 11 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/national-implementation-plan-for-the-sustainable-development-goals-2022-2024.

[84] Kelly, J. Andrew, et al. "Just Transition Indicator Framework for Ireland: Evidence Synthesis Report 6." *epa.ie*, Environmental Protection Agency, Apr. 2025, www.epa.ie/publications/research/evidence-synthesis-reports/Evidence-Synthesis-Report-6.pdf.

Green Hydrogen in Ireland

Hydrogen (H_2) is a carbon-free gas which can be produced from hydrocarbon reforming or water electrolysis, with electrolysis utilising renewable energy sources resulting in near-zero life cycle carbon emissions. Due to the high potential for renewable energy development in Ireland (in particular, offshore wind), renewable hydrogen is anticipated to play a key role as a renewable gas, providing flexible backup electricity generation and medium/high-grade heat for industry. Furthermore, there is a significant role for hydrogen as a feedstock in the production of e-fuels also known as Power-to-X.

Specifically, Ireland's National Hydrogen Strategy states three primary strategic reasons for developing an indigenous hydrogen sector: decarbonisation, energy security, and industrial and export market opportunities. However, it is important to point out potential trade-offs in achieving these goals. A recent NexSys policy paper has pointed out that to achieve both decarbonisation goals and energy security for Ireland, substantial amounts of hydrogen will be required.[85] However, if renewable energy and/or hydrogen production projects are not ramped up, it is likely further hydrogen imports will be required to cover domestic needs, conflicting with energy security and the desire to be a potential energy exporter. If Ireland wants to avoid becoming reliant on hydrogen imports in the future, infrastructure for hydrogen production must be initiated now to ensure Ireland is not left behind. This will only be possible by establishing a regulatory and policy framework well in advance of 2030.

Policy Considerations

Emanating from this research, the following policy inputs were suggested to kick start Ireland's hydrogen sector:

Regulation

- Begin coordinated work with the United Kingdom to raise the current 0.1% by volume hydrogen blending limit to a minimum of the EU's 2% interconnection requirement and prepare for higher levels in line with technical evidence, while finalising domestic safety standards and supporting early regional hydrogen clusters.

Certification

- Create a national hydrogen certification scheme aligned with EU RFNBO standards to ensure market access, build investor confidence, and guarantee low emissions integrity.
- Implement a lifecycle carbon-intensity threshold ($\leq$ 3–4 kg CO_2eq/kg H_2) to ensure all hydrogen in Ireland, domestic or imported, meets low-carbon standards.
- Ensure alignment with EU and UK schemes by embedding lifecycle GHG accounting, additionality, and temporal/geographic correlation in line with RED III and Delegated Regulation 2023/1184.

[85] Vance, Charlene, Maham Hussain, et al. "Green Hydrogen in Ireland: Moving to the Next Stage." *nexsys-energy.ie*, University College Dublin, Oct. 2025, www.nexsys-energy.ie/t4media/NexSys_Policy_Paper__Green_Hydrogen_in_Ireland.pdf.

Market Reform

- Implement critical energy market reforms within the Single Electricity Market (SEM) to enable the electrolysers to access surplus renewable electricity and allow electrolysers to provide valuable grid services.
- Introduce long-term revenue support schemes to de-risk private investment in renewable hydrogen production and use.

Financing

- Begin targeted financing of pilot projects to de-risk early-stage investments, test new applications, and gather essential data to guide the long-term, evidence-based deployment of a large-scale hydrogen ecosystem, along with developing an indigenous hydrogen industry.
- Establish a dedicated national hydrogen fund that leverages the EHB's 'Auctions-as-a-Service' scheme, alongside exchequer support, to build a domestic supply chain.

To support the development of the hydrogen economy in Ireland, scientific evidence on the technical, economic, and environmental impacts of potential hydrogen production and consumption pathways is needed. NexSys researchers have explored this through various research projects.

A way of reducing the sensitivity of hydrogen price to electricity price is by utilising curtailed power. The Irish Government's promise to pay for curtailed power has created a situation where in a few years potentially 11-29% of all renewable energy generated will be curtailed with no incentive for other uses. NexSys researchers have found that hydrogen produced from this power could have a minimum levelised cost of hydrogen (LCoH) of 1.20-9.31 €/kg (36-276 €/MWh), with a LCoH of 1.26-2.44 €/kg (38-73 €/MWh) likely based on the current trajectory for renewable energy installations and grid improvements.[86] This means that despite high electrolyser costs, green hydrogen can be cost-competitive in Ireland. However, this is only possible if RESS contracts are clarified and this curtailed power is made available at zero cost.

Ireland could consider exporting green hydrogen or its derivatives (Power-to-X). A recent paper[87] explored this scenario, completing a techno-economic assessment of large-scale green hydrogen production from wind and solar resources in the Republic of Ireland. Three locations were chosen for a quantitative analysis of a number of scenarios to determine the LCoE, and the LCoH in 2030 and 2040. It was determined that the south (Cork region) has the least cost for locating a hydrogen production hub and for export ranging from 3.53 €/kgH_2 to 2.75 €/kgH_2 in 2030 and 2040.

[86] Vance, Charlene, et al. "Techno-economic optimization of green hydrogen production from curtailed power in Ireland: Impact of future renewable energy installations, weather variability, and grid constraints." *International Journal of Hydrogen Energy*, vol. 161, no. 150675, Aug. 2025, www.sciencedirect.com/science/article/pii/S0360319925036742?via%3Dihub.

[87] Habour, Riadh M., Khaled Y. Benyounis, and James G. Carton. "Green hydrogen production from renewable sources for export." *International Journal of Hydrogen Energy* 128 (2025): 760-770.

In order to understand the potential role, challenges and opportunities that Power-to-X can play in decarbonisation pathways, a techno-economic study has been carried out on the production of Green Ammonia.[88] [89] Ammonia from fossil sources has a price of approximately 575 € per ton (S&P Global Commodity Insights, 2025), which poses a significant cost barrier for production using green hydrogen. An energy system optimisation study analysing the combined use of green hydrogen for flexible power and ammonia generation indicated that a competitive case for indigenous green hydrogen production emerges under strict regulatory restrictions on electricity sector emissions and the subsequent large-scale deployment of wind and solar generation. In addition, for green ammonia to achieve commercial viability, financial incentives that reward the avoided emissions are essential. The study concluded that for ammonia production to be economically viable, particularly when utilising surplus renewable electricity, it requires an additional financial benefit equivalent to the value generated by a carbon price exceeding 210 €/tCO_2. Studies by other researchers forecast the cost of green ammonia from wind and solar energies to be 694 €/tNH_3 in Germany, 511 €/tNH_3 in Spain, and 436 €/tNH_3 in Saudi Arabia in 2050. A techno economic assessment of green ammonia production in the Republic of Ireland based on wind and solar resources was carried out with several scenarios assessed. The south region is revealed as the least cost location, at 736 €/tNH_3 and 624 €/tNH_3 in 2030 and 2040 respectively.

NexSys research points to the conclusions that hydrogen will have a role to play in the energy transition especially when we look to sectors where electricity cannot be used, or for periods of low renewable availability. As part of theReFuelEU Aviation regulation the EU has committed to 1.2% synthetic aviation fuel in 2030 and 35% synthetic aviation fuel in 2050; this fuel all begins with hydrogen. Therefore while the technology is not currently competitive economically, there are regulations in place to ensure a future demand, thereby bringing economies of scale and cost reduction. Through green hydrogen Ireland's renewable potential can be harnessed to decarbonise the energy system beyond electricity.

---

[88] Kenny, Jolie, David Timoney, and Eoin Syron. "A techno-economic analysis of global renewable hydrogen value chains." *International Journal of Hydrogen Energy* 79 (2024): 690-701.

[89] Khammadov, Kamran, et al. "Modelling the Influence of Hydrogen Use in Power Generation and Ammonia Conversion on the LongTerm Deployment of Hydrogen Technologies." *World Hydrogen Technologies Convention*, Dublin, International Association for Hydrogen Energy, 2025, www.whtc2025.com/conference-proceedings.

5. Renewable Energy

Introduction

Decarbonisation of the electricity system relies heavily on building sufficient renewable energy generation capacity and supporting this with various forms of storage and flexibility.

CAP 2024 has 2030 targets for 9 GW of onshore wind generation, 8 GW of solar PV and 5 GW of offshore wind. As an overview of the current situation, **Figure 5.1** shows the historical growth in renewable energy capacity, the 2030 targets, plausible projected capacities based on expert opinion from the SEAI DESS study, and required capacities as indicated in EirGrid's Tomorrow's Energy Scenarios.[90]

The historical data shows that the pace of addition of onshore wind has significantly slowed in recent years, to the point where it is now very unlikely that the 2030 target of 9 GW will be achieved. In contrast the pace of addition of PV has been quite rapid. If this pace of growth is maintained it is conceivable that the target of 8 GW PV might be achieved. However any changes to the RESS support scheme and any delays in putting any new scheme in place presents a risk to achieving the target. The pace of addition of small scale solar through the micro generation scheme has been particularly rapid and there is still significant potential for further take up.

In terms of future projections, the recent SEAI study derived plausible projections for future build out of renewables based on the pooling of opinions for a group of experts. The figure shows the median or best estimate from this study covering the years 2025 to 2040. The figure also shows the projections used in the EirGird Tomorrow's Energy Scenarios (TES) out to 2050. Two bounds for each category of renewables is included which correspond to two different scenarios, namely the Self-Sustaining scenario and the Offshore Opportunity scenario, both of which envisage a net-zero electricity system by 2040. Note for the offshore wind the upper bound corresponds to the lower bounds for onshore wind and solar PV.

Although missing the CAP targets for 2030, the expert opinion median projections for onshore wind and solar PV still anticipate substantial increases over the years to 2040. The PV projections exceed the Eirgrid scenario figures and the onshore wind falls midway between the two scenarios projections by 2040. This balanced portfolio of onshore wind and solar PV has a positive impact on the duration and frequency of RES droughts as further discussed in the *Renewable Energy Resources* section below.

Progress on build-out of offshore wind to date has been very slow and it is highly unlikely that the 2030 target of 5 GW will be met. The expert opinion projections suggest that this may be achievable somewhere in the mid 2030's but in general the expert opinions indicate that even

[90] Sustainable Energy Authority of Ireland. "Decarbonised Electricity System Study: Forecasts of Plausible Rates of Generation Technology Deployment 2024–2040." *seai.ie*, Sustainable Energy Authority of Ireland | Government of Ireland, June 2024, www.seai.ie/sites/default/files/publications/dess-rates-of-generation-technology-deployment.pdf.

the lower of the EirGrid scenario requirements will not be met by 2040. This clearly shows a lack of confidence in the ability of the current system to deliver on the ambitious offshore wind target. The main barriers cited are complex and lengthy planning processes, including exposure to legal challenges. NexSys research has also highlighted the lack of port infrastructure, in particular the lack of marshalling ports in the Republic of Ireland equipped to deliver offshore wind projects as a major barrier (discussed further under *Offshore Renewable Energy Port Capacity* below). Other barriers and challenges related to the development of the sector are discussed further in the *Offshore Renewable Energy* section. Scale up of offshore wind will be critical to delivering on Ireland's decarbonisation goals but additionally there is significant potential for related industrial development opportunities and these are also discussed further under *Offshore Renewable Energy*.

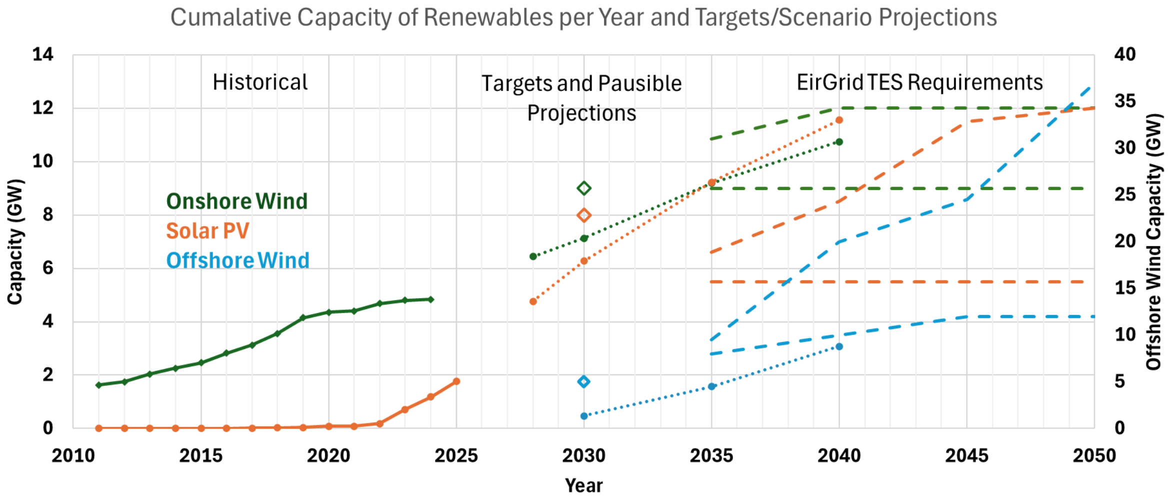

Figure 5.1: Historical capacity of renewable generation, CAP targets, projections for SEAI DESS study and projections in EirGrid TES study.

In general the timelines for successful completion of renewable energy projects can be impacted by public acceptance and the degree of local opposition to such projects. Gaining an understanding of the factors which influence public acceptance is therefore of significant importance to the successful delivery of renewable energy targets. *The Public Acceptance of Wind Farms* section describes findings of NexSys research on how much an information deficit might impact on public acceptance of wind farms.

Clean Dispatchable Generation

Even with the addition of large quantities of renewables there still remains a very significant need in the system for clean dispatchable generation. The current system has approximately 5 GW of dispatchable generation and the EirGrid TES projections show this growing to approximately 6 GW gas generation capacity across most of the scenarios. In the short to medium term conventional gas generation remains vitally important in the system for supply during times of low renewables and for balancing the variability of renewables. In the longer term as the build out of renewables progresses this dispatchable generation may run less often and will need to transition to running on clean fuels. Potential options include hydrogen, ammonia, biomethane, biomass and gas generation with carbon capture and storage. However at this stage there is still considerable uncertainty around the approach. As discussed earlier under *Green Hydrogen in Ireland*, hydrogen and ammonia production are relatively immature and are currently retarded by a lack of infrastructure, regulation and high costs. Indigenous biomethane and biomass can certainly have a role to play but the capacity from indigenous sources is limited. Carbon capture and storage technologies are still relatively immature and expensive. Nuclear in the form of Small Modular Reactors is also a possibility, but deliverability must be questioned considering the legislative changes needed and the likely strong opposition which would arise, issues which a forthcoming NexSys policy paper will explore.

System Stability Considerations

A vitally important consideration for the power system under its transition to net-zero is its stability, i.e. the ability of the grid to withstand and recover from events such as sudden loss of lines, generators or loads. Traditionally this stability has relied on the technical characteristics of conventional, synchronous generation such as their inertia, their ability to supply currents much greater than rated for short periods of time, and their ability to support voltage. With the displacement of conventional generation by generation from wind and solar much greater consideration has to be given to exactly where these stabilising properties come from. Unless new sources which provide inertia, grid strength, fault currents, and voltage support are added to the system, then stability considerations will impose a limit on how much conventional generators can be removed from the system. In fact this is already the case with system stability considerations imposing a constraint that there must be a minimum number of conventional generators online at any time, which at times of high renewable generation leads to curtailment of renewables.[91] Plans are already underway by EirGird to connect more synchronous condensers to the system to counteract the reduction in stability services from conventional generation, but other technology options such as grid forming battery storage or grid forming HVDC interconnectors are also important options to be considered.

Renewable Energy Resources

Optimising the energy system requires evaluating multiple scenarios to balance critical factors such as costs, efficiency, resilience, carbon emissions, and meteorological variability. One of the primary challenges for high-renewable energy systems is handling extended periods with minimal wind and solar generation, often known as Dunkelflaute (dark doldrums) events. These low-generation events can last from several hours to a number of days, leading to system resilience risks if not effectively managed. NexSys research has been using advanced modelling to explore the frequency and duration of such events and also to understand the system resources which can be employed to mitigate their impact.

[91] M. Hurtado et al.,"Analysis of wind energy curtailment in the Ireland and Northern Ireland power systems", IEEE Power & Energy Society General Meeting, 2023.

RES Resource Modelling

Modelling the behaviour of Renewable Energy Sources is a crucial part of planning for the ever-increasing role which they will play in Ireland's future electricity generation. Although wind turbines have existed in Ireland for a number of years, there is less generation data for photovoltaic electricity generation. This lack of historical RES generation data makes it difficult to plan for extreme RES generation events, as can happen during sustained periods of low wind speeds and cloudy skies, i.e. Dunkelflaute Events.

To address this gap, NexSys researchers have built a digital twin of RES generation in Ireland, for wind as well as PV, and calibrated it against records of actual generation from these sources. This digital twin has then been used to generate over 80 years of hourly RES generation data, by driving the model with historical weather data.

One important use of the digital twin has been to investigate RES generation drought events. RES droughts were defined using a threshold on 24-hour rolling average capacity factor, allowing robust estimation of event frequency, duration, return periods, and seasonal patterns. Two RES generation energy scenarios were simulated, one reflecting the mix of wind and solar PV capacity on the EirGrid network (Republic of Ireland) at the end of 2023 ("91W-9PV" - 5.9 GW wind, 0.6 GW solar PV) and one reflecting a future 2030 mix of wind and solar PV ("57W-43PV" - 11.45 GW wind, 8.6 GW solar PV as per Climate Action Plan 2024).

Enablers

- Integration of solar PV capacity significantly reduces the frequency, severity, and seasonality of RES droughts compared to a wind-dominated system. For example, a 1-in-10 year RES drought event for the current infrastructure (91W-9PV) would last for 12 days. By increasing the share of solar PV (57W-43PV), the duration of a 1-in-10 year event drops significantly, to 7 days.
- Diversifying Ireland's renewable portfolio yields greater supply resilience and mitigates extreme events driven by weather-dependent energy sources.
- Regionally validated datasets, with accurate wind turbine and solar PV models suited to Irish installations, enable reliable quantification of RES drought risk.

Barriers

- Generic datasets tend to underestimate the frequency and duration of RES droughts, creating risks to system reliability and adequacy.
- Potential data gaps in region-specific performance metrics and weather-RE coupling that could hinder precise drought risk assessment.
- Uncertainty in future resource mix dynamics and deployment timelines may challenge the applicability of drought projections.

Policy Considerations

- Prioritize development and use of regionally validated, Ireland-specific datasets and models for wind and solar installations to improve drought quantification.

- Move toward a balanced mix of wind and solar PV by 2030 to reduce drought frequency and extend return periods for severe multi-day events.
- Establish ongoing validation and updating of datasets as technologies and deployment scales evolve, ensuring resilience assessments stay policy-relevant and decision-ready.

In ongoing research, this approach is being extended to a wider European region. This will allow us to investigate the role of electricity interconnections in reducing the impact of extreme RES generation events.

Addressing Dunkelflaute Events

From a resilience and security of supply perspective it is critically important to have sufficient means to ride through Dunkelflaute events. Suggested solutions often involve incentivising the deployment of advanced long-duration storage, additional interconnection to neighbouring grids, and utilisation of backup fossil-fired generation.

Long duration storage solutions offer a promising path forward, since they can store energy during surplus renewable (or low electricity price) periods for later deployment during prolonged low-generation periods. Recent research involving NexSys researchers has developed a sensitivity optimisation approach to evaluate the potential value of additional grid interconnections (net transfer capacity) and various long-duration storage options, particularly iron air batteries.[92] By exploring the performance and feasibility of battery technologies as a long-term energy storage solution, this study contributes to evaluation of the resilience of future systems under decarbonisation goals.

The methodology adopted a scenario-based approach, starting from a baseline scenario utilising typical/averaged meteorological and demand data, which serves to establish reference costs and portfolio sizing. Key metrics include total system cost, emissions reductions, system reliability, and portfolio utilisation (and, hence, plant profitability), with a focus on maintaining load during critical periods without resorting to excessive fossil-fuel use. Consequently, a balance is sought between solutions that achieve sufficient flexibility, system resilience and economic viability. Modelling is based on an open-source framework for optimising complex energy systems. The case study is based on the future Ireland power system, with a target of 80% of renewable electricity by 2030, mostly involving onshore and offshore wind, and solar PV generation, and with limited HVDC interconnection capacity to Great Britain and France.

The findings highlight the importance of integrating long-term energy storage and expanding grid interconnection to mitigate the impacts of Dunlelflaute events. The results show that installation of long-term energy storage solutions can achieve a 14% reduction in emissions during the Dunkelflaute period and increased interconnection can reduce emissions by 26%. Individually, both offer significant benefits, however their combined implementation, not

[92] R. Delubac, M. Esmaeili and D. Flynn, "Addressing Dunkelflaute Events in Energy Systems with High Renewable Shares," 2025 21st International Conference on the European Energy Market (EEM), Lisbon, Portugal, 2025, pp. 1-5, doi: 10.1109/EEM64765.2025.11050148.

surprisingly, yields more substantial reductions in CO_2 emission (38%) and a reduction in operational costs of 8%.

Offshore Renewable Energy

Offshore renewable energy and in particular wind is a vital element of Ireland's net-zero pathway. Although progress has been slow, the development of Offshore Wind has transformative potential for the Irish energy system. There is clearly a timeline mismatch however in terms of the ambition around offshore wind, the project approvals and the development of the associated science and technology support. The ambition is high, but project approvals are slower than expected, leading to the distinct possibility of missing the ambitious scenarios and deadlines. In terms of offshore wind technologies, some technologies have been more popular in certain markets. The Netherlands has continued with monopole solutions, while Denmark has espoused more of the floating solutions. Several new technologies, including wave devices and floating solar are upcoming rapidly, which can be beneficial as an additional resource of energy. A timely creation of a well established and engaged network of business hubs, industry, policymakers and researchers is required within this decade. Significant and well strategised investment towards early TRL investments are required, so that maximum benefit is obtained in diverse sectors.

Offshore wind policy is multifaceted and is also influenced by stakeholder groups, both national and international. These policies range widely, covering aspects such as compliance around engineering risk/performance, environmental/social impacts, economic competitiveness, planning, public perception, export control, and even the economic/geopolitical zeitgeist. Key policies, which ideally should be synergistic include marine spatial planning, environmental protection regulations and Ireland's aspirations for renewable energy solutions.

Economic Opportunities for Offshore Wind

Apart from the critical role in decarbonisation, significant economic development opportunities exist for Ireland in the Offshore Wind sector. While it is not envisaged that Ireland will become a key manufacturer, there are significant opportunities in areas related to lifetime performance, operations, maintenance and data analytics with decision making. These include the development, use and adaptation of novel technologies in association with data analytics and AI, to deliver a digital transformation to the sector, not just for the country but creating solutions for the global market. Lifetime O&M, including testing and assessment at conceptual stage or during evolution of technological readiness levels (TLS) via wave basin or laboratory testing, is particularly important. Similarly important is the consideration of decommissioning based on lifetime performance and possible circularity of these structures or systems. This allows for a whole life approach, with opportunities for small to medium enterprise in terms of contracts for lifetime maintenance which is especially considering that Ireland is unlikely to be a major manufacturer of the large devices themselves. This opportunity in digital transformation goes hand in hand with the opportunity for global scientific leadership.

Offshore wind is a sector where complex challenges in modeling the physics, structural engineering and dynamics, at component, device or array levels comes with the uncertainties of geotechnics and lifetime exposure conditions. These challenges are being addressed by NexSys researchers. There are several cross-sectoral possibilities, with benefits also for environmental aspects like aquaculture and coastal aspects.

As the sector moves ahead rapidly, Ireland is in an excellent position to deliver several fundamental solutions through the support of a critical cohort of researchers such as NexSys. Nexsys Offshore Wind research has been a pioneer in delivering several solutions for a derisked and competitive offshore wind future, along with translation of learning for such approaches. It has established the first reference project for offshore wind monitoring in Ireland through Arklow Bank Wind Farm, and for onshore wind through Bellacorick Wind Farm,[93] both at the end of their lives. In terms of sustainability and circular economy, researchers here have established extensive benchmarks and guidance for the repurposing of wind turbine blades at the end of their lives for other structures.[94] [95] [96] There has been extensive work on demonstration of new technologies for such assessment, including wireless monitoring[97] and non-contact Laser Doppler Vibrometry,[98] along with long term monitoring using vibrating wire strain gauges. A particular focus on dynamic cables has started with contributions to standardisation and a first cohort of doctorates in Ireland in this topic. In analyses, NexSys developed extensive open source software for analysis of flexible and complex offshore structures,[99] with deep scientific impact.

In data analytics, NexSys researchers have developed some of the most extensive feature markers and created novel spatiotemporal time series and statistical methods for anomaly detection, prediction[100] [101] and visualisation of resources.[102] Farm level simulations and a wide range of control solutions have also been developed. New testing protocols for wave basin tests during the development stage have also been created. Combined, the solutions provide

---

[93] O'Connor D., et al. "Operational wind turbine foundation monitoring implementation for an end of life wind farm in Ireland." *Wind Europe End-of-Life Issues & Strategies* (EoLIS) Seminar. Gothenberg, Sweden, 2024.

[94] Pakrashi, V., et al. "Some challenges and opportunities around lifetime performance and durability of wind turbines." *Wind Energy Engineering* (2023): 289-298.

[95] Ruane K., et al. "Testing and Analysis of a Pedestrian Bridge made of Discarded Wind Turbine Blades." *The Ninth International Conference on Structural Engineering, Mechanics and Computation*, SEMC 2025, Cape Town, South Africa, 2025.

[96] Ruane K., et al.. "Condition-state Inspection of Decommissioned Wind Turbine Blades for Repurposing." *6th International Conference on Offshore Renewable Energy.* London, UK. 2025,

[97] Pakrashi, V., et al. "Some challenges and opportunities around lifetime performance and durability of wind turbines." *Wind Energy Engineering* (2023): 289-298.

[98] MacAuley, N., et al. "Non-Contact Measurements of Wind Turbine Blades Repurposed as Pedestrian Bridges." *Transport Research Arena Conference*, Cham, Switzerland, 2024.

[99] Bali, Seevani, et al. "A finite volume adaptation of beam-to-beam contact interactions implemented for geometrically exact Simo–Reissner beams." *Computational mechanics* 75.1 (2025): 237-263.

[100] Ashkarkalaei, Mohadeseh, et al. "Optimum feature selection for the supervised damage classification of an operating wind turbine blade." *Structural Health Monitoring* (2025): 14759217251313815.

[101] Ashkarkalaei, Mohadeseh, et al. "Feature selection for unsupervised defect detection of a wind turbine blade considering operational and environmental conditions." *Mechanical Systems and Signal Processing* 230 (2025): 112568.

[102] Begu, Blerta, et al. "A nonparametric penalized likelihood approach to density estimation of space–time point patterns." *Spatial Statistics* 61 (2024): 100824.

new insights,[103] tools,[104] [105] guidance and benchmarks[106] to make offshore wind and its related infrastructure or systems de-risked, competitive and adaptable to the offshore wind sector, with benchmarks and examples focused around Ireland. There have been extensive engagement for best practice guidance and standardisation pathways, with several global bodies, including International Energy Agency (IEA), European Academy of Wind Engineering (EAWE), Cooperation in Science and Technology (COST) and several diversified funding routes, both national and international. Encouragement of small business initiatives with public engagement has been carried out (e.g. Murrough business park). At this point there is a significant gap in facilities for laboratory and large-scale testing for Offshore Wind in Ireland and this must be addressed as soon as possible.

Barriers

There are significant challenges to be overcome to fully develop Ireland's offshore wind.. A specific challenge related to the development of port infrastructure is discussed in more detail below. Other challenges relate to finance, planning and global market conditions. To advance Ireland's offshore wind aspirations faster and more effectively, there is a need to holistically look into the policies and the related barriers and opportunities to support decision making in an evidence based fashion, while being competitive enough to not be left behind. Key barriers include the following:

- The financial competitiveness of offshore wind is not yet mature enough, or is subsidised enough to reach some of the proposed targets from policies, as well as translating to commercial projects.
- Marine spatial planning and certain challenges around sustainability indicators also create, often necessary constraints and required checks.
- There is currently a gap in Ireland for small to medium enterprises, and for technology companies, to fully address all the engineering needs for a transition to offshore wind, despite significant progress in recent years.
- Without adequate investment in research there is a barrier in sustaining a critical mass of excellence around science and technology. A sustained investment and long-term commitment to offshore wind, similar to other successful sectors, can deliver this technology in the medium to long term.
- There is a gap in reference projects in terms of existing onshore or offshore farms and a translation of such learning from one sector to another, but such reference benchmarks are currently being created. The barriers are not significantly unlike what has been for this sector in several other countries.

[103] Baisthakur, Shubham, et al. "Impact of Sources of Damping on the Fragility Estimates of Wind Turbine Towers." *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering* 10.4 (2024): 041202.
[104] Gogoi, Ankush, et al. "Weak Ito–Taylor schemes for geometric stochastic differential equations on the S2 manifold." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 481.2321 (2025).
[105] Warby, Cian, et al. "An Ecologically Consistent Model of Growth for Hard-Bodied Marine Organisms." *Journal of Marine Science and Engineering* 12.11 (2024): 2067.
[106] Deignan, Cian, et al. "Portability of short term wind power forecasting: investigating model calibration using wind power data from Ireland and UK." *Scientific Reports* 15.1 (2025): 33891.

- The context for the sector in general can be challenging with global geopolitics and market conditions continuing to dominate some of the major decisions.

Offshore Renewable Energy Port Capacity

Delivery of offshore renewable energy (ORE) at scale is a critical component to Ireland's proposed decarbonisation pathway. The 2025 *Climate Action Plan* (CAP) has retained a headline target of at least 5 GW of offshore renewable wind energy installed capacity by 2030,[107] while the *Future Framework for Offshore Wind*, sets ORE targets of 20 GW of installed capacity by 2040.[108] Without these renewable energy sources, Ireland does not have a credible path to meet its legally binding emissions reduction targets. Against a backdrop of a recent WindEurope statement that 'one of the most pressing challenges today is the lack of timely investment in vessel manufacturing and port infrastructure', a look at Ireland's policy on ORE port facilities is timely.[109]

ORE development has been identified as a once in a generation opportunity for economic growth and job creation; it can reduce the cost of energy for consumers and reduce our reliance on fossil fuels, ensuring energy security; essential to decarbonise sectors such as industry, transport and heating. *Powering Prosperity – Ireland's Offshore Wind Industrial Strategy* was published in 2024 and it advocates for the huge economic benefits of reaching Ireland's offshore renewable energy targets.[110]

DCU research conducted for NexSys first assessed the construction phase of fixed ORE globally as well as turbine technology encompassing the expected large turbine and blades characteristics and the ORE vessels that transport them. The research then reviewed all ports potentially suitable for ORE on the island of Ireland, including operations & maintenance ports, recognising the limited research completed in Ireland. A matrix of port attributes was constructed which was used as an assessment tool against Irish ports. This matrix takes into account the growth of the equipment that is being used offshore and, in turn, the size of the vessels that will be needed for both inbound and outbound port movement. DCU proceeded to build a model, incorporating the attributes of the geophysical characteristics of each port, and matched that to planned ORE development over the next 2 decades.

---

[107] Department of Climate, Energy and the Environment. "Climate Action Plan 2025." *gov.ie*, DECC, 3 Sept. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2025.

[108] Department of Environment, Climate and Communications. "Future Framework for Offshore Renewable Energy: 2025 Review." *gov.ie.DECC*, DECC | Government of Ireland, 2025, assets.gov.ie/static/documents/Future_Framework_for_Offshore_Renewable_Energy__2025_Review.pdf

[109] WindEurope. "Europe Needs Stronger Ports and More Vessels to Meet Its Offshore Wind Goals." *WindEurope*, 26 Aug. 2025, windeurope.org/news/europe-needs-stronger-ports-and-more-vessels-to-meet-its-offshore-wind-goals

[110] Department of Enterprise, Trade and Employment. "Powering Prosperity – Ireland's Offshore Wind Industrial Strategy." *enterprise.gov.ie*, DETE | Government of Ireland, 8 Mar. 2024, enterprise.gov.ie/en/publications/powering-prosperity.html.

Key Findings

The analysis found that Ireland's existing port infrastructure to deploy fixed bottom offshore wind is not fit for purpose. This finding is echoed by a recent KPMG report.[111]

Ireland has limited commercial ports. State owned ports include Dublin, Shannon Foynes, Waterford, Galway, Cork Ringaskiddy, Rosslare Europort, and Drogheda (including the proposed port at Bremore). Greenore (O&M) and Bantry are both private commercial ports.

Of these ports, several have, to date, chosen not to focus on ORE deployment or are precluded from doing so due to geophysical constraints. Dublin has focused on the movement of goods and container shipping and not ORE. Shannon Foynes is not currently being considered for fixed bottom ORE development due to its location distance from the proposed fixed wind installation sites. Galway and Waterford are suitable O&M ports but not for ORE marshalling / development. Belfast has previously been used for ORE projects off the west coast of the UK and has been recently selected for investment by the UK Government, but was discounted from our analysis as it will be heavily engaged with UK projects within its area of operations on the west coast of the UK. Both Bremore and Bantry have potential for ORE development, as mentioned later.

Only two ports, Cork Ringaskiddy and Rosslare Europort, are engaged with early plans and have allocated some limited space to support fixed bottom offshore wind farm construction and marshalling. In aggregate, our analysis is that Irish ports are constrained by location, geophysical attributes and a lack of space and investment to support the logistics of planned offshore renewable wind energy development.

Port infrastructure in Ireland represents a fundamental constraint and barrier to the quantity of ORE capacity that can be installed each year, raising questions around the feasibility of these targets. At present, there is no marshalling port in the Republic of Ireland equipped to deliver an offshore wind project, and current Government policy does not include a plan to provide the port infrastructure to bridge this gap in the years ahead, nor does it empower the Irish Maritime Development Office (IMDO) to prioritise this. Without intervention, port capacity will endanger the delivery of the committed offshore renewable wind energy targets, inhibit the country's ability to attain its climate targets, and lead to a missed opportunity for job creation and cheaper energy.

Policy Considerations

A recent NexSys Policy Paper details the critical infrastructure and necessary actions required to meet Ireland's offshore wind energy goals, including the following recommendations.

- Create a coordinated national implementation plan for ORE development at Irish ports. A coordinated national implementation plan should expand on DECC's Government-led Offshore Renewable Energy (ORE) framework to include a strategy

[111] Collins, Kieran, and James Delahunt. "Ireland's Ports - Unlocking Offshore Renewable Energy." *KPMG*, 4 Sept. 2025, kpmg.com/ie/en/insights/energy-utilities-telecoms/irelands-ports-renewable-energy.html.

for marshalling port infrastructure. This plan needs to incorporate total port requirements, provide necessary planning and funding, and ensure development serves the national interest, aligning with European legislation. Crucially, this requires legislative reform to officially empower the Irish Maritime Development Office (IMDO) to prioritise and coordinate ORE port development nationwide.

- Maximise quayside space in ports for efficient ORE rollout - Based on current projections for marshalling activities at Rosslare Europort (21 ha) and Cork Ringaskiddy (23 ha), the Republic will be constrained to marshalling no more than the equivalent of 1 GW of ORE every two years. Taking stock of this capacity as part of strategic plans is critical.
- Adopt a specialised multiport approach - Industry norms are increasingly using specialised ports for ORE marshalling to separate out the key functions of foundations being staged at one and the installation of the turbine occurring from a separate port. with one port. A plan-led approach for a national installation strategy should consider such specialisation as part of a multiport strategy designating ports for foundation marshalling or turbine marshalling and to direct development accordingly.
- Identify the geophysical limitations of Irish ports for ORE - ORE equipment is growing in size and the geophysical conditions constrain the ability for ports to manage both cargo and ORE. A robust assessment of current constraints and potential opportunities, such as those presented by the Bantry and Bremore ports for customisation, should not be overlooked.
- Identify the number of marshalling ports needed for Ireland's ORE targets - NexSys research demonstrates that Ireland needs 4 dedicated ORE marshalling ports to meet Ireland's planned fixed bottom ORE development requirements, with only 2 such ports currently planned. Ireland will need to identify the number of marshalling ports needed and, through centralised project coordination, ensure that an efficient schedule is generated utilising Ireland's limited resources.
- Provide funding for critical ORE port infrastructure - As publicly-owned entities, Irish ports must pursue long-term funding instruments that align with the lifespan of the assets. Because current port balance sheets lack the capacity to independently secure the significant capital needed to construct ORE marshalling ports, Government support is essential to both underpin the ports' business cases and provide the necessary funds for investment. Ultimately, this necessitates a Government-led plan backed by dedicated funding.

Public Acceptance of Wind Farms

Wind energy is essential to national decarbonisation plans, yet local opposition continues to slow or block new developments. Governments, developers and NGOs often assume that if people knew more about the benefits of wind energy developments, they would be more likely to support these projects. This "information deficit" model underpins many public-engagement strategies in Ireland and internationally. But despite this widespread assumption, there is surprisingly little evidence that providing more information actually shifts public attitudes towards wind farms. Many factors such as political identity, place attachment, risk perceptions, and cognitive biases shape how people process new information, particularly when the topic is contentious.

NexSys research conducted at University College Dublin tested whether information about the economic impacts of wind farms influences public attitudes and behaviour. A nationally representative UK sample (n = 1,629) was randomly exposed to combinations of positive and negative arguments from academic articles, newspapers, or tweets.

Participants then rated their attitudes, had the opportunity to sign a renewable-energy petition, and could donate part of a raffle prize to a clean-energy campaign. The intention was to mirror a real "information environment" where citizens encounter competing claims from diverse sources.

Key Findings

The study found that for the population as a whole, providing information, regardless of whether it was positive, negative, or mixed, had no meaningful effect on overall public attitudes, donation decisions, or petition-signing behaviour. Prior attitudes were far more influential than any information treatment. These findings cast doubt on the information deficit model by providing evidence that resistance to wind energy cannot be explained simply by a lack of knowledge.

However, the results also reveal that negative information can matter for some groups. Among men in the sample, exposure to negative economic arguments reduced support for wind farms, even when those arguments were outnumbered three to one by positive arguments. Women on the other hand showed no measurable shift. This reflects broader evidence that negative messages are typically more influential than positive messages. The result is that communication strategies highlighting the benefits of windfarms may be undermined by a small amount of negative information in the "information environment".

The research also examined whether traits linked to motivated reasoning such as closed-mindedness changed the effect of information. Predictably, individuals with high levels of closed-mindedness were less responsive to any type of information, while more open-minded respondents showed clearer reactions to negative messaging. Perceived information quality had little moderating effect, while actual knowledge of wind farms was associated with more sceptical attitudes but a greater willingness to support renewable-energy initiatives through petition signing.

The findings suggest that communication strategies built on the delivery of factual information about the benefits of wind farms are unlikely to meaningfully shift public opinion. Positive claims about economic benefits do not reliably increase support, while negative narratives can have disproportionate influence among certain groups.

Policy Considerations

As a consequence of these findings, policymakers and developers may need to replace information based communication strategies with approaches that are supported by clearer evidence of success. Community benefit schemes, participatory planning processes, and long-term local engagement may prove more effective than attempts to persuade through information provision.

6. Energy and the Built Environment

Introduction

Ireland's buildings dominate national energy demand and emissions, with residential buildings responsible for 15% of national greenhouse gas emissions.[112] This energy demand is driven primarily by building heating needs (itself responsible for around 33% of Ireland's total energy use and approximately 20% of greenhouse gas emissions) and water use.

These energy uses are largely non-discretionary for households, and increased energy costs therefore raise the risk of energy deprivation for vulnerable communities. NexSys research has examined opportunities to reduce and decarbonise this energy consumption within the framework of a Just Transition. At the community level, our research is examining deploying advanced data analytics and modelling to guide urban sustainability through a tool that can be used to test "what-if" decarbonisation scenarios at national and city scales. Complementary to these efforts are opportunities to make buildings more active nodes within the energy system. NexSys researchers have examined how this can be made possible through emerging technologies such as peer-to-peer energy trading.

A key opportunity to reduce building energy demand relates to the heating of buildings which is still largely based on fossil fuels (notably oil and gas boilers). Policy measures to achieve emissions reductions in this space include fabric first building renovations, the electrification of building heating systems via the installation of heat pumps and the adoption of new district heating (DH) schemes, as examined in the *District Heating* section. Although district heating currently supplies under 1% of heat demand in Ireland, a pilot district heating system in Tallaght and planned large schemes in Dublin signals momentum. NexSys researchers investigate pathways to decarbonisation of buildings through modelling of decarbonisation scenarios using a novel national-scale digital twin.

Heat Networks are limited in number, but are crucial for decarbonising the heating sector, and the government supports their development. Given the challenges of gas networks with a disseminated population, heat networks may also be challenging, but there are local community heat networks elsewhere, and the future alignment to local geothermal resources may be promising. Energy efficiency has a significant focus especially in buildings to reduce overall energy consumption and reliance on fossil fuels.

In addition to the energy consumed for heating, significant energy demand within buildings is driven by water use through hot water production, pumping, appliances, and catering equipment. In 2016, heating water accounted for approximately 19% of the total residential energy usage.[113] Research from a NexSys affiliated academic found that reducing per-capita consumption by 20% could save around 0.45 kg CO_2 per property per day, while a 40%

---

[112] Sustainable Energy Authority of Ireland. "Energy-related Greenhouse Gas (GHG) Emissions." *seai.ie*, 2024, www.seai.ie/data-and-insights/seai-statistics/co2.

[113] Sustainable Energy Authority of Ireland. "Energy in the Residential Sector: 2018 Report." *seai.ie*, SEAI | Government of Ireland, www.seai.ie/sites/default/files/publications/Energy-in-the-Residential-Sector-2018-Final.pdf.

reduction could cut over a third of water-related emissions across the entire water supply and wastewater system.[114] Therefore, integrating water considerations supports the development of comprehensive and effective building energy strategies, as discussed below in the *Water-Energy Conservation in Buildings* section.

The energy consumption of buildings has a profound impact on the wellbeing of building residents, and is felt most acutely by those at risk of or experiencing energy poverty. Using data from the Growing Up in Ireland survey, a NexSys investigation of the impacts of residential energy and transport poverty on children and young people is the first to establish a link between these forms of poverty and mental health, explored further in the *Household Energy Deprivation* section.

Retrofitting & New Buildings

In 2024, SEAI supported 54,000 property upgrades (up 13% year on year), including 21,800 BER B2 upgrades (up 24%) and 7,700 upgrades in energy poverty households (up 31%). In addition, 3,600 homes were retrofitted with heat pumps, bringing the cumulative total of heat pump retrofits since 2019 to 14,194 by the end of 2024.[115] In total, by the end of 2024 there were approximately 153,000 homes in Ireland with heat pumps, up from 119,000 at the end of 2024.[116] While progress is clear, it remains modest against 2030 goals of 500,000 BER B2 retrofits and 600,000 heat pumps, underlining the scale of acceleration required.

To meet the Climate Action Plan target of 500,000 B2-level home energy upgrades by 2030, an average of 75,000 upgrades per year will be required from 2026 onwards.[117][5] Maintaining momentum and strengthening homeowner engagement will be essential to support this transition. It will be vital to continue to focus on raising awareness of the benefits of upgrades, including lower energy bills, improved BER ratings, and the financial support available, such as low-interest loans for heat pump installation. The key barriers are the payback periods associated with renovation activities and the availability of skilled workers (particularly as the provision of new housing units is a current national priority).

Newly constructed buildings generally consume less energy than their older counterparts. Legislation in this regard is still advancing the recast Energy Performance of Buildings Directive (EPBD, EU/2024/1275) requires all new public buildings to be ZEB from 1 January

---

[114] Cotterill, S., and P. Melville-Shreeve. "A Framework for improving domestic water conservation in Ireland." *Policy Brief for An Fóram Uisce* (2021).

[115] Sustainable Energy Authority of Ireland. "National Retrofit Plan: Full Year Report 2024." *seai.ie*, SEAI, Apr. 2025, www.seai.ie/sites/default/files/publications/SEAI-Retrofit-Full-Year-Report-2024.pdf.

[116] Sustainable Energy Authority of Ireland. "Energy in Ireland 2025 Report." *seai.ie*, SEAI, Dec. 2025, https://www.seai.ie/sites/default/files/publications/Energy-in-Ireland-2025.pdf

[117] Department of Climate, Energy and the Environment. "Residential Energy Efficiency." *gov.ie*, 3 Dec. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/policy-information/residential-energy-efficiency.

2028 and all other new buildings from 1 January 2030, with very high energy performance and no on-site fossil-fuel emissions. Ireland must transpose these provisions by May 2026.[118]

Policy Considerations

The policy direction for building energy is clear as Climate Action Plan 2025 (CAP25)[119] sets quantified outcomes for the built environment by 2030: the equivalent of 500,000 homes retrofitted to at least BER B2/cost-optimal level; up to 2.7 TWh per year of heat delivered by district heating (with up to 0.8 TWh by 2025); and rapid heat-pump deployment across new and existing stock. Current trajectories indicate that these targets will be missed by a considerable margin.

Current consumption will shift along three vectors:

1. **Deep retrofit and cost optimal retrofit.** Scaling to 500,000 home-equivalents at B2 means lower delivered energy per square metre and reduced peak heat demand, enabling right-sized low-temperature systems and network ready buildings. The National Retrofit Plan (2025 report) promotes a pathway and funding architecture to reach this volume by 2030.

2. **Electrification of heat.** Heat pumps in existing homes (hundreds of thousands by 2030) will further cut final energy use due to targeted seasonal performance factors of approximately 3, while raising electricity's share of final consumption. Adequate grid capacity and smart controls will be essential to manage new winter peaks, particularly in vulnerable parts of the distribution grid.

3. **District heating in heat-dense areas.** CAP25's 2.7 TWh target implies connecting a meaningful share of urban load by 2030. The Climate Change Advisory Council notes the interim 0.8 TWh milestone by 2025 (a target that has been missed) and the need to accelerate from today's very low base. Policy focus is on zoning, consumer protection and tapping waste/ambient heat at scale.

Increased participation in residential renovation requires greater engagement on behalf of homeowners. The one stop shop concept, where homeowners can engage with a single point of contact who will manage the project and associated grants for them, has proven successful in other countries. This approach is now available in Ireland and is being widely promoted.

Improving energy efficiency in buildings through deep retrofits like insulation and heat pump upgrades is foundational for flexibility but faces financial barriers. NexSys modeling of

[118] Irish Green Building Council. "Transposing the Energy Performance of Buildings Directive (EPBD) Into Irish Law." *igbc.ie*, IGBC, Feb. 2025, www.igbc.ie/wp-content/uploads/2025/02/IGBC-EPBD-MEP-Report-1.pdf.

[119] Department of Climate, Energy and the Environment. "Climate Action Plan 2025." *gov.ie*, DECC, 3 Sept. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/climate-action-plan-2025.

residential retrofits found that even under optimistic conditions (e.g. low-cost loans or grants), comprehensive retrofits often remain uneconomical for homeowners due to high upfront costs and long payback periods. Research employed a probabilistic Monte Carlo simulator applied to representative Irish housing data to evaluate retrofit scenarios. It compared, for example, adding a heat pump (with a green loan) versus a full deep retrofit (heat pump + insulation + grants). The outcomes were sobering: deep retrofits, even with subsidies, often need ~15-year paybacks and achieve only 2/3 of ambitious energy targets, while simpler upgrades pay off in 12 years but still fall short of full decarbonization goals.[120] This highlights the tough economics of deep retrofit under current conditions. In one study, residential heating/cooling use was measured across a neighborhood. These real-world data help identify inefficiencies in existing systems and calibrate the models to actual usage patterns.[121]

In summary, without stronger policy intervention, many households will not invest in upgrades that reduce demand and enable flexible, low-carbon technologies. The research underscores an urgent need for policies to reduce upfront costs and de-risk retrofitting (for example, expanded grants, low-interest financing, or tax incentives). For policymakers, the message is clear: energy flexibility starts with efficiency, and that requires lowering the financial hurdles for building upgrades. By making deep retrofits more accessible, Ireland can both cut baseline energy use and ensure homes are equipped (with heat pumps, better insulation, etc.) to shift or shed loads in response to grid needs. Policymakers should therefore consider green mortgages, grants or on-bill financing to lower upfront costs.

District Heating

Heating (including both building and industrial uses) accounts for around 42% of Ireland's total energy use and approximately 33% of greenhouse gas emissions.[122] At present, 90% of heat demand is supplied by fossil fuels, with 65% of this imported. As domestic gas fields such as Corrib and Kinsale decline, Ireland will face growing dependence on imports, creating risks for energy security alongside climate challenges.

Renewable heat deployment has increased in the last decade but remains low by European standards. In 2013, renewables supplied just 5.2% of Ireland's heat demand, rising to 8.0% in 2023. Despite this progress, Ireland fell short of its 2020 renewable heat target of 12%, reaching only 6%.[123] Meeting national and EU climate objectives requires accelerating the uptake of renewable and low-carbon heating technologies.

---

[120] Pallonetto, F. et al. "Advancing retrofitting feasibility analysis: A probabilistic application to Ireland's housing stock". Energy and Sustainability Conference, Crete, 2025.
[121] Mohseni-Gharyehsafa, B. et al. "Energy performance evaluation of residential HVAC systems in a community setting." Energy and Sustainability Conference, Crete, 2025.
[122] Sustainable Energy Authority of Ireland. "Energy-related Greenhouse Gas (GHG) Emissions." *seai.ie*, 2024, www.seai.ie/data-and-insights/seai-statistics/co2.
[123] Sustainable Energy Authority of Ireland. "Renewables." *seai.ie*, www.seai.ie/data-and-insights/seai-statistics/renewables.

District heating has been repeatedly identified as a key pathway to these objectives. The SEAI's National Heat Study[124] concluded that district heating could meet over 50% of Ireland's heat demand, particularly in cities and large towns where heat density is high and renewable and waste heat sources are available. District heating offers a practical means to decarbonise heat, reduce fossil fuel imports, and improve energy security by harnessing indigenous resources such as waste heat, geothermal, and large-scale heat pumps.

Ireland's first large-scale operational network, the Tallaght District Heating Scheme,[125] commenced in 2023. It captures waste heat from an Amazon Web Services data centre and supplies council buildings, the Technological University Dublin campus, and local affordable housing. Expansion is planned to connect further consumers. In parallel, the Dublin District Heating System is progressing to capture heat from the Poolbeg Waste-to-Energy Plant for distribution across the city. Several local authorities, supported by SEAI and the Department of the Environment, Climate and Communications, are undertaking feasibility studies and pilot projects with the aim of building a national portfolio of schemes,[126] with contributions from NexSys researchers working with local authorities and energy agencies on the technical elements of these studies.

Significant barriers have, however, limited the pace of rollout. SEAI's analysis shows that heat remains dominated by fossil fuels, with only a modest shift in the past decade,[127] reflecting the high capital intensity of district heating infrastructure. Heat networks require major upfront investment in buried pipework, energy centres and customer substations, while revenues build only gradually as connections increase. Access to low cost, long term finance for this infrastructure has been limited, particularly for local authorities that must balance district heating against competing capital priorities. On the legislative side, the Heat Networks and Miscellaneous Provisions Bill 2024[128] represents Ireland's first dedicated heat networks legislation, but the sector is currently in a transition phase while detailed licensing, tariff methodologies and consumer protection arrangements are developed by the Commission for Regulation of Utilities. This period of regulatory uncertainty can slow investment decisions and complicate project timelines.

In response to these barriers, new funding mechanisms and policy measures are beginning to act as important enablers. In November 2025, the Government launched a €5 million District Heating Pre-Construction Fund, financed from the Climate Action Fund and administered by

---

124 Sustainable Energy Authority of Ireland. "National Heat Study: Net Zero by 2050." *seai.ie*, Feb. 2022, www.seai.ie/sites/default/files/publications/National-Heat-Study-Summary-Report.pdf. https://www.seai.ie/data-and-insights/national-heat-study

125 Heatworks. "Learn More About District Heating." Heatworks.ie.

126 Codema - Dublin's Energy Agency. "District Heating - Codema." *Codema*, 27 May 2025, www.codema.ie/our-work/district-heating.

127 Sustainable Energy Authority of Ireland. "Energy in Ireland." *seai.ei*, www.seai.ie/data-and-insights/seai-statistics/key-publications/energy-in-ireland. Energy in Ireland 2024 Report

128 Department of Climate, Energy and the Environment, "Heat (Networks and Miscellaneous Provisions) Bill 2024." *gov.ie*, 12 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/heat-networks-and-miscellaneous-provisions-bill-2024. Heat (Networks and Miscellaneous Provisions) Bill 2024

the Department of Climate, Energy and the Environment.[129] This fund supports pre-construction costs for efficient district heating projects, including feasibility, design, planning and early commercial work, and is explicitly intended to bridge the gap until significant capital funding is in place. In parallel, the Department's NDP Sectoral Capital Plan for 2026-2030 designates an indicative allocation of €50 million to €100 million for District Heating Infrastructure from the Infrastructure, Climate and Nature Fund, signalling dedicated multi-annual capital support for the build-out of heat networks later this decade.[130] Together, these two distinct schemes provide a clearer pathway from early project development through to construction.

These developments mark a significant step in positioning district heating as a cornerstone of Ireland's low carbon transition. The combination of local authority leadership, demonstration projects, emerging regulatory clarity and dedicated funding has created momentum. However, large-scale deployment will require continued policy support, targeted investment and close coordination with electricity system planning, since future district heating schemes will rely increasingly on large heat pumps operating within a renewable-led power system. Recent work by NexSys researchers[131] illustrates that when district heating networks are allowed to participate in electricity flexibility markets, they can shift consumption to periods with higher renewable output, lowering operational emissions while supporting grid stability. The ability to earn flexibility revenues also strengthens the economic case for district heating, providing a direct incentive to contribute to sector coupling and to operate in a way that aligns heat demand with low carbon electricity availability. Embedding this integrated heat–electricity perspective within national and regional planning frameworks will improve overall system resilience, reduce renewable curtailment and enhance the role of district heating in Ireland's climate and energy security objectives.

NexSys research focusing on data center cooling and waste heat recovery research is shaping best practices, showing how smarter systems cut energy demand and enable integration into national district heating goals. As data centre servers continue to become more power-hungry and more densely packed to meet the growing needs of AI, cooling technology is moving from air cooling to liquid cooling, or a hybrid of both. While this move is driven primarily by cooling limitations, it could also help enable waste heat recovery. One of the main barriers to waste heat recovery is the low quality (i.e., low temperature differential to the ambient) at which heat could be extracted from air-cooled systems.[132] Liquid cooling, if implemented appropriately,

---

[129] Department of Climate, Energy and the Environment. "€5 Million Pre-construction Fund Launched to Accelerate District Heating Projects in Ireland." *gov.ie*, 13 Nov. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/press-releases/5-million-pre-construction-fund-launched-to-accelerate-district-heating-projects-in-ireland.

[130] Department of Climate, Energy and the Environment, "Minister O'Brien Announces Publication of Department's NDP Sectoral Capital Plan for 2026-2030." *gov.ie*, 24 Nov. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/press-releases/minister-obrien-announces-publication-of-departments-ndp-sectoral-capital-plan-for-2026-2030.

[131] Etemad, Alireza, et al. "Evaluating the impact of thermal energy storage on grid flexibility in district thermal source networks." *Journal of Physics: Conference Series*. Vol. 3140. No. 6. IOP Publishing, 2025.

[132] Wahlroos M, Pärssinen M, Rinne S, Syri S, Manner J, Future views on waste heat utilization – Case of data centers in Northern Europe, *Renewable and Sustainable Energy Reviews*, 82: 1749-1764, 2018, https://doi.org/10.1016/j.rser.2017.10.058

allows the waste heat quality to be increased. A second main barrier is increased investment cost.

With the cooling bottleneck caused by AI demands, the migration to liquid cooling seems inevitable however this still leaves the remaining infrastructure costs to transport heat from data centres to end users. It is worth noting the evolution to 4th generation district heating (4GDH),[133] where the goal is to lower the required quality of (waste) heat that can be used effectively for residential and commercial buildings, which addresses the heat quality challenge from the demand side.

Looking to 2030 and beyond, Ireland's heat sector must also align with the Renewable Energy in Heating target (12% by 2030) and the broader energy-efficiency obligations under the recast Energy Efficiency Directive. By the mid-2030s, as Energy Performance for Building EPBD-driven ZEB standards take hold, typical new buildings should exhibit very low delivered energy consumption intensities, with heat met predominantly by heat pumps and DH, and with fossil boilers effectively phased out. Efforts to test and adapt 4GDH in Ireland, such as through the Tallaght District Heating Scheme supported by the Interreg North-West Europe project HeatNet NWE, should be expanded and accelerated to support effective policy development.

Water-Energy Conservation in Buildings

A significant proportion of the energy used by buildings is related to water through heating, pumping and use by appliances. Although Ireland is a water-rich country, its water supply systems face pressure from population growth, rising living standards, housing development, and ageing infrastructure.[134] Uisce Éireann has responded with leakage reduction programmes and campaigns to promote conservation.[135] In parallel, a framework developed for An Fóram Uisce, based on research funded by The Energy Systems Integration Partnership Programme (ESIPP) (a precursor to NexSys), recommended these practical measures: introducing mandatory water labelling and stronger building standards, creating a national water conservation team, distributing free water-saving kits, and supporting coordination and education through workshops and best-practice sharing.[136]

An Fóram Uisce's report also highlights the multiple benefits of water conservation, including contributions to Ireland's net-zero targets, since lower water demand reduces energy use and greenhouse gas emissions. Indeed, energy is required at every stage of the water cycle: abstraction, treatment, and distribution of drinking water; collection and treatment of wastewater; and within buildings for pumping, water heating, and appliances (**Figure 6.1**). Water and wastewater utilities account for a large share of municipalities' electricity use, while

---

[133] Lund H, *et al*., The status of 4th generation district heating: Research and results, Energy, 164: 147-159, 2018, https://doi.org/10.1016/j.energy.2018.08.206

[134] Buckley, Eva, Philip Crowe, and Sarah Cotterill. "Addressing the housing crisis in Irish towns: an exploration of water infrastructure capacity challenges." *International Journal of Water Resources Development* (2025): 1-22.

[135] Uisce Éireann. "National Water Resources Plan | Uisce Eireann." *water.ie*, www.water.ie/projects/strategic-plans/national-water-resources.

[136] Cotterill, S., and P. Melville-Shreeve. "A Framework for improving domestic water conservation in Ireland." *Policy Brief for An Fóram Uisce* (2021).

water-related energy consumption represents approximately 20% of Irish residential buildings' energy demand.[137]

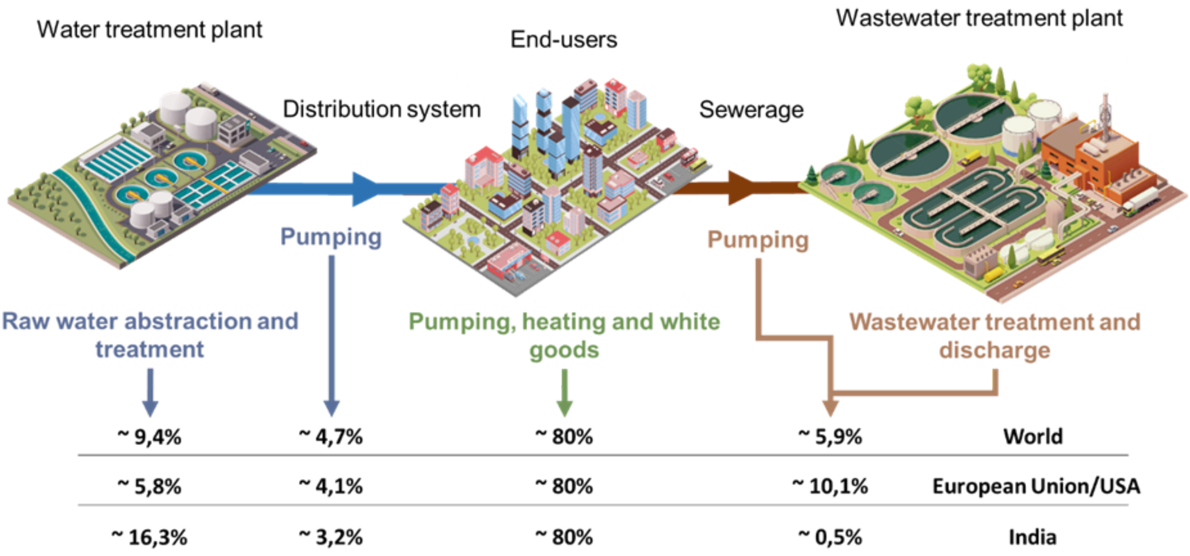

Figure 6.1: Energy use breakdown by activity in the urban water cycle[138]

NexSys research shows that conservation measures targeting hot water use (e.g. in showers or baths) offer the greatest energy savings. Since approximately 80% of the energy linked to the urban water sector occurs in buildings, primarily for water heating, including water use in the Building Energy Rating (BER) certificate is recommended. This inclusion would create stronger links between water and energy efficiency in buildings.[139]

Alternative water sources such as rainwater harvesting (RWH) or reuse of lightly polluted water (e.g. from bathroom sinks or showers, sometimes referred to as grey water) are less effective for energy savings. The energy needed for additional pumping and on-site treatment often outweighs the savings from reduced demand on centralised systems, except where supplies are especially energy-intensive, like desalination or long-distance water transfers. However, life-cycle assessments suggest that decentralised systems can lower the overall environmental footprint of the water sector.[140]

In Ireland, RWH has particular potential due to steady, abundant rainfall throughout the year and the presence of private group water schemes. These independent schemes supply many rural households but face ongoing challenges with cost and water quality.[141] For these reasons,

---

[137] Sustainable Energy Authority of Ireland. "Residential Energy Statistics in Ireland." *seai.ie*, 2025, www.seai.ie/data-and-insights/seai-statistics/residential.

[138] Jacque, Hugo, et al. "Implications of water conservation measures on urban water cycle: A review." *Sustainable Production and Consumption* 50 (2024): 571-586.

[139] Cotterill, S., and P. Melville-Shreeve. "A Framework for improving domestic water conservation in Ireland." *Policy Brief for An Fóram Uisce* (2021).

[140] Jacque, Hugo, et al. "Implications of water conservation measures on urban water cycle: A review." *Sustainable Production and Consumption* 50 (2024): 571-586.

[141] Li, Zhe, Fergal Boyle, and Anthony Reynolds. "Rainwater harvesting and greywater treatment systems for domestic application in Ireland." *Desalination* 260.1-3 (2010): 1-8.

alternative sources should not be overlooked, as they can complement other conservation measures and improve resilience in certain contexts.

Barriers

Several barriers slow the adoption of water–energy conservation measures. The absence of domestic water charges limits financial incentives for households, despite strong motivation to reduce energy bills. The lack of widespread water metering also makes it difficult to detect and fix leaks or to track the impact of conservation initiatives. More broadly, limited data on water and energy use across the system constrains both utility planning and research into the effectiveness of conservation measures. Closer collaboration between Uisce Éireann and research programmes such as NexSys is essential to improve data access and develop evidence-based strategies.

Policy Considerations

Finally, further research is needed on how water conservation affects wastewater treatment plant energy demand. Early results suggest that assuming energy use falls proportionate to wastewater volume overestimate savings. A better understanding of these dynamics is essential for a realistic assessment of water–energy measures. Further research should examine the potential of RWH for Irish households, both at the individual house and group scheme levels, as well as public willingness to adopt or invest in such systems. Policy actions could include awareness campaigns, educational initiatives, and financial incentives such as rebates or subsidies to support RWH adoption.

Building Energy Flexibility & Peer-to-Peer Trading

Achieving Ireland's climate goals (such as 80% renewable electricity by 2030) will require not just more wind and solar, but smarter ways to use energy when and where it's available. In practice, this means empowering communities, homes, and businesses to become more flexible in how they consume and produce energy. From a policymaker's perspective, energy flexibility is a crucial resource to ease grid constraints and balance supply and demand as renewables rise. The NexSys research programme has been investigating how to harness this flexibility at the community, district, and city levels, and its findings highlight key areas where policy support is needed to unlock local energy flexibility for Ireland's net-zero pathway.

As discussed earlier in this chapter, improving energy efficiency in buildings through deep retrofits like insulation and heat pump upgrades is foundational for flexibility but faces financial barriers. However, upgrading physical infrastructure is only part of the solution; buildings and local networks also need to become smart and responsive. NexSys researchers envision the concept of an "active node" building that *"generates, stores, manages, and exchanges energy bidirectionally with the grid"*. In practice, this means homes, businesses, or community centers with solar panels, battery storage, electric vehicles, or smart heating/cooling systems actively adjusting their import or export of power in real-time.[142] To achieve this vision, technical requirements must be in place: real-time data acquisition, building management systems, secure communication networks, and hardware like smart meters, controllable inverters, EV chargers, and grid-interactive HVAC controls. Crucially, NexSys findings point out that technology alone is not enough; there are significant *challenges* that policy must address to enable active energy nodes at scale. These include interoperability and standardization issues (devices and platforms need common standards to communicate), regulatory and market barriers (e.g. rules that hinder P2P energy trading or demand response participation), the high upfront costs of smart equipment, and even behavioral hurdles like occupant engagement and acceptance of new controls. From a policymaking standpoint, this implies a need for comprehensive frameworks and incentives that encourage the adoption of smart-energy tech and ensure different systems work together. For instance, developing standards for smart appliances, mandating demand-response readiness in new buildings, or providing training and awareness programs for consumers can all help transform passive energy consumers into active flexible participants in the energy system.

Peer-to-Peer Energy Trading

NexSys researchers are examining emerging approaches to energy flexibility for households. Peer-to-peer (P2P) energy trading has emerged as a market mechanism allowing households, businesses, and communities to trade electricity directly. Unlike the traditional model where prosumers export excess power to the grid for a fixed Feed-in Tariff (FiT), P2P models enable flexible, locally negotiated exchanges. This enhances flexibility, creates market diversity, and positions citizens as active participants in the clean energy transition.

The benefits for P2P energy trading are threefold. First, it strengthens system efficiency by matching local supply with local demand. Second, it generates economic benefits: prosumers can receive higher returns than FiT rates, while consumers can access renewable energy below retail tariffs. Third, it delivers social and environmental gains by enhancing community engagement, advancing decarbonisation objectives, and improving resilience in decentralised energy systems.

NexSys Case Study

Ireland has introduced supportive mechanisms such as the Renewable Energy Feed-in Tariff (REFIT) and the Microgeneration Support Scheme (MSS) with its Clean Export Guarantee (CEG).[143] [144] While these schemes incentivise small-scale generation, they stop short of

---

142 Bampoulas, Adamantios, et al. "[A Bayesian deep-learning framework for assessing the energy flexibility of residential buildings with multicomponent energy systems.]" *Applied Energy* 348 (2023): 121576.

143 Department of Climate, Energy and the Environment. "Renewable Energy Feed-in Tariff (REFIT) Scheme." *gov.ie*, 15 Apr. 2025, www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/renewable-energy-feed-in-tariff-refit-scheme.

144 Department of Climate, Energy and the Environment. "Micro-generation Support Scheme." *gov.ie*, Aug. 2023,

enabling direct peer transactions. Pilot projects illustrate both potential and limitations. The ESB Networks Dingle project revealed challenges due to the absence of dynamic pricing and unclear supplier incentives, while the CityXChange initiative was hindered by more focus on EV infrastructure and network constraints.[145] [146] European and global examples demonstrate how P2P can deliver system and social value.[147] International pilots demonstrate significant benefits: reductions of 7–10% in household energy costs, and doubled export revenues for prosumers compared to conventional tariffs.

Barriers and Enablers

In Ireland, the absence of clear rules on licensing, billing, and settlement remains a critical barrier. GDPR requirements restrict the secure flow of consumption and generation data, hindering the integration of third-party platforms. Electricity suppliers have little commercial incentive to participate, as P2P threatens established business models. Additionally, the limited visibility and controllability of the low-voltage network make it challenging to manage congestion and operational risks under decentralised trading.

Despite these challenges, Ireland has several strengths that can accelerate P2P deployment. The national smart meter rollout provides the infrastructure for time-of-use and dynamic tariffs. Distributed generation from rooftop PV and community-owned assets continues to expand. EU legislation through the RED II legally recognises P2P trading, providing a supportive policy backdrop. Most importantly, Ireland's Sustainable Energy Communities (SECs) offer a strong foundation to trial peer-based models within trusted local governance structures.[148]

Policy Considerations

As further outlined in a recent NexSys policy paper,[149] a phased and coordinated approach is essential to transition P2P from concept to mainstream. Short-term actions should focus on:

---

www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/micro-generation/#micro-generation-support-scheme-mss. Micro-generation Support Scheme

145 Egan, Fergal. *The Dingle Electrification Project: Sharing learnings from the peer-to-peer energy trading objective*. DOC-181220-DNG, ESB Networks, Dec. 2020, esbnetworksprdsastd01.blob.core.windows.net/media/docs/default-source/publications/the-dingle-electrification-project---sharing-learnings-from-the-peer-to-peer-energy-trading-objective.pdf?sfvrsn=211af907_0.

146 +CityxChange. "Positive City ExChange." *cityxchange.eu*, cityxchange.eu.

147 Malik, Sweta, et al. "Towards Peer-to-Peer (P2P) Energy Trading: A Policy Pathway for Ireland's Decentralised Energy Future." *nexsys-energy.ie*, www.nexsys-energy.ie/t4media/NexSys_Policy_Brief__Peer_to_Peer_Energy_Trading_.pdf.

148 Sustainable Energy Authority of Ireland. "Sustainable Energy Community Network." *seai.ie*, 10 Dec. 2025, www.seai.ie/plan-your-energy-journey/for-your-community/sustainable-energy-communities. Sustainable Energy Communities | SEAI

149 Malik, Sweta, et al. "Towards Peer-to-Peer (P2P) Energy Trading: A Policy Pathway for Ireland's Decentralised Energy Future." *nexsys-energy.ie*, www.nexsys-energy.ie/t4media/NexSys_Policy_Brief__Peer_to_Peer_Energy_Trading_.pdf.

- Revise the MSS to integrate dynamic pricing, enabling prosumers to capture real-time value and consumers to benefit from lower costs.
- SECs should be supported to pilot P2P using secure data-sharing mechanisms and digital platforms.

In the medium term:

- Clear business models must be developed to incentivise suppliers and DSOs, for example through transaction fees, supplier-enabled billing, or flexibility services.
- Robust data governance must accompany this, with the Smart Meter Data Access Code and GDPR-compliant frameworks ensuring trust and transparency.

Long-term measures should include:

- The establishment of a comprehensive legal and regulatory framework for P2P, supported by sandbox trials, explicit supplier responsibilities, and defined settlement procedures.

Data and Modelling for Urban Transitions

NexSys research is employing advanced data analytics and modelling to guide urban sustainability. A multi-scale emissions model for Ireland, integrating transport, weather, land-use and sectoral energy data in the Weather Research & Forecasting (WRF) framework[150] is under development. A case study shows how this tool can test "what-if" decarbonisation scenarios at national and city scales. The model is already aiding local planning: for example, Dublin's climate office uses it to generate "Climate Vitals" (emission trends, urban heat indicators, etc.) for tracking progress.[151] A data-driven method using high-resolution (1 km) public data is used to quantify cities' exposure to climate hazards (extreme heat, flooding, etc.). This approach creates a common basis to compare diverse cities. Early results show cities can be ranked by vulnerability, helping planners worldwide prioritize adaptation for the most at-risk areas.[152]

These data and models can directly inform the approach of policymakers. The national GHG framework provides an evidence base to quantify how actions (transport electrification, home retrofits, etc.) affect Ireland's emissions trajectory. Dublin's adoption of Climate Vitals exemplifies research in practice: officials now track citywide emissions and heat-island patterns to pinpoint where interventions are needed. On the international stage, the global risk work means Irish research contributes to global benchmarking of urban resilience.

---

[150] Sati, A.P., Mills, G., Pilla, F., and Fealy, R. "Urban Transport-Based Emissions: A Multi-Scale Modelling Approach Using WRF and MUNICH Models" in Dublin, Ireland. 12th International Conference on Urban Climate, Rotterdam, The Netherlands. July 8, 2025.

[151] Sati, A.P. et al. (2025). "Creating a comprehensive model to support greenhouse gas emission strategies: A case study for Ireland", Journal of the European Meteorological Society, vol. 3, 2025, https://doi.org/10.1016/j.jemets.2025.100020

[152] Li, Z. and Mills, G. "Generating Urban Canopy Parameter for Global Cities Using a Data-Driven Approach", 12th International Conference on Urban Climate, Rotterdam, The Netherlands, 7–11 Jul 2025, ICUC12-534, https://doi.org/10.5194/icuc12-534 , 2025.

Household Energy Deprivation

The preceding research insights examining energy use in the built environment must be contextualised from the perspective of the impact this energy use has on residents' wellbeing. Energy is a key component in a number of services that are essential to our daily lives, such as heating, cooling, cooking, travelling, lighting, and refrigeration. It is also considered essential for a range of social capabilities, such as work life, social participation, communication, health and education.[153] Energy poverty and or energy deprivation affects families, groups and/or households who are unable to access and/or to afford these essential energy services. It is also important to acknowledge that the issue of energy poverty is relevant in both the residential and transport sectors with transport examined in closer detail in the next chapter.[154]

Residential energy poverty usually refers to families or households that are having trouble heating their homes and/or affording to keep their homes adequately warm. It contributes to and exacerbates some significant social and environmental problems, including poor mental and physical health; social exclusion, stress and stigma; lower educational outcomes; as well as fossil fuel usage and energy consumption levels which are unhealthy for humans and the planet.[155] Going without adequate heating for prolonged periods of time can result in the continued use of coping strategies which are harmful to those living in the home and this, in turn, may worsen their energy poverty.

NexSys Key Findings

Using data from the Growing Up in Ireland survey, a NexSys investigation of the impacts of residential energy and transport poverty on children and young people is the first to establish a link between these forms of poverty and mental health.[156] In the case of residential energy poverty, our longitudinal analysis reveals that these effects remain after controlling for social economic groups, i.e. it is not all about income. It also confirms its detrimental effects on educational outcomes (in line with national/international research), but adds new evidence about the extent to which cumulative experiences of energy deprivation are damaging to the wellbeing of children and adolescents.

Further, a NexSys systematic review on residential energy poverty and transport poverty[157] - the first to examine both sectors to the best of our knowledge - is critical to understanding

[153] Day, Rosie, Gordon Walker, and Neil Simcock. "Conceptualising energy use and energy poverty using a capabilities framework." *Energy Policy* 93 (2016): 255-264.
[154] Dingley, Orla. "Addressing Energy Poverty in Ireland." *Public Policy.ie*, Nov. 2023, publicpolicy.ie/environment/addressing-energy-poverty-in-ireland.
[155] Winston, Nessa, et al. "Combating Residential Energy Poverty in Existing Dwellings: Eco-social Policies and Sustainable Welfare in Denmark and Ireland." *Policy Press eBooks*, 2025, pp. 196–209. https://doi.org/10.51952/9781447372851.ch014.
[156] Da Silva Pedroso, Monika, et al. "Improving Child Wellbeing: The Effects of Transport and Residential Energy Poverty on Education and Mental Health of Children and Adolescents." *Child Indicators Research* 18.6 (2025): 2557-2595.
[157] Dingley, Orla, et al. "A systematic review and meta-analysis of residential and transport energy poverty." *Energy Research & Social Science* 124 (2025): 104054.

their conceptualisations and how their dimensions are defined and measured. This is essential from a policy impact perspective.

Research using TILDA (The Irish Longitudinal Study on Ageing) data on energy deprivation among older people in Ireland reveals that living alone triples the risk of residential energy poverty; that older people in poor health are three times more likely to be in residential energy poverty; and that having an occupational or private pension reduces the risk of residential energy poverty by half.[158]

Using the Household Budget Survey and Exiobase emissions data, we are conducting a novel assessment of social inequalities in carbon emissions in the residential energy and transport sectors. Preliminary results reveal important socio-demographic variations in household emissions, including substantially higher residential energy-related (per capita) emissions among larger families/households, especially those with children, as well as among households from lower income groups.[159]

Barriers

In relation to residential energy poverty, a significant barrier is the fact that existing datasets do not investigate all of the important aspects of energy deprivation, including harmful coping mechanisms some people adopt, such as limiting or reducing heating to certain rooms/sections in the house, or times during the day. In addition, ongoing research on the incidence of energy deprivation among older people reveals the limitations of current policies to address residential and public transport poverty for this age group. The same can be said in relation to policies to alleviate the energy poverty situation of children and their families, especially younger children.

Enablers

An important first step in addressing the problem of residential energy poverty is the identification of households having trouble heating their homes and/or keeping their homes adequately warm. A second step would be to address whether this lack of residential thermal comfort is related to affordability (e.g. energy cost-related issues; self-disconnection; arrears in energy bills, insulation problems), accessibility (e.g. type of fuel/main heating type; payment options available), or a mix of these problems. This investigation would benefit from data from more meaningful survey or census questions that would capture the complex issue of residential energy poverty in its entirety. In addition, this type of data would assist in the implementation of more effective, targeted policies.

Monitoring the factors which moderate residential energy poverty or vulnerability would be very useful for effective policy design and implementation. These factors may include

[158] Dingley, O. "Enhancing resilience in older adult populations: addressing the multiple faces of energy and transport poverty in Ireland". ESPANet Stream 11 (2025).(forthcoming).

[159] Winston, N., da Silva Pedroso, M., & Mac Domhnaill, C. "Resilience, inequalities and CO2 emissions: towards a just transition in the residential and transport sectors in Ireland?" ESPANet Stream 11 (2025). (forthcoming).

household composition (e.g. family size, lone parents, people with chronic illness or disabilities), spatial (e.g. rural, urban, periurban) and socio-demographic variables (e.g. income, house tenure). It would be helpful to create 'energy-use profiles' which reveal typical annual energy consumption profiles for different types of households (e.g. lone parents, people with disabilities). This could improve the targeting and speed of rollout of measures to the most vulnerable households.

Policy Considerations

As stated in the recent NexSys Submission[160] to Ireland's Social Climate Plan, vulnerable families and households should be prioritised as they are less likely to be in a position to afford and cope with climate change mitigation and adaptation. Particularly, we recommend prioritising building retrofit supports for vulnerable households in local authority social housing and approved housing body (AHB) social housing. This is the most cost-efficient way to reach those households most affected by energy poverty. This should be combined with the following:

- Prioritise targeted, full cost energy upgrades for low income vulnerable groups, specifically: Disabled people; lone parents; large families; working poor families; older people; young children; renters.
- Change the focus of the SEAI Sustainable Energy Community Mentors work to prioritise the most vulnerable households. This would make it more similar to the free 'Green Doctors Scheme' in the UK. It would ensure energy experts visit low income, vulnerable households to help them reduce bills and emissions. They can also provide training on the smart meters, time of use tariffs, the correct use of heat pumps and dynamic electricity pricing. The scheme could be advertised via community services (e.g. public health nurses, GPs, family resource centres) and these services could also refer those most in need to the scheme.
- Return to unit-based energy benefit v. cash-based subsidies (e.g. fuel allowance) to ensure minimum level of electricity/gas regardless of cost. The eligibility criteria and seasons could be as per the Fuel Allowance.
- Reserve access to SEAI grants to the most disadvantaged households for a period.

Finally, national definitions and indicators of both transport and energy poverty are required and these need to be included in all relevant household surveys including: the Growing up in Ireland Survey, Tilda, SILC and the National Student Survey.

[160] Winston, N., da Silva Pedroso, M., Dingley, O., & Doody, J. "NexSys Submission to Consultation on the Development of Ireland's Social Climate Plan." 2025. https://www.nexsys-energy.ie/t4media/Submission%20to%20Social%20Climate%20Plan%20Consultation.pdf

7. Transport

Introduction

Transport represented the largest share of energy consumption in 2023, accounting for 43.4% of overall demand in Ireland and 94% of this demand was fulfilled by fossil fuels. The modal share of energy demand is presented in **Figure 7.1.**

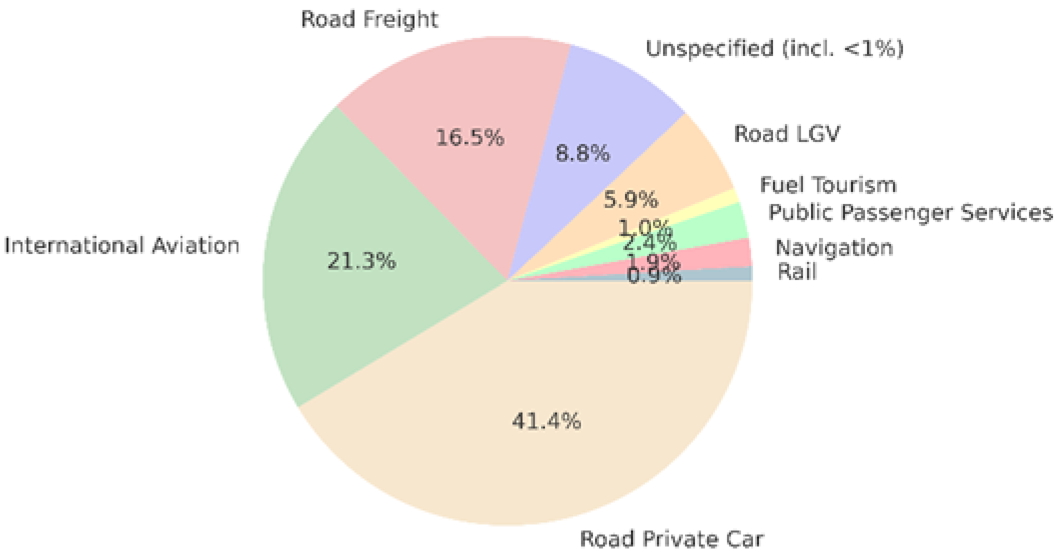

Figure 7.1: Transport energy use by mode

Transport has the highest energy demand of any sector in the Irish economy, and the energy demand from all three of the largest sub-sectors of transport – private car use, international aviation, and HGV road freight – are increasing.[161] Without rapid rollout of electrification and alternative fuels, this demand and related greenhouse gas (GHG) emissions will undermine sectoral carbon budgets and the Government's targets for carbon neutrality by 2050.

Diesel is the primary energy product in the transport sector. The majority of passenger cars and almost all road freight vehicles are powered by diesel. About 8.5% of the diesel and 4.2% of the petrol used for road traffic in Ireland are biofuels.[162] In Ireland, there is a target of a 43% overall renewable energy share (RES) under the Renewable Energy Directive (RED) by 2030. Additionally, it is planned to have 70% use of sustainable aviation fuel (SAF) by 2050 as part of the ReFuelEU Aviation Initiative. Current trajectories suggest Ireland will exceed its first and second sectoral carbon budgets for transport by 1.1 and 5.4 million tonnes of CO_2 equivalent, respectively, and achieve only a 29% reduction in total emissions by 2030—well short of the 51% target. Non-compliance is expected to impose substantial fiscal costs.[163]

---

[161] Sustainable Energy Authority of Ireland. "Energy in Ireland 2025" seai.ie, Dec. 2025, https://www.seai.ie/sites/default/files/publications/Energy-in-Ireland-2025.pdf

[162] Sustainable Energy Authority of Ireland. "Energy in Ireland." *seai.ie*, www.seai.ie/data-and-insights/seai-statistics/key-publications/energy-in-ireland.

[163] Climate Change Advisory Council. "A Colossal Missed Opportunity - Ireland's climate action and the potential costs of missing targets." *climatecouncil.ie*, 3 March 2025, https://www.climatecouncil.ie/councilpublications/otherpublications/Ireland%E2%80%99s%20cli

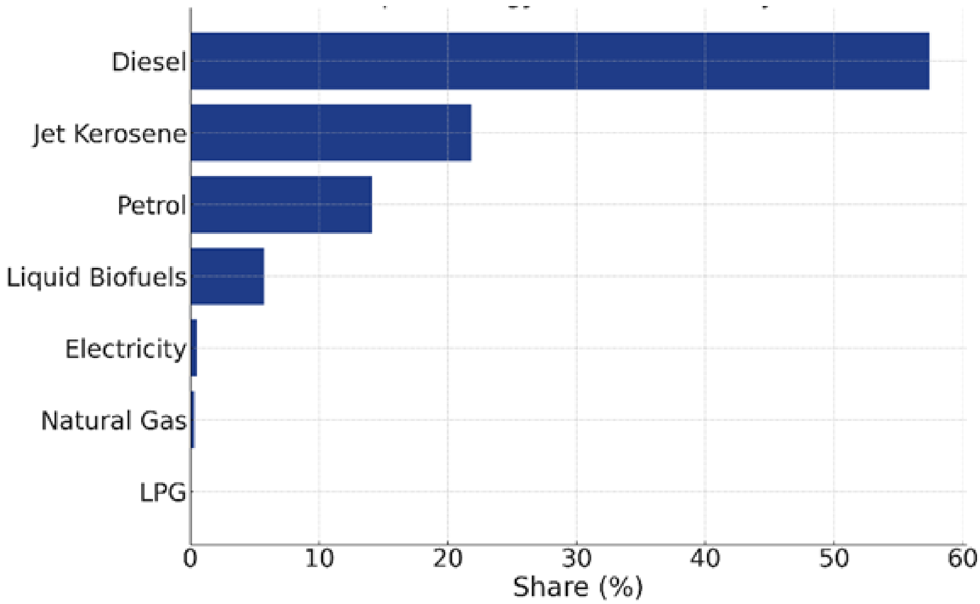

Figure 7.2: Transport energy use by fuel type

Effective decarbonisation requires a multi-faceted approach and the Irish Government has planned to adopt an "Avoid-Shift-Improve" strategy.[164] Reduction in demand particularly in passenger cars, modal shift in freight traffic as well as commuters and an overall increase in use of renewable energy are planned. The research carried out in NexSys aligns with these objectives.

NexSys research findings bring attention to possible areas of demand reduction, methods of decarbonisation as well as improved use of renewable fuels. Modelling shows that the total passenger transport demand is projected to rise from 69 billion pkm in 2024 to 98 billion pkm by 2050, without appropriate policy interventions. Policies such as a ban on the sale of new internal combustion engine (ICE) vehicles, including hybrids, or further increases in carbon taxation may be critical to restrict CO_2 emissions from the transport sector in Ireland. Additionally, a spatial model of transport energy demand shows higher energy demand beyond the suburbs resulting from spatial separation between housing and workplaces. This is closely linked with the housing crisis and high cost of living in Ireland especially in its urban centres.

In Ireland, light goods vehicles (LGVs), particularly those between 2 and 3.5 tonnes, represent the fastest-growing segment of the freight sector, reflecting strong economic growth. NexSys findings also address opportunities for reducing energy related CO_2 emission levels for LGVs, specifically how small and medium enterprises (SMEs) can successfully transition to fully electric fleets. This shift is made viable through supportive policies aimed at both developing the necessary charging infrastructure and improving access to the Electric Vehicle (EV) market. The heavy duty vehicles in the freight sector in Ireland relies heavily on diesel and requires strong support for the shift to alternative and renewable fuels. Critical infrastructure

---

mate%20action%20and%20the%20potential%20costs%20of%20missing%20targets%20FINAL.pdf

[164] Department of Transport. "National Sustainable Mobility Policy." *gov.ie/transport*, Department of Transport | Government of Ireland, 9 Sept. 2025, assets.gov.ie/static/documents/sustainable-mobility-policy.pdf.

investments for alternative fuels and vehicles will be necessary as well as cross-border harmonisation of policies based on feedback from Heavy Goods Freight Operators. The energy demand for international aviation increased by 12.9% in 2023. Our findings identify the critical need for green hydrogen and a mix of other sustainable fuels for decarbonising this sector. However, in all cases the costs are substantial and fiscal support is required for achieving the 2030 and 2050 targets.

Ultimately, situating energy poverty within the context of transport decarbonisation is essential in Ireland to support a just transition. NexSys research shows that the high cost of decarbonising transport disproportionately affects rural households, older people, and children in low income families. These groups face greater isolation due to limited transport options, with many rural households effectively trapped and reliant on car ownership with limited resources to achieve transport decarbonisation.

Passenger Transport Modelling and Projections

A NexSys study produced by ESRI-based researchers provides a newly developed passenger transport model for Ireland, I3E-Transport, designed to evaluate technological and behavioural decarbonisation policies.[165] The model is integrated with a Computable General Equilibrium (CGE) model, the Ireland Environment–Energy–Economy (I3E) Model, enabling analysis of how transport policies interact with fuel prices and broader economic activity.[166] I3E-Transport employs a nested multinomial logit framework to capture decision-making across multiple levels—including mode choice, and for the car mode by fuel type, engine size, and vehicle vintage—while incorporating features such as vehicle scrappage, distance decay, and changes in efficiency. The model is calibrated on data from 2008-2023, including travel behaviour, vehicle stock, fuel prices, taxation, and energy performance. This framework is applied to a set of policy scenarios for 2025–2050. These include a business-as-usual baseline, Ireland's planned carbon tax trajectory, and ICE phase-out policy scenarios, both with and without hybrid vehicles, which also include planned changes in the level of carbon taxation.

The results, shown in **Figures 7.3, 7.4 and 7.5** indicate that in the absence of a sales ban on new ICE vehicles from 2035 or additional policy measures—such as further increases in carbon taxation—projected growth in national income and population drives a sustained expansion in passenger transport activity. This leads to continued increases in vehicle stock, energy use, and CO_2 emissions from the sector. Total passenger transport demand is projected to rise from 69 billion pkm in 2024 to 98 billion pkm by 2050. The additional demand is met predominantly by private cars, with the modal composition remaining broadly unchanged over the projection period: cars account for 87% of total demand, buses for 8%, rail for 4%, and light rail for 1%.

[165] Cassidy, Daniel, and Kelly de Bruin. "Evaluating transport decarbonisation policies under carbon budget constraints: The role of carbon pricing and ICE bans". ESRI Working Paper No. 815, Dublin: ESRI; Passenger transport consists of transport by private car, bus, rail, and light rail. 2025.

[166] de Bruin, K., & Yakut, A. M. "Technical Documentation of the I3E Model, v4. 0. *The Economic and Social Research Institute*". 2021.

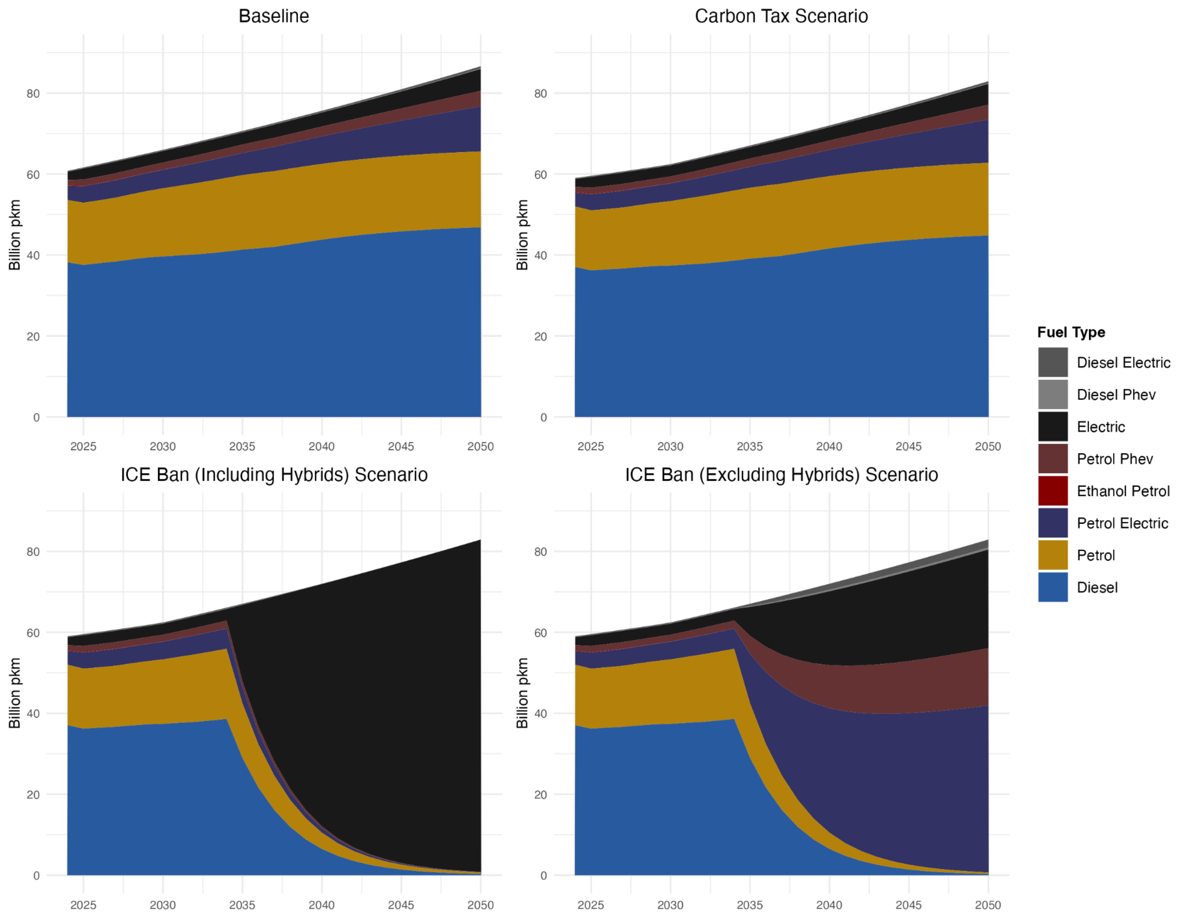

Figure 7.3: Projected transport demand by fuel type (private passenger cars) 2025-2050

Note: transport demand is expressed in passenger kilometres using a load factor of 1.65 persons per car.

This expansion translates into higher energy use, which grows from 27 TWh in 2024 to over 32 TWh by the mid-2030s before falling back to 30 TWh in 2050, reflecting greater energy efficiency and a greater penetration of hybrid alternative vehicles, as shown in **Figure 7.4**. Petrol and diesel remain the primary fuels, accounting for over 90% of total energy consumption, reflecting minimal fleet transformation. Consequently, CO_2 emissions increase from six and a half million tonnes in 2024 to over seven and a half million tonnes by 2040, before alternative vehicle uptake and improved energy efficiency levels reduce emissions to just over seven million tonnes as shown in Figure 3. This baseline trajectory serves as a reference point for evaluating the effectiveness of alternative decarbonisation policies.

Increasing carbon taxation delivers only marginal reductions in transport demand and emissions. Total passenger transport activity falls by just under five billion pkm relative to the baseline, while emissions reductions too remain modest—no more than 0.4 million tonnes below the baseline by 2050—illustrating the limited capacity of relatively small price signals alone to induce structural change in the passenger transport sector.

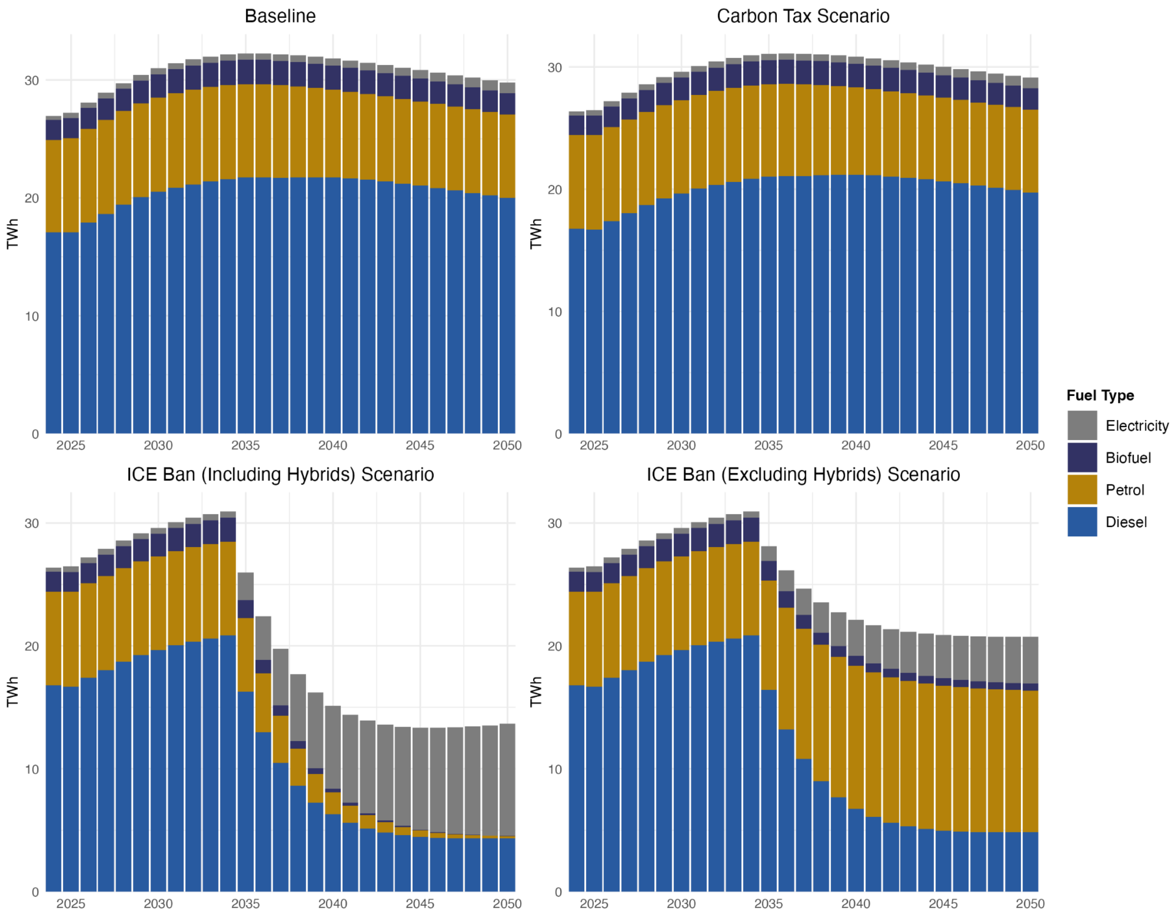

Figure 7.4: Projected energy consumption (passenger transportation), 2025-2050

ICE bans have a far more pronounced impact, however, the scope of the ban—whether hybrids are included—emerges as a critical determinant of outcomes. Under a partial ban, where hybrids remain permitted, demand shifts substantially towards them after the ban's introduction in 2035. By 2050, conventional petrol hybrids account for nearly 50% of car passenger-kilometres, plug-in hybrids for 17%, and battery-electric vehicles (BEVs) for 30%. This preference for hybrids sustains high levels of petrol consumption, which reaches 56% of total energy use by 2050, while electricity accounts for just 18%. Consequently, emissions reductions are diluted: although emissions fall by almost 2.9 million tonnes relative to the baseline, they remain too high with less than a 50% reduction on today's levels, underscoring the limitations of hybrid-focused strategies.

Extending the ban to include hybrids (a comprehensive ban) fundamentally alters the trajectory. From 2035 onwards, the car fleet transitions entirely to BEVs, driving deep decarbonisation. Electricity's share of energy use rises to 67% by 2050, while fossil fuel consumption declines sharply. Emissions fall below 2.5 million tonnes by 2040 and reach approximately 1.2 million tonnes by 2050—more than 5.8 million tonnes lower than the baseline. Under the comprehensive ICE ban, the remaining emissions in 2050, 1.2 million tonnes, are largely generated by public transport modes, for which we make no assumptions on decarbonisation trends. This scenario demonstrates that stringent regulatory instruments, combined with broad technological coverage, are essential for achieving near-complete decarbonisation.

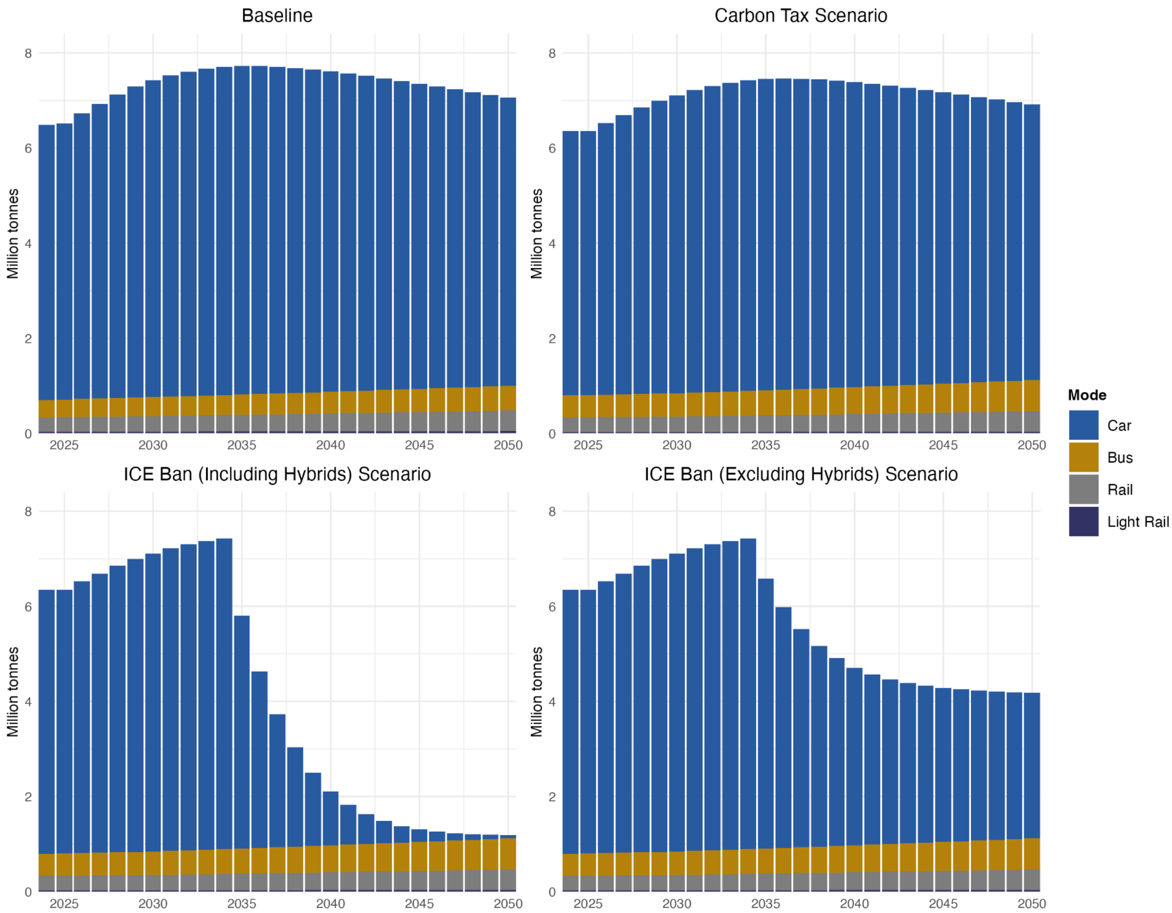

Figure 7.5: Projected $C0_2$ emissions (passenger transportation), 2025-2050

Taken collectively, the scenario outcomes highlight the scale and timing of changes achievable within passenger transport. The next step of this research was to assess how these trajectories compare with Ireland's sectoral emissions-reduction targets. Even under a comprehensive ICE ban, the sector would not meet its 2030 target until the late 2030s and would exceed the sectoral ceilings of the 2031–2035 and 2036–2040 carbon budgets. Faster electrification of public transport alongside a 2035 ban improves outcomes but still leaves the sector off-track, indicating that the timing of regulatory measures is critical. An ICE ban beginning in 2035 is therefore insufficient to meet near-term obligations.

More broadly, the results show that no single instrument can align the sector with Ireland's climate objectives. Deep reductions require a policy mix that combines regulation, carbon pricing, biofuel blending mandates, and fuel-efficiency standards to address both new and existing vehicles. Measures that reduce transport demand—through public transport investment, active travel infrastructure, and spatial planning that shortens trip distances—will also be essential. Coordinated implementation is necessary: pricing can support behavioural change, standards can limit emissions from the legacy fleet, and infrastructure investment can shift travel towards lower-emission modes. Meeting Ireland's sectoral targets will depend on integrating demand reduction, modal shift, and clean technology adoption within a unified strategy.

Spatial Distribution of Household Private Transport Energy Demand

Transport is a major source of energy consumption and CO2 emissions in Ireland, with private cars dominating passenger travel. While national statistics provide comprehensive information on vehicle activity, the absence of spatially disaggregated transport emission estimates limits the capacity for localised policy analysis and reduces the ability to strategically locate EV infrastructure. A study conducted by a NexSys researcher develops a census-driven, bottom-up framework to estimate private-car energy demand at the Small Area (SA) level across Ireland.[167] The approach integrates Census population and commuting statistics with county-level vehicle registration data to derive annual vehicle-kilometres travelled (VKT) and associated energy demand for each SA.[168] [169] [170] [171] By combining VKT with fuel type-specific emission intensities, the framework provides a fine-grained spatial profile of private-car energy demand.

Key Findings

Private-car energy demand is estimated at the level of Small Areas across Ireland, enabling direct comparison between different parts of the country and highlighting clear contrasts between urban and suburban regions. **Figure 7.6** illustrates a QGIS heatmap of estimated private-car energy demand at SA level, with values mapped from low (green) to high (red). The results reveal a strong east–west gradient and a pronounced clustering around metropolitan regions. The highest levels of energy demand occur in the suburban belts of counties such as Wicklow, Cork, Kildare, and Clare, while the lowest values appear in dense urban cores including Dublin City and Limerick City. Much of the west and north-west, including Donegal, Mayo, and Connemara, exhibits predominantly low demand, consistent with lower population density, shorter commutes, and reduced car reliance. In contrast, the eastern seaboard and main inter-urban corridors contain many Small Areas with medium to high private-car energy demand. White polygons in some city cores represent zones with little or no resident commuting population, such as commercial or industrial districts. Because the model allocates energy demand to places of residence rather than destinations, commuting activity generated

[167] Peng, Tianduo, et al. "Development and application of China provincial road transport energy demand and GHG emissions analysis model." *Applied Energy* 222 (2018): 313-328.
[168] CSO. *Census 2016 Small Area Population Statistics - CSO - Central Statistics Office*. 15 July 2024, www.cso.ie/en/census/census2016reports/census2016smallareapopulationstatistics.
[169] CSO. *Census 2022 Small Area Population Statistics - CSO - Central Statistics Office*. 22 Oct. 2024, www.cso.ie/en/census/census2022/census2022smallareapopulationstatistics.
[170] CSO. *Vehicle Kilometers Travelled Sustainability and Transport Transport Hub - Central Statistics Office*. 11 Jan. 2024, www.cso.ie/en/releasesandpublications/hubs/p-transo/transporthub/sustainabilityandtransport/vehiclekilometerstravelled.
[171] CSO. *Vehicle Kilometres Road Traffic Volumes Transport Hub - Central Statistics Office*. 24 May 2024, www.cso.ie/en/releasesandpublications/hubs/p-transo/transporthub/roadtrafficvolumes/vehiclekilometres.

by inbound workers is attributed to their home Small Areas. **Figure 7.7** further reinforces the regional patterns, showing the highest concentrations of private-car energy demand in suburban zones surrounding Dublin, Cork, Galway, and Limerick. These areas exhibit higher car dependence and longer travel distances compared with compact, well-served urban centres.

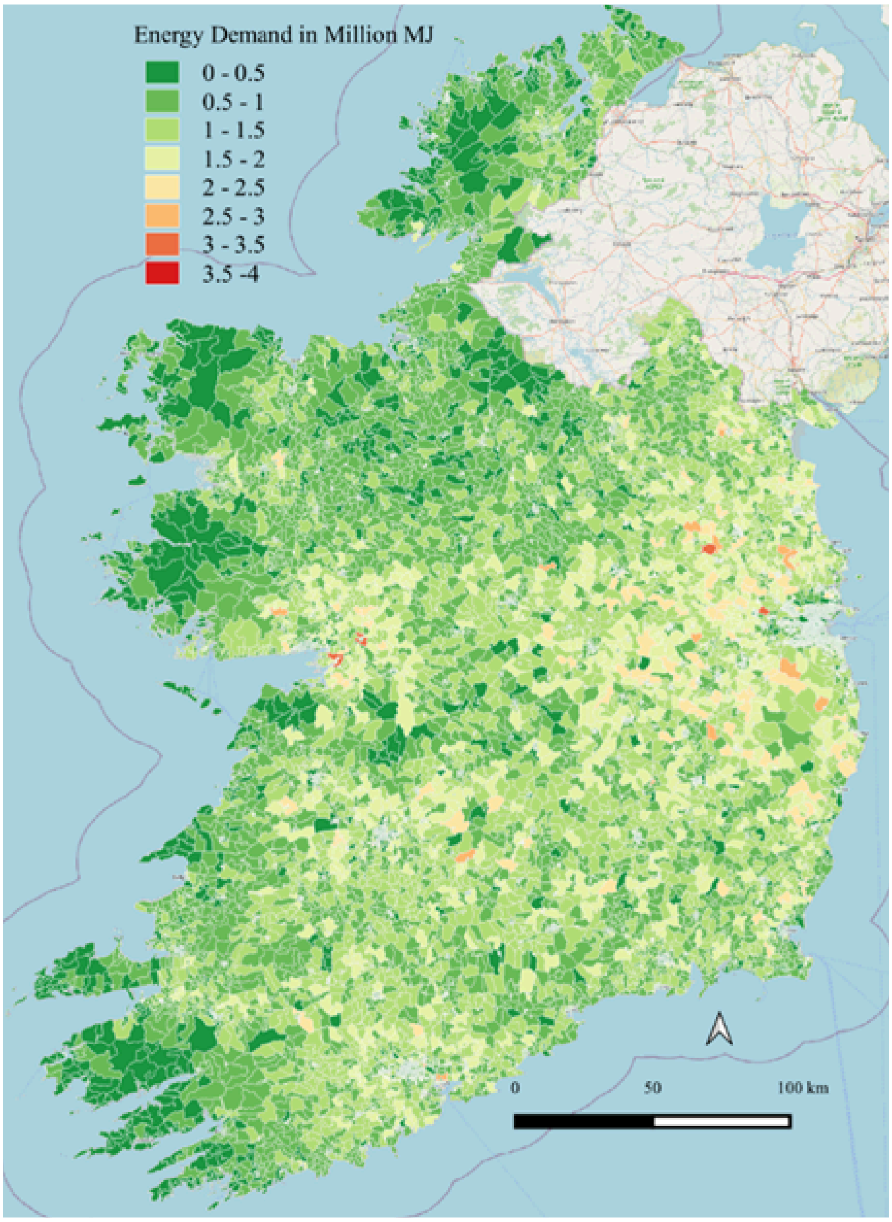

Figure 7.6: Variation of estimated private-car energy demand across Ireland at SA level, in million MJ for the year 2022

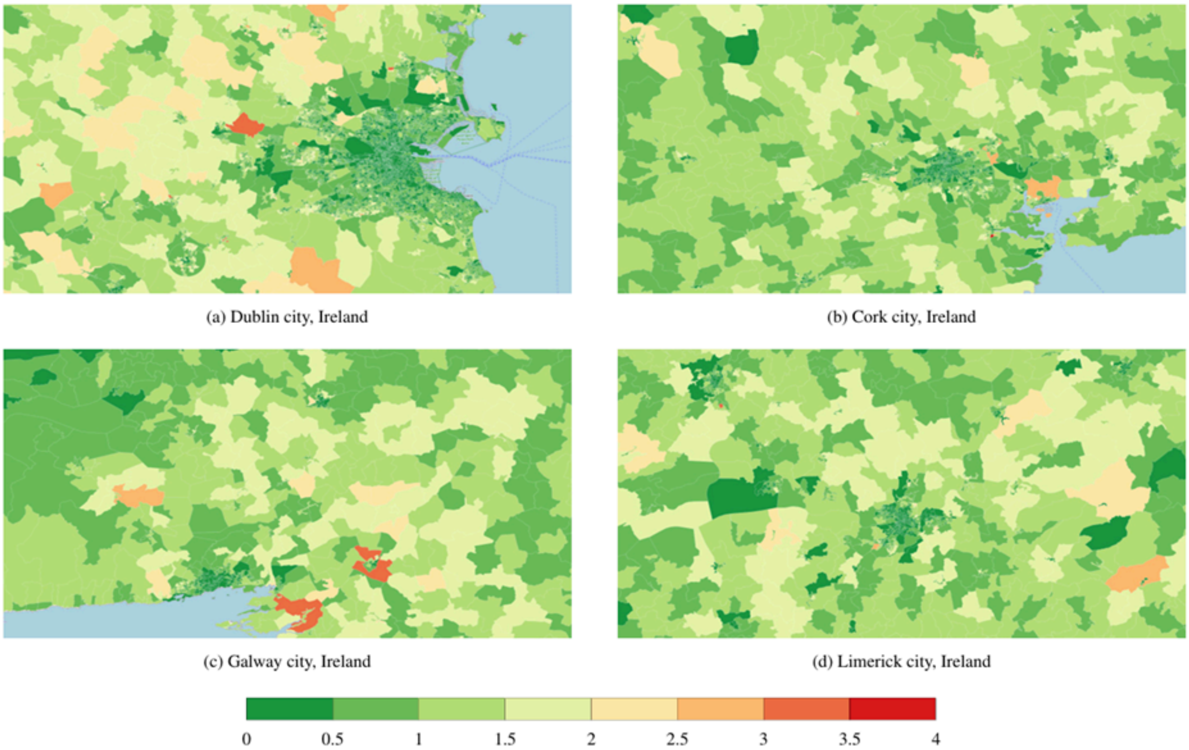

Figure 7.7: SA-level transport energy demand in million MJ for Ireland's major cities in 2022 (lower at city centres, higher in surrounding suburban areas).

Policy Considerations

The findings underscore the significance of suburban commuter belts for transport-energy policy, suggesting that targeted interventions in these zones, such as demand management, improved public transport, and support for cleaner vehicles, may deliver substantial reductions in national energy demand. The study demonstrates how open, policy-relevant data can be integrated within a bottom-up framework to generate high-resolution transport energy indicators, bridging national reporting and local planning. Additionally, integrating transport energy in urban and regional planning would help to mitigate the impacts of low-density, scattered, and car-dependent housing developments.

Preferences for Electric Light Vehicles Among SMEs

A NexSys study examined the adoption preferences and barriers for electric light commercial vehicles (ELCVs) among small and medium-sized enterprises (SMEs) in Ireland. Using a discrete choice experiment (DCE) with 446 firms, the analysis captured stated preferences across internal combustion engine (ICE), battery electric (BEV), and plug-in hybrid (PHEV) vehicles. The findings highlight that operational attributes—such as driving range, fuel cost, and charging time—play a decisive role in shaping firm decisions, while upfront purchase price has a comparatively limited influence.

The study employs mixed logit models to account for varying priorities of SMEs when choosing ELCVs . The SMEs exhibit a strong willingness to pay for operational improvements that boost efficiency and minimize operational downtime, confirming that business continuity is paramount. The analysis showed that SMEs would pay approximately €43 per additional kilometre of range, €42 per €100 reduction in fuel costs, and €60 per hour reduction in charging time. These valuations indicate that efficiency and minimising operational disruptions are central to SME decision-making.

A subsequent latent class analysis further revealed two distinct SME segments:

1. Status Quo-Oriented (58% of respondents): This group showed general support for BEVs but limited sensitivity to cost and performance improvements.
2. Operationally Driven (42%): These firms' choices were strongly guided by practical operational considerations, including range, charging convenience, and fuel efficiency.

These segments align with international evidence distinguishing "principled" from "operationally motivated" adopters, demonstrating meaningful heterogeneity within SME fleets that policy must address.

Simulation scenarios reinforced these insights. Notably, reductions in purchase price or fuel costs alone had minimal impact on BEV adoption. Conversely, increases in driving range produced substantial uptake gains. The estimated price elasticities were near zero, underscoring the limited effectiveness of price-focused incentives when isolated from operational improvements. Charging time emerged as a significant barrier, highlighting the need for infrastructure investments that reduce vehicle downtime.

The policy implication is clear: operationally driven firms are likely to respond to financial incentives and enhanced charging options, while status quo-oriented firms may require trust-building measures, demonstrations, and service guarantees to mitigate perceived risks.

The findings highlight clear enablers, barriers, and policy implications.

Enablers

The strongest enablers are operational performance and reliability, factors that directly affect daily business continuity. Firms show a high willingness to pay for efficiency gains that reduce downtime, confirming that improvements in range, fuel economy, and charging time influence adoption more than purchase price incentives. The national road network EV charging plan 2024–2030 provides a strategic framework for scaling public and depot charging infrastructure, and its implementation will be central to enabling commercial fleet electrification. Further to this, transparent total cost of ownership tools and reliability guarantees can help reduce uncertainty.

Barriers

The main barriers are long charging times, limited infrastructure access, and ongoing concerns about range and dependability. These operational constraints reinforce perceived risk and explain the limited response to price-based subsidies.

Policy Considerations

- Policy design must shift from cost-centred measures to operations-centred strategies to accelerate the adoption of ELCVs by SMEs. Incentives should be redesigned to reward performance improvements—such as faster charging, longer range, and higher energy efficiency—rather than focusing solely on reducing the upfront purchase price.
- Actionable policy inputs for accelerating SME adoption should focus on two parallel tracks: linking incentives to operational performance and building trust through practical experience.
- Differentiated Financial Incentives: Financial support, such as EV grants, Vehicle Registration Tax (VRT) relief, and reduced annual motor tax, should be tied to measurable operational outcomes like improvements in range, energy efficiency, or reduced charging time. This approach rewards performance that directly benefits business continuity.
- Prioritised Charging Infrastructure: Investment must prioritise depot and workplace charging, simplifying grid access and installation for SMEs. This rollout should be strategically aligned with the National Road Network EV Charging Plan (2024–2030).
- Building Trust and Reducing Uncertainty: Given the two distinct SME segments identified, differentiated strategies are essential. A greater number of demonstrations and trial programmes (like the SEAI EV fleet trial) can provide SMEs with hands-on experience, normalise electric fleet operations, and reduce uncertainty around vehicle reliability.
- Service Guarantees: Implementing service guarantees covering range and maintenance can further strengthen confidence, particularly among status quo-oriented firms, ensuring that both operational and behavioural barriers are addressed in parallel.

Conclusion and Strategic Shift

Overall, this NexSys research underscores that conventional subsidies targeting purchase price alone are insufficient for sustainable adoption. For policymakers in Ireland and similar markets, the findings suggest prioritizing range-extension technologies, rapidly expanding depot and workplace charging facilities, improving transparency around the Total Cost of Ownership (TCO), and directly addressing attitudinal factors like perceived reliability.

Manufacturers also have a role to play by tailoring product offerings and marketing to distinct SME segments, recognizing the diversity of motivations across the commercial fleet sector. This study provides a blueprint for accelerating commercial transport decarbonisation by grounding policy in the operational realities and heterogeneity that conventional approaches often overlook.

Freight Assessment & Archetypes

There are now a number of technologies and alternative low and zero carbon fuels available to help reduce emissions in the transport sector in Ireland. But in 2023 over 99% of heavy goods vehicles (HGVs) still used diesel which accounts for over 14% of all transport emissions.

A forthcoming NexSys study (in press) analyses the decarbonisation potential for heavy goods vehicles (HGVs) in Ireland. It uses a mixed-methods approach, combining qualitative interviews with fleet operators of all sizes (small to large) and quantitative data analysis to develop archetypal insights. The focus is on heavy-duty diesel trucks used for medium to long-haul operations that operate mostly fully loaded, as these significantly contribute to greenhouse gas emissions and local air pollution.

Data was gathered through semi-structured interviews, facilitated by collaborations with vehicle associations. While larger operators are expected to be the first to adopt alternative-fueled vehicles, inputs from operators of all scales were crucial for this study.

Questions within the survey are designed to collect information under four categories:

1. Profile of respondents entails the very basic information; e.g., fleet size, depot locations, types of trucks in their fleet, etc
2. Operation of respondents involves the details of their operation e.g., annual mileage, annual fuel consumption, distance between refuelling, regions in which they operate, travel to, typical travel routes and delivery patterns, usual travel routes and operational patterns.
3. Challenges and opportunities in transitioning to lower-emission vehicles; Intentions for decarbonisation to ascertain the level of awareness towards decarbonisation and the changes it might entail e.g., impacts of carbon tax on their business, the future of their business. As well as the attitude towards acquiring low-emission vehicles e.g., what low emission vehicle (LEV) technology have they considered, do they have an LEV in their fleet, etc. Factors that would influence their decision in acquiring a LEV, the related barriers, and the support/incentives they would welcome.

A purposive sampling method was used to gather over 4% of fleet vehicles or almost 1% of the operators on the island of Ireland.

Many fleet operator participants are beginning to use sustainable hydrotreated vegetable oil (HVO) as a drop in fuel and Bio-compressed natural gas (Bio-CNG) as an available alternative fuel, both growing in use but acknowledged as not the only or long term solution.

The geographic spread that HGVs travel underscores the importance of cross-border cooperation and harmonised policies to effectively decarbonise HGV operations, specifically with battery electric and hydrogen fuel cell electric HGVs in Northern Ireland, the UK & France.

Many operators support initiatives to introduce hydrogen trucks when it is available, mainly for heavy goods, over longer distances with fast refill requirements, citing green hydrogen could significantly reduce transport emissions as well as stimulate the development of a green hydrogen market which could bring more work into the haulage industry.

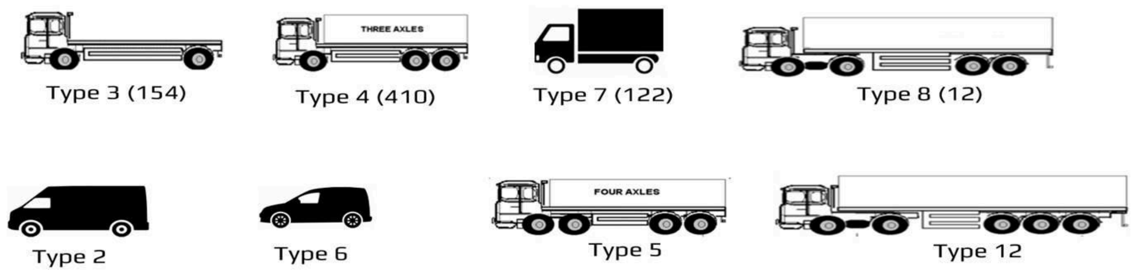

Figure 7.8 Main Vehicles identified in the study.

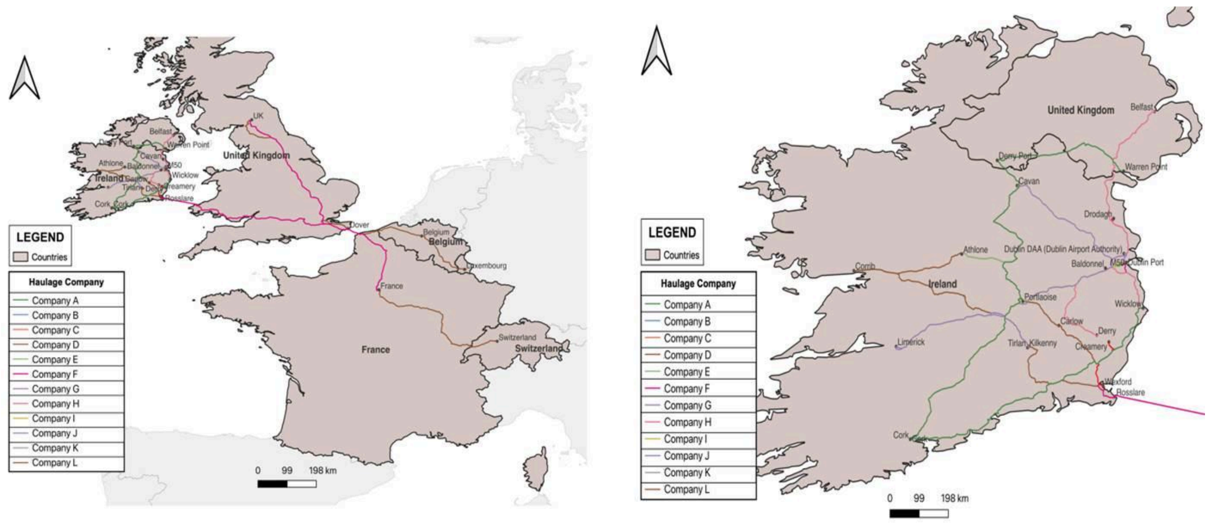

Figure 7.9 Representation of the usual travel routes of participants.

Customer preference and what the vehicles carry affects the fuel performance and operational logistics. Ireland has a vibrant agricultural, food, pharmaceutical, building and technology industry and this is echoed in the products that participants carry day to day. Two thirds (2/3) of participants are mostly weight constrained day to day while operating their HGVs. Many operators mentioned that their smaller vehicles were more volume constrained than weight constrained and these may suit battery electric vehicles. Others described their heavy laden loads with no compromise for long charging or limited range and therefore are researching hydrogen as an alternative. The results are highlighted in **Figure 7.10** by the types of goods carried across distances and possible usefulness for battery electric and hydrogen fuel cell electric HGV.

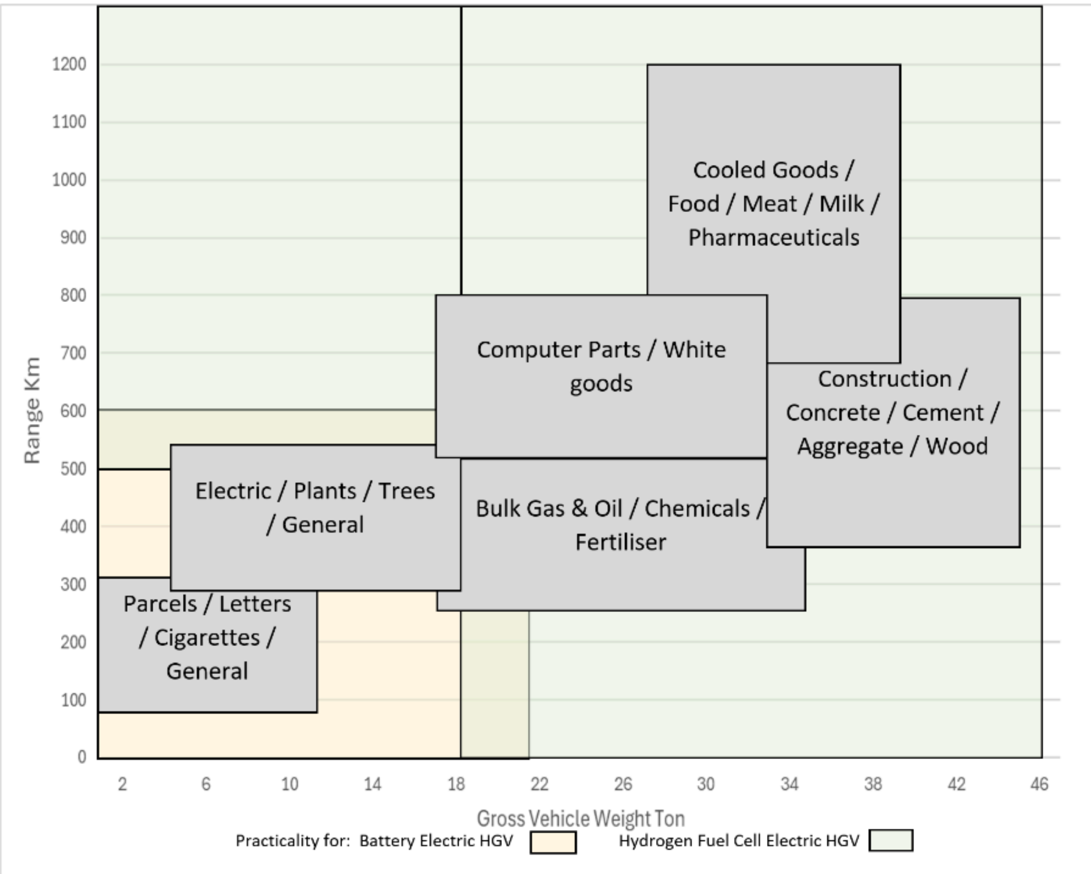

Figure 7.10 Types & weight of goods carried by participants across distances.

Policy Considerations

Overall, the message from operators highlighted a need for the Government (or relevant body) to provide several decarbonisation infrastructure elements, including vehicles, fuel stations, and fuel. This provision requires an urgent mechanism (policy or regulatory support) to reduce risk and increase the reliability of all elements for early adopters.

Specifically, cross-border cooperation and harmonised policies are necessary to effectively decarbonise HGV operations, specifically with battery electric and hydrogen fuel cell electric HGVs in Northern Ireland, the UK & France.

To support the uptake of hydrogen trucks for heavy goods operators, rapid development and implementation of plans for infrastructure to facilitate fast refill of green hydrogen is critical.

Life Cycle Assessment of Hydrogen for Heavy Duty Transport

A desktop environmental life cycle assessment was conducted to evaluate the environmental impacts of hydrogen used for sustainable mobility in Ireland, specifically the production, transport and refuelling of hydrogen for heavy goods vehicles. A total of 12 process configurations/scenarios based on four distinct technologies to produce hydrogen were assessed – steam methane reforming, steam methane reforming with carbon capture and storage, methane pyrolysis and renewable-energy-powered polymer electrolyte membrane electrolysis. These technologies are commonly referred to as grey, blue, turquoise and green hydrogen production, respectively.

While the transport sector accounts for the greatest share of energy consumption in Ireland, heavy goods vehicles are large consumers in the sector, responsible for 9.2 TWh of energy consumption. Potential sustainable ways to fuel/power transport vehicles include biofuels, HVO, biomethane, and battery and hydrogen fuel cells, which offer reduced greenhouse gas emissions compared with fossil fuel diesel or petrol fuels. Implementing a mix of these technologies can lead to a cleaner and more sustainable future for transport, reducing reliance on fossil fuels and mitigating climate change impacts.

Through the life cycle assessment, it was found that green hydrogen production is the least harmful technology in terms of climate change and water pollution in key life cycle impact assessment categories – global warming potential, acidification potential, eutrophication potential and marine aquatic ecotoxicity potential – compared with diesel and grey, blue and turquoise hydrogen production (e.g. global warming potential is under 1 kg CO2 eq/kg H2 compared with between 5 and 11 kg CO2 eq/kg H2 for the other methods).

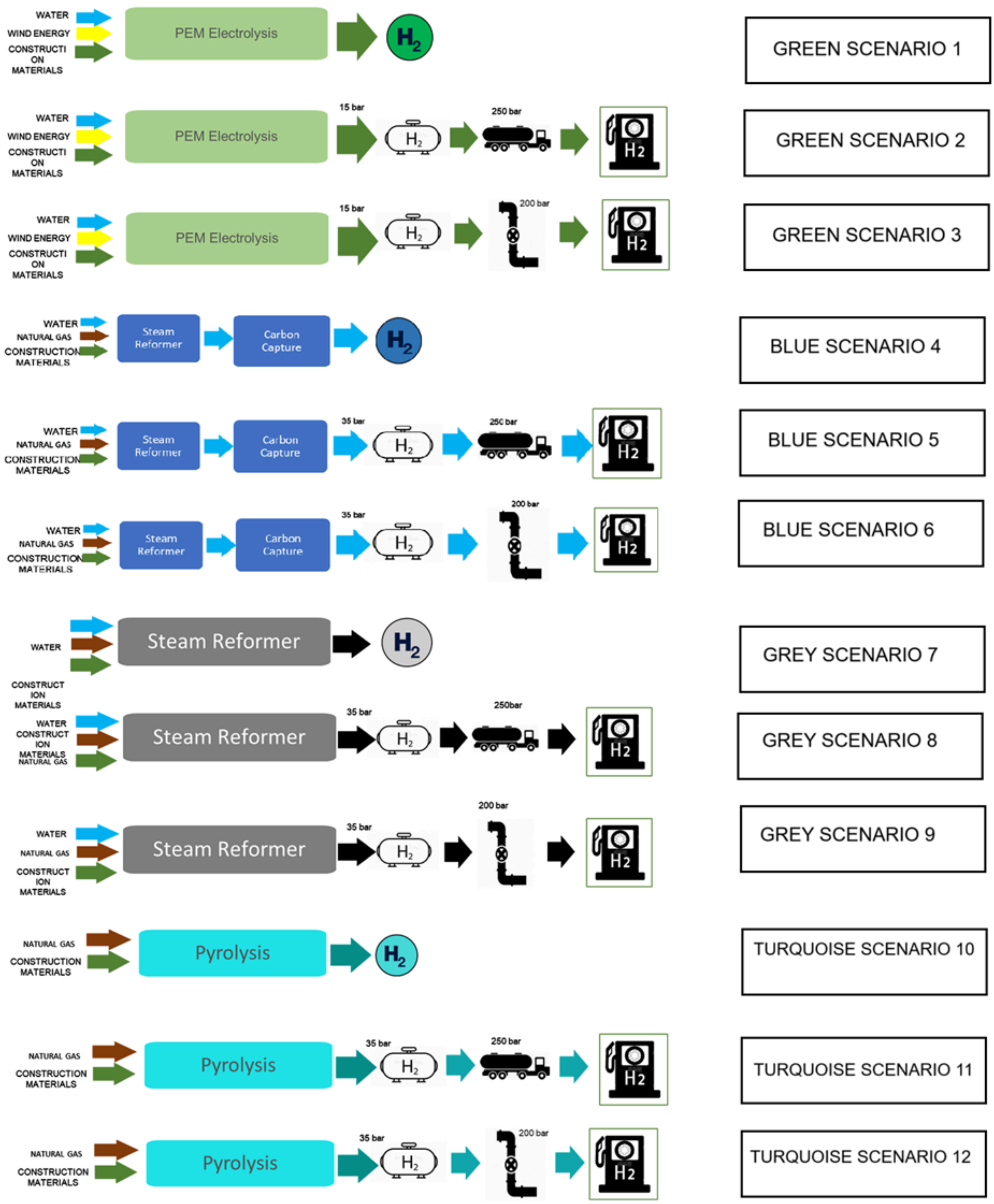

Figure 7.11: Scenarios developed based on various hydrogen production and transport pathways.

Transition to Commercial Vehicle Electrification Policy

Overview of Road Freight in Ireland and the Transition to Zero carbon

A forthcoming NexSys report (in press) describes the makeup of road freight in Ireland, analysing in terms of the volumes and values by sector, as well as traffic shares, volumes, and values by economic sector, drawing on data from the Central Statistics Office (CSO) and the National Vehicle and Driver Registration. The comprehensive characterisation of the sector is used to develop indices of road freight activity and assess the potential for electrification or adoption of renewal energy options based on the transport requirements for economic sectors.

The project enables identification of transport intensity at very detailed spatial scales, and facilitates the assessment of critical impacts related to the: (i) roll out of energy grid capacity (ii) vulnerability of economic sectors to, and economic costs of disruption caused by extreme weather events (iii) economic benefits and costs of preventive maintenance interventions for transport infrastructure.

Barriers: Over-reliance on Road Vehicles and Slow Transition

Transport of freight in Ireland is overwhelmingly road-based, with 97% of all freight moved by road. As an open island economy, international movement of freight is critically important and heavily dependent on roads for access to ports, airports and border crossings. Much of the maritime freight is roll-on/roll-off; much of Ireland's air freight is 'air trucked' to the major European cargo airports under airway bill.

The road haulage sector is heavily dependent on fossil fuels and has been slow to transition to alternate fuels, particularly compared with the Irish private car fleet. Goods vehicles make up 21% of the total vehicle fleet.

Fuel Composition: The goods vehicle fleet is overwhelmingly diesel. Although a small but growing share of electric, hybrid, and other renewable (hydrogen and biofuel) vehicles has been added since 2019, second-hand goods vehicles—which make up a significant portion of annual registrations—are even less likely to use renewable fuels. Tractors, which account for over 4% of the fleet, are almost exclusively diesel. This composition highlights the significant decarbonisation challenge in the commercial freight sector.

Vehicle Size and Electrification Potential: The size distribution of goods vehicles is concentrated in the 1,300kg – 2,300kg unladen weight class (75% of new registrations in 2024). While electric vehicles are present, they are disproportionately concentrated in the smaller, lighter commercial classes (e.g., 40% of all commercial EVs are in the 1,500kg-1,800 kg class). They are also more likely to be hybrid than fully electric.

Table 7.1 shows the numbers of new and second-hand goods vehicles by fuel type. Small numbers of gas, ethanol and hydrogen vehicles have been registered in the Irish fleet in the last 5 years ('Other' in Table 1).

Table 7.1: New and Second-hand Goods Vehicles by type of fuel, 2010 to 2024 Fuel types: All: all fuel types; D: Diesel; E: electric; H: Hybrid; Other: other fuel types; P: petrol

Year	All Goods Vehicles						Secondhand Goods Vehicles					
	All	D	E	H	Other	P	All	D	E	H	Other	P
2010	18717	18596	17	2	4	98	8207	8113	0	0	3	91
2011	16415	16354	18	2	2	39	5227	5197	0	0	2	28
2012	15586	15529	33	6	1	17	4731	4712	1	0	1	17
2013	18557	18521	7	0	11	18	7533	7507	0	0	8	18
2014	25328	25283	8	0	8	29	9074	9042	0	0	5	27
2015	31291	31250	12	1	2	26	8352	8326	0	0	2	24
2016	38976	38923	11	3	2	37	10925	10888	1	1	2	33
2017	38269	38189	34	2	5	39	14168	14134	2	1	3	28
2018	40317	40188	69	7	15	38	14858	14816	2	5	5	30
2019	39797	39397	295	50	15	40	15152	15070	2	45	5	30
2020	33248	32642	445	70	20	71	11753	11665	2	35	1	50
2021	39018	37721	898	281	24	94	10631	10463	4	97	1	66
2022	31718	30809	418	294	30	167	8063	7835	7	170	5	46
2023	38481	37049	743	405	28	256	9443	9063	9	302	4	65
2024	41780	40282	885	318	66	229	10978	10759	14	153	3	49

Key Findings on Sectoral Demand and Constraints

The potential for electrification of the fleet depends on a number of factors. A NexSys survey of Small and Medium Enterprises (SMEs), reported in the *Preferences for Electric Light Vehicles Among SMEs* section, identifies the key drivers of commercial EV adoption as well as sectors that can transition to full electrification more quickly and others that will require alternate solutions. The limited availability of suitable vehicles in the Irish market, as well as charging time and range anxiety are identified as key factors constraining adoption.

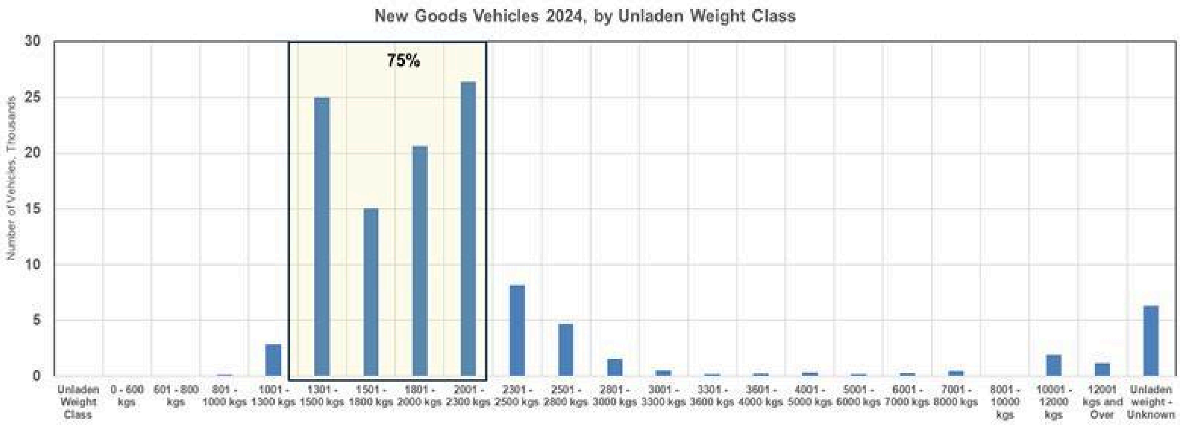

Figure 7.12: Distribution of the goods vehicle fleet in 2024 by weight class[172]

Table 7.2 sets out the main categories of road freight activity over the 3 years from 2022 to 2024. CSO data consistently identifies Construction as the sector with the largest tonnage carried by road, averaging approximately 40% of total activity between 2022 and 2024. Retail and wholesale represent the second largest category at 19%, while delivery of materials/fuels to factories and agriculture account for 10% each. These largest tonnage sectors present the greatest challenge for transition and will require alternative solutions beyond the natural progression of vehicle electrification.

[172] CSO. *Vehicles Licensed for the First Time Archive 2024 - CSO - Central Statistics Office.* 14 Jan. 2025, www.cso.ie/en/statistics/transport/vehicleslicensedforthefirsttime/vehicleslicensedforthefirsttimearchive2024.

Table 7.2: Summary of key commercial sectors generating freight traffic based on tonnes carried by type of work, 2022 to 2024 [173] [174] [175]

Commercial Sector	2022	2023	2024
Construction	**41%**	**39%**	**35%**
Retail/Wholesale	**19%**	**18%**	**19%**
Delivery of materials and fuels to factories	**10%**	**10%**	**10%**
Agriculture	**10%**	**8%**	**8%**
Import/Export Work	**8%**	**8%**	**9%**
Total	**88%**	**84%**	**81%**

Table 7.3 summarises the distribution of tonnes carried and tonne-kilometres travelled by vehicle size, highlighting the dominance of large Heavy Goods Vehicles (>12,500kgs) in the carriage of most freight tonnage.

[173] CSO. *Road Freight Transport Survey Quarter 4 and Year 2022 - Central Statistics Office*. 28 June 2023, www.cso.ie/en/releasesandpublications/ep/p-rfts/roadfreighttransportsurveyquarter4andyear2022.

[174] CSO. *Road Freight Transport Survey Quarter 4 and Year 2023 - Central Statistics Office*. 4 July 2024, www.cso.ie/en/releasesandpublications/ep/p-rfts/roadfreighttransportsurveyquarter4andyear2023.

[175] CSO. *Road Freight Transport Survey Quarter 2 2024 - Central Statistics Office*. 21 Nov. 2024, www.cso.ie/en/releasesandpublications/ep/p-rfts/roadfreighttransportsurveyquarter22024.

Table 7.3: Total tonnes carried and tonne-kilometres by vehicle weight, 2022 to 2024

Vehicle Class	Tonne-Kilometres			Tonnes Carried		
(unladen weight)	2022	2023	2024	2022	2023	2024
2,000 - 5000 kgs	3%	4%	3%	5%	6%	4%
5,001 - 7,500 kgs	1%	1%	1%	2%	1%	2%
7,501 - 10,000 kgs	8%	7%	6%	7%	7%	7%
10,001 - 12,500 kgs	19%	18%	20%	22%	20%	20%
Over 12,500 kgs	68%	71%	69%	64%	66%	67%

Decarbonisation Barriers

The energy requirements to facilitate the roll-out of electrification of commercial transport can be quantified based on the distribution of economic activities and the transport intensity indicators, work that NexSys researchers are undertaking and that will inform future Roadmap reports. The potential for full electrification of commercial freight depends heavily on the transport requirements of each commercial sector. Sectors like Construction, which handle high tonnage and often require heavy-duty vehicles, currently have limited potential for electrification and will require alternate solutions to decarbonise and meet net zero targets. Earlier sections of this report have focused on NexSys studies examining different segments of the commercial vehicle fleet. Access to suitable vehicles in the Irish market presents an additional barrier that must be taken into account.

Policy Considerations

Freight vehicles comprise a significant proportion (21%) of the transport sector, a sector that is critical to achieve net zero if Ireland is to reach its climate action goals.

These studies collectively demonstrate the need for a coordinated suite of policies and enabling measures to accelerate the decarbonisation of commercial freight transport, which continues to lag significantly behind private transport, with awareness that various sectors will require unique solutions and timelines for phase-in.

- The market supply of low- and zero-carbon commercial vehicles and fuels must expand. This requires a balanced mix of incentives and regulation designed to:
    - Broaden vehicle offerings and strengthen competition among distributors.
    - Reduce the total cost of ownership (TCO) for commercial operators.
- For users, the nationwide rollout of high-power charging infrastructure suitable for commercial vehicles is urgent. Investments will need to be focused to support improved Depot Charging to offset high installation costs, often requiring expensive grid upgrades.
- Additionally investment in Optimisation Models that successfully optimise and share “behind-the-meter” charging capacity across commercial sites (and potentially residential sites where appropriate) could significantly increase effective system capacity. Enabling the development and scaling of such models will require well-designed, flexible, and low-cost policy frameworks.

Sustainable Aviation Fuels

Aviation is the second largest source of GHG emissions in the transport sector, representing 4% of EU greenhouse gas (GHG) emissions.[176] Furthermore, air transport is a rapidly growing sector, with EU air passenger numbers increasing by 19% from 2022 to 2023.[177] To address this issue, the ReFuelEU Aviation Initiative has been introduced as part of the 'Fit for 55' package. This policy mandates a proportion of all jet fuel used within the EU aviation sector to be sustainable aviation fuel (SAF), with the level increasing every five years. By 2050, 70% of all jet fuel will need to be SAF. Furthermore, ReFuelEU requires some portion of this SAF to be synthetic, or derived from renewable hydrogen and captured CO2. By 2050, at least half of all SAF (or 35% of all jet fuel) will need to be synthetic.

---

[176] European Commission. “ReFuelEU Aviation.” *Mobility and Transport*, 2024, transport.ec.europa.eu/transport-modes/air/environment/refueleu-aviation_en.

[177] European Union. “EuroStat: Air Passenger Transport Statistics.” *ec.europa.eu*, Dec. 2025, ec.europa.eu/eurostat/statistics-explained/index.php?title=Air_passenger_transport_statistics.

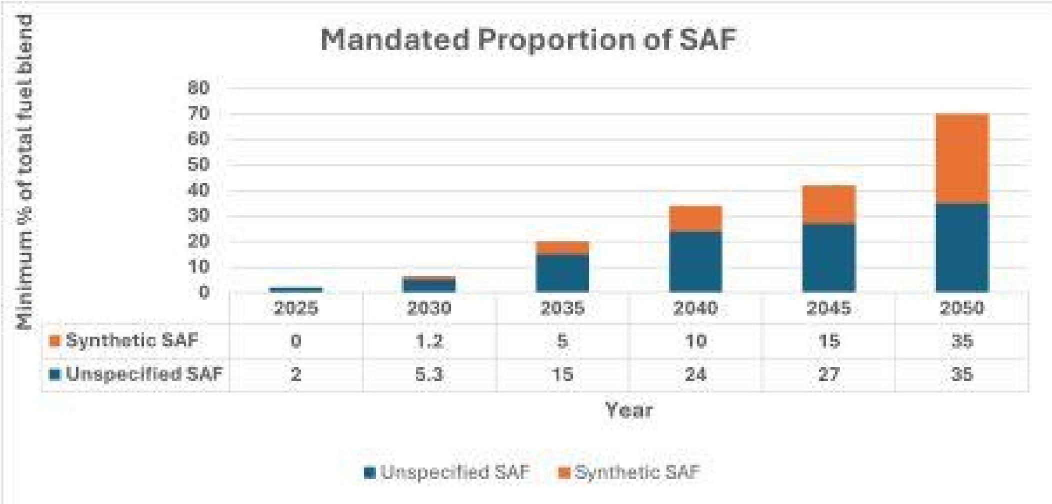

Figure 7.13: Mandated proportion of synthetic and unspecified SAF in aviation fuel from ReFuelEU. Unspecified SAF can be comprised of biofuels or synthetic SAF.

By 2035, a minimum of 5% of Europe's jet fuel will need to be synthetic SAF. For Ireland, which consumes 50% more jet kerosene than it does petrol,[178] this will equate to 232 kt of synthetic SAF demand by 2035.

A recent student project supervised by NexSys researchers investigated what it would cost to produce all this within Ireland's borders. The study[179] investigated the optimum SAF production route for production based in Ireland, at a scale sufficient to meet the projected 2035 domestic demand. The findings showed that to process at least 230 kt of SAF annually, a production facility equivalent to approximately one-quarter the size of Whitegate refinery will be required. Furthermore, 1,100 to 1,600 MW of electrolysers and a total of 1,000 kt of Direct Air Carbon Capture (DAC) capacity will be needed. This will require 8.37 TWh of renewable electricity, which amounts to 3 GW of installed offshore wind dedicated exclusively to e-fuel production. Leveraging Ireland's biogas potential can help reduce reliance on the less proven DAC technology. However, in all cases the costs are substantial, with Irish SAF production costing 3.72-6.96 €/kg: six to twelvefold more than the current price of Jet Fuel A1. Key questions still must be answered on how this will affect the greater economy and society, and whether additional or alternative policies will be needed to enable a just energy transition.[180]

---

[178] Sustainable Energy Authority of Ireland. "Energy in Ireland." *seai.ei*, www.seai.ie/data-and-insights/seai-statistics/key-publications/energy-in-ireland.

[179] Toole, Ben, et al. *Techno-Economic Investigation Into the Optimal e-Kerosene Production Route in Ireland to Satisfy 2035 Domestic SAF Demand*. University College Dublin, 2025, www.researchgate.net/publication/394087049_Techno-Economic_Investigation_into_the_Optimal_e-Kerosene_Production_Route_in_Ireland_to_Satisfy_2035_Domestic_SAF_Demand.

[180] Toole, Ben, et al. "What Will It Cost to Decarbonise Aviation? A Study on Irish SAF Production." *Engineers Ireland*, 8 Sept. 2025,

Policy Considerations

These findings necessitate urgent and coordinated action to meet the 2035 and 2050 Sustainable Aviation Fuel (SAF) goals. A clear national strategy is needed that outlines pathways for indigenous production by developing the required facilities and securing 3 GW of dedicated offshore wind energy. Furthermore, large-scale research and development into both DAC and biogas potential is critical to ensure supply. Finally, the SAF strategy must proactively address the significant cost impacts of domestic production to enable an equitable energy transition.

Transport Poverty

Energy vulnerability is deeply connected with transport poverty, often leading to a double energy vulnerability where at-risk households struggle with energy costs both in their homes and through their transport usage. NexSys research has examined this relationship, and, in contrast with the literature on residential energy poverty, research on transport poverty and its impacts is relatively recent and not as well developed.

Overall, transport poverty has been defined as a lack of access to essential goods and services.[181] The term has been used to refer to problems of transport affordability, externalities such as noise and air pollution, traffic-related pedestrian accidents and deaths, long commutes, and inaccessibility to public transport services. Existing research indicates that transport poverty increases social exclusion, limits individuals' capacity of social participation, hinders people's wellbeing, imposes restrictions on transport modes, and negatively influences productivity and personal utility.[182]

Key Findings

NexSys research on the effects of transport poverty among children highlights that children living in rural areas of Ireland, especially girls and those from low-income families, face educational and mental health disadvantages related to poor transport services.[183] In addition, we investigated socio-demographic differences in household CO2 emissions by sector (including residential energy and transport) in Ireland. This revealed that travel-related emissions are significantly higher among higher-income and more educated households,

www.engineersireland.ie/News/what-will-it-cost-to-decarbonise-aviation-a-study-on-irish-saf-production.

[181] Lucas, Karen. "Transport and social exclusion: Where are we now?." *Transport policy* 20 (2012): 105-113.

[182] Del Rio, Jonathan Furszyfer, et al. "The demographics of energy and mobility poverty: assessing equity and justice in Ireland, Mexico, and the United Arab Emirates." *Global Environmental Change* 81 (2023): 102703.

[183] Da Silva Pedroso, Monika, et al. "Improving Child Wellbeing: The Effects of Transport and Residential Energy Poverty on Education and Mental Health of Children and Adolescents." *Child Indicators Research* 18.6 (2025): 2557-2595.

especially emissions related to air travel. Household emissions tend to be lower in rural areas, but car-related emissions are highest among rural households.[184] This could provide further evidence of the 'trapping' of rural households in terms of transport.[185]

The examination of public transport poverty among older people in Ireland reveals that 42% of all respondents are experiencing this issue, but spatial differences are significant. For instance, the risk of experiencing transport poverty is three and a half times greater for those living in rural areas, and living in towns/cities outside Dublin doubles this risk. Those in public transport poverty are two and a half times more likely to drive frequently, and almost two-thirds had not used their travel pass in the last month. Highest travel pass usage was observed in Dublin, which further underlines spatial inequalities in terms of who can benefit from transport welfare mechanisms currently in place. [186]

We run simulations to reduce the energy usage of households with the highest energy consumption rates while increasing the energy usage of the lowest-consuming households. Preliminary results suggest this redistribution would result in both lower total energy usage and carbon emissions, particularly in the transport sector.[187]

Barriers / Challenges

There is no Irish indicator of transport poverty and household surveys have relatively limited data on the issue, a barrier that the government can resolve. Similarly, the identification of groups that may be at risk of transport poverty would require an investigation of the availability, affordability and accessibility of sustainable mobility services. The formal recognition, definition and measurement of transport poverty is required in Ireland.

Enablers

Better indicators and measures of transport inequality can be implemented. For instance, we have worked with TILDA in Trinity College Dublin, supplying them with some improved survey questions for current and future rounds of the Longitudinal Study of Aging in Ireland. Improved data will serve as a critical enabler to address transport poverty. Particularly important is the assessment of: 1) the availability and adequacy of public transport, especially in rural areas, 2) accessibility to essential services, such as health services and education, and 3) the accessibility of active and sustainable travel modes.

Certain moderating factors are associated with the risk of becoming transport poor, including health problems (e.g. physical mobility, certain disabilities) as well as geography (e.g. living in

[184] Winston, N., da Silva Pedroso, M., & Mac Domhnaill, C. "Resilience, inequalities and CO2 emissions: towards a just transition in the residential and transport sectors in Ireland?" ESPANet Stream 11 2025. Winston_et_al_2025_Resilience_Inequalities_Emissions_ESPAnet_2025.pdf. Forthcoming.

[185] Carroll, Páraic, Rodolfo Benevenuto, and Brian Caulfield. "Identifying hotspots of transport disadvantage and car dependency in rural Ireland." *Transport policy* 101 (2021): 46-56.

[186] Dingley, O. Enhancing resilience in older adult populations: addressing the multiple faces of energy and transport poverty in Ireland. ESPANet Stream 11 2025. Dingley_Energy poverty impacts on older people (TILDA).docx. Forthcoming.

[187] Winston, N., da Silva Pedroso, M., & Mac Domhnaill, C. "Energy poverty, inequalities and CO2 emissions: advancing a just transition via energy redistribution policies in Ireland." Forthcoming.

rural areas) and socio-demographic characteristics (income, age, and gender). Addressing these associations would ultimately promote the development of more effective sustainable mobility policies.

Policy Considerations

As outlined in a recent NexSys Submission[188] to Ireland's Social Climate Plan, vulnerable households and families need to be prioritised as they are more likely to be in a disadvantaged position to cope with/afford climate mitigation and adaptation strategies. Lacking adequate, affordable and accessible transport services is associated with a higher incidence of isolation and social exclusion. Research indicates that this is particularly true for younger and older people, people with mobility issues, and those with certain disabilities.

Households located in rural areas are also more likely to be affected by transport poverty, which can lead to the 'trapping' of these households in their local areas, or 'force' them to own and drive private cars in order to fulfill their daily activities and or access essential services. Households located in urban areas are more likely to be served by a variety of transport services, which might be more adequate and accessible than those available in rural areas.

Geographic differences in fares also need to be addressed. For instance, in the major cities and commuter belts, reduced Leap Card fares are based on TFI zones, while families living outside these areas have greater problems with accessibility and affordability. The costs for these households are not only financial but also include time taken to travel to essential services and activities.

In particular, recommended measures related to investment in the transport sector considered urgent are the following:

- Expanding the eligibility criteria for the school bus schemes and improving the integration between it and public transport.
- Expanding the Safe Routes to School Programme to increase active travel. This will give more young vulnerable transport users a low/no cost transport option for travel to school.
- Extending access to TFI Local Link Community Car Scheme as coverage is limited and there are long waiting lists.
- Extending access to TFI Local Link beyond rural areas to peri-urban areas where there is a lack of public transport (e.g. North-West or South-west Dublin). This would reduce forced car ownership in suburban and peri-urban areas.

These measures will benefit those most vulnerable to transport poverty, particularly those in rural areas where public and active transport options are more limited. In line with Just

[188] Winston, N., da Silva Pedroso, M., Dingley, O., & Doody, J. "NexSys Submission to Consultation on the Development of Ireland's Social Climate Plan" https://www.nexsys-energy.ie/t4media/Submission%20to%20Social%20Climate%20Plan%20Consultation.pdf. 2025.

Transition principles, these measures also take a community and place-based approach to transport poverty rather than relying on individualistic or national strategies.

8. Areas for Further Investigation

Introduction

The pathways outlined in this Roadmap Report confirm that while a net-zero energy system for Ireland is grounded in engineering reality, the precise trajectory to reach it remains subject to significant complexity. Future research should accommodate the diverse scope and scales of the challenges that have emerged. This chapter outlines some possible areas for future work, recognising that our research agenda must operate simultaneously at the micro-level of technical validation and the macro-level of systemic strategy. This is not intended to be an exhaustive examination of all possible avenues of research prompted by this Report. Instead, it seeks to identify and briefly discuss certain topics at both the granular and strategic level which are prompted by the gaps emerging from the research outputs discussed in previous chapters. These have been grouped into areas of investigation based on scale and timeframe.

Granular & Immediate (The Micro Scale)

Some of the identified gaps are immediate and technical. For instance, the need for regionally validated wind and solar datasets These are actions required to de-risk specific projects and validate the performance of individual technologies.

Systemic & Strategic (The Macro Scale)

Conversely, other areas of investigation are very significant in scope, addressing national infrastructure or societal shifts. Questions surrounding the optimal portfolio of generation for 2050, or the design of a national hydrogen network require a "whole-systems" perspective that transcends individual technologies. These macro-level investigations are essential to ensure that individual technical successes do not aggregate into a systemic failure.

This duality is intentional. We cannot resolve national grid constraints without understanding local flexibility markets , nor can we address transport poverty without granular spatial data on household needs. Any research agenda should therefore be designed to bridge these scales, ensuring that high-level policy is informed by ground-level technical realities.

Navigating the Unknown

Finally, this chapter acknowledges the limits of current foresight. While many "known unknowns" are documented here; such as the precise future cost of green hydrogen or the adoption rates of electric heavy goods vehicles; we must also prepare for "unknown unknowns”. The energy landscape is volatile, influenced by rapid technological breakthroughs, shifting geopolitical realities, and accelerating climate impacts. There are gaps within our identified research gaps; interactions between variables, such as the interplay between extreme weather "Dunkelflaute" events and new interconnection dependencies, that are only beginning to crystallise.

Therefore, the future work suggested here is not an exhaustive list. It is instead indicative of some of the questions our research community can answer in support of identifying and responding to the emerging challenges that will inevitably define the next decade of the energy transition.

Sources of Clean Fuels

One of the aspects of the pathway to a net-zero energy system with greatest uncertainty is the most feasible pathways for decarbonisation of the hard to abate sectors such as aviation, industrial heating, and possibly heavy duty transport. For these sectors there is still considerable uncertainty regarding the mix of fuels and especially the source of these fuels, which can satisfy net-zero objectives. There is also the potential for significant competition from the different sectors for clean fuels with power generation, transport, and industry all potentially requiring large quantities of clean fuels. There is the distinct possibility that Ireland will become a net importer of these fuels should indigenous sources, such as offshore wind potential, not be fully exploited. In addition large-scale research and development into both Direct Air Capture and biogas potential is critical to understand how sustainable aviation fuels targets can be met.

Timelines for Buildout of Renewables vs. Electrification of Demand

The timing of the build out of renewables and the electrification of demand are unlikely to go in lockstep with one another. If buildout of renewables exceeds demand electrification then there will be an excess of renewables, resulting in increased dispatch down at least for a period of time. This excess should present an opportunity to stimulate other uses for the excess renewables, e.g. stimulating the green hydrogen supply and therefore potentially earlier decarbonisation of industrial heating and aviation fuels. The interplay between these aspects and the optimal use of excess renewables to accelerate the transition of net-zero is worthy of further research.

Technology Options for the Decarbonised Electricity System

There is still a wide range of different possibilities for the optimal portfolio of generation, storage and demand side technologies which could meet the goals of a decarbonised electricity system. The challenge is to understand the range of technologies which offer the best balance between technical characteristics, costs and deliverability. In this respect the ongoing Decarbonised Electricity System Study by SEAI is a notable activity which aims to bring more clarity to this by identifying a technology portfolio which balances costs and deliverability.[189] However, even with further clarity on the technology portfolio, there remains a role for further research in understanding the interaction and complementarity between different technologies and the more fine-grained detail of their operation in a decarbonised electricity system.

[189] Sustainable Energy Authority of Ireland. "Decarbonised Electricity System Study: Forecasts of Plausible Rates of Generation Technology Deployment 2024–2040." *seai.ie*, Sustainable Energy Authority of Ireland | Government of Ireland, June 2024, www.seai.ie/sites/default/files/publications/dess-rates-of-generation-technology-deployment.pdf.

Decarbonised Power System Operational Detail

The operational detail of the power system under decarbonised scenarios especially operation under 100% renewable generation and cross sector coupling is an area for further research. Of particular interest is the range of system services required to support such a system, the source of such services and the market structures necessary to incentivise them. Ensuring power system stability is a critical consideration as the dynamics of the system reliant on variable renewable generation is fundamentally different from that of a system reliant on conventional generation. Here the role of new technologies such as grid forming batteries, grid forming HVDC and synchronous condensers, in supplying sufficient system support and stability services requires further investigation.

Offshore Wind

The criticality of rapidly developing the offshore wind sector in Ireland cannot be overstated. The role for floating offshore and the details of structures and technologies which can make it less expensive, the interplay between offshore wind, interconnection and power to gas and the eventual very significant demand for clean fuels are just a few of the exciting areas for research. There is also a strong opportunity to create critical benchmarks, guidelines and pathways to standardisation for best practice guidance in areas such as offshore wind farm monitoring, through Irish case studies. This can make Ireland's participation strategic, focused, excellent and with a value creation that far exceeds the possibilities suggested by the more obvious immediate commercial opportunities.

Detailed Impact of Building Decarbonisation

As discussed in earlier sections NexSys research has already been studying behavioural aspects related to the uptake of clean energy technologies and there is considerable scope to capture these aspects in mathematical models which can help understand the impact of different incentives on uptake. For example a major barrier to home retrofits, which are a key aspect of building decarbonisation is the high upfront cost. The NexSys research carried out so far indicates that innovative financing to encourage home energy upgrades is essential. As explored earlier in this chapter, analysis shows that without major subsidies or new loan models, most homeowners cannot recoup deep-retrofit costs. A detailed report on on-bill financing is in progress, outlining how such schemes could operate in Ireland and what regulations are needed. Such measures could make comprehensive upgrades financially accessible to more households.

The continued decarbonisation of buildings provides substantial opportunities for providing flexibility to the system. Prime examples for exploitation include increased use of home and building energy management systems, and coupling with EV charging, heat pump control and thermal storage. There is a growing work on "active node" buildings that generate, store and trade energy with the grid. NexSys is identifying the technological requirements (smart meters, building-management systems, cybersecurity) and regulatory issues (interoperability, data privacy, etc.) to enable networks of such smart, self-sufficient buildings which can also provide flexibility to the wider energy system.

There is also a significant role for research in understanding the impact of building decarbonisation at a more granular spatial level. To address this NexSys researchers are creating a national-scale digital twin that enables comparisons of multiple decarbonisation scenarios for the buildings sector and has the potential to become a powerful decision support tool for policy makers, utility network planners and urban planners. In this context a digital twin refers to a continuously updated representation of the national dwelling stock that links physical characteristics, occupancy behaviour, heating technologies, and spatial information to model energy use at hourly resolution. The purpose is to move from static surveys to a dynamic framework that can test policy options, examine operational impacts, and support planning at national and local levels.

Modelling for Urban Transitions

NexSys researchers are developing detailed models for greenhouse gas emissions which can account for the complexity of different landscapes (urban, rural, etc) and their associated anthropogenic or natural emissions. The model framework provides a tool for identifying the profile of net GHG emissions at national and local scales and the development and evaluation of location based mitigation policies. Future NexSys work will refine these tools and translate them into practice. Climate-modelling researchers plan to incorporate even finer data (e.g. real-time transport flows, building-level energy use) for more precise local plans in urban environments. The plan is to publish an Ireland case study and roll out the Climate Vitals as a public dashboard to engage citizens.

Electrification of Heavy Duty Transport

Although the plan for decarbonisation of the private vehicle fleet is clear enough with an emphasis on direct electrification, there is much more uncertainty and much less progress, regarding heavy duty vehicles. In this respect there is a significant gap for further research to inform Ireland's plans to achieve the overall transport sector goals for decarbonisation. One important aspect is the more detailed analysis of the HGV sector in terms of spatial and temporal characteristics. An assessment of the spatial distribution of economic activity with traffic flows on the national road network by vehicle type (LGV, HGV-1 and HGV-2), economic sector, average journey distances and average values per tonne of freight is essential to identify locations where infrastructure investments are most needed to support transition to alternative fuels for heavy goods vehicles. The role for alternative fuels other than battery electrification and their likely uptake or incentivisation is also an area of particular interest for further research.

9. Annex of Policy Considerations

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
1.4.1	Energy Systems	Dynamic Electricity Pricing	Rollout automation technologies alongside dynamic pricing to improve demand-side flexibility	DCEE, SEAI, Electricity Suppliers	2026
1.4.2	Energy Systems	Dynamic Electricity Pricing	Offer bill protection for phase-in period to customers availing of dynamic price electricity contracts	CRU, Electricity Suppliers	2026
1.5.1	Energy Systems	Vehicle to Grid Technology	Support and promote the adoption of automated home energy management systems in support of vehicle to grid technology rollout.	SEAI	2026-2030
1.5.2	Energy Systems	Vehicle to Grid Technology	Make price responsive V1G charging a default charging strategy for EVs.	CRU, ESB Networks, Energy Suppliers	2026-2030
1.5.3	Energy Systems	Vehicle to Grid Technology	Implement additional incentives for customers to move from V1G to V2G EV charging.	DCEE, SEAI	2026-2030
1.5.4	Energy Systems	Vehicle to Grid Technology	Examine the implementation of local flexibility markets to mitigate local grid congestion from	CRU, ESB Networks	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			V2G.		
1.5.5	Energy Systems	Vehicle to Grid Technology	Promote standards to ensure interoperability between different vendor equipment and data sharing between systems.	NSAI, Industry	2026-2027
1.6.1	Energy Systems	Private Wires	Ensure private wire users contribute transparently to grid maintenance via levies or fees.	DCEE, CRU	2026
1.6.2	Energy Systems	Private Wires	Establish clear licensing and approval criteria that align private wires with national energy and climate goals, while encouraging innovative projects like rural cooperatives, industrial decarbonization, and campus models.	DCEE, CRU	2026
1.6.3	Energy Systems	Private Wires	Integrate comprehensive environmental impact assessments, including water usage and resource impacts, especially for data centres and generation facilities, into planning and regulation.	DCEE, An Coimisiún Pleanála, EPA	2026-2027
1.6.4	Energy Systems	Private Wires	Require full disclosure of carbon emissions	DCEE, EPA	2026-2027

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			and annual performance reporting for all private generation and storage assets to ensure accountability.		
1.6.5	Energy Systems	Private Wires	Utilise pilot projects, regulatory sandboxes, active stakeholder engagement, and ongoing policy reviews to maintain responsiveness to technological advances and evolving energy profiles and demand.	DCEE	2027-2030
1.7.1	Energy Systems	Green Hydrogen in Ireland	Begin coordinated work with the United Kingdom to raise the current 0.1% by volume hydrogen blending limit to a minimum of the EU's 2% interconnection requirement and prepare for higher levels in line with technical evidence, while finalising domestic safety standards and supporting early regional hydrogen clusters.	DCEE, Gas Networks Ireland, CRU, Ofgem	2026-2030
1.7.2	Energy Systems	Green Hydrogen in Ireland	Create a national hydrogen certification scheme aligned with EU RFNBO	CRU, DCEE, Gas Networks Ireland	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			standards to ensure market access, build investor confidence, and guarantee low emissions integrity.		
1.7.3	Energy Systems	Green Hydrogen in Ireland	Begin coordinated work with the United Kingdom to raise the current 0.1% by volume hydrogen blending limit to a minimum of the EU's 2% interconnection requirement and prepare for higher levels in line with technical evidence, while finalising domestic safety standards and supporting early regional hydrogen clusters.	CRU, DCEE, Gas Networks Ireland	2026-2030
1.7.4	Energy Systems	Green Hydrogen in Ireland	Create a national hydrogen certification scheme aligned with EU RFNBO standards to ensure market access, build investor confidence, and guarantee low emissions integrity.	DCEE	2026-2030
1.7.5	Energy Systems	Green Hydrogen in	Implement a lifecycle	CRU, GNI	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
		Ireland	carbon-intensity threshold (≤ 3–4 kg CO_2eq/kg H_2) to ensure all hydrogen in Ireland, domestic or imported, meets low-carbon standards.		
1.7.6	Energy Systems	Green Hydrogen in Ireland	Ensure alignment with EU and UK schemes by embedding lifecycle GHG accounting, additionality, and temporal/geographic correlation in line with RED III and Delegated Regulation 2023/1184.	CRU in coordination with GNI and NSAI	2026-2030
1.7.7	Energy Systems	Green Hydrogen in Ireland	Implement critical energy market reforms within the Single Electricity Market (SEM) to enable the electrolysers to access surplus renewable electricity and allow electrolysers to provide valuable grid services.	CRU, DCEE, in coordination with EirGrid, SEMO, and industry participants	2026-2030
1.7.8	Energy Systems	Green Hydrogen in Ireland	Introduce long-term revenue support schemes to	DCEE, D/Finance	2030+

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			de-risk private investment in renewable hydrogen production and use.		
1.7.9	Energy Systems	Green Hydrogen in Ireland	Begin targeted financing of pilot projects to de-risk early-stage investments, test new applications, and gather essential data to guide the long-term, evidence-based deployment of a large-scale hydrogen ecosystem, along with developing an indigenous hydrogen industry.	DCEE, D/Finance	2026-2030
1.7.10	Energy Systems	Green Hydrogen in Ireland	Establish a dedicated national hydrogen fund that leverages the EHB's 'Auctions-as-a-Service' scheme, alongside exchequer support, to build a domestic supply chain.	DCEE, D/Finance	2026-2030
2.2.1	Renewable Energy	Renewable Energy Resources	Prioritise development and use of regionally	DCEE	2026+

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			validated, Ireland-specific datasets and models for wind and solar installations to improve drought quantification.		
2.2.1	Renewable Energy	Renewable Energy Resources	Move toward a balanced mix of wind and solar PV by 2030 to reduce drought frequency and extend return periods for severe multi-day events.	DCEE, EirGrid	2026-2030
2.2.3	Renewable Energy	Renewable Energy Resources	Establish ongoing validation and updating of datasets as technologies and deployment scales evolve, ensuring resilience assessments stay policy-relevant and decision-ready.	DCEE, HEIs	2026+
2.4.1	Renewable Energy	Offshore Renewable Energy Port Capacity	Create a coordinated national implementation plan for ORE development at Irish ports	D/Transport, DCEE	2026-2027
2.4.2	Renewable Energy	Offshore Renewable Energy Port Capacity	Maximise quayside space in ports for efficient ORE rollout	IMDO, Port Companies	2027+

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
2.4.3	Renewable Energy	Offshore Renewable Energy Port Capacity	Adopt a specialised multiport approach	Port Companies, D/Transport	2027+
2.4.4	Renewable Energy	Offshore Renewable Energy Port Capacity	Identify the geophysical limitations of Irish ports for ORE	IMDO, D/Transport	2026-2027
2.4.5	Renewable Energy	Offshore Renewable Energy Port Capacity	Identify the number of marshalling ports needed for Ireland's ORE targets	IMDO, D/Transport	2026-2027
2.4.5	Renewable Energy	Offshore Renewable Energy Port Capacity	Provide funding for critical ORE port infrastructure	D/Transport, D/Finance	2026+
2.5.5	Renewable Energy	Public Acceptance of Wind Farms	Replace information based communication strategies for wind farms with approaches that are supported by clearer evidence of success, e.g. community benefit schemes, participatory planning processes and long-term local engagement.	Industry, DCEE, SEAI	2026+
3.2.1	Energy and the Built Environment	Retrofitting & New Buildings	Examine green mortgages, grants or on-bill financing to lower upfront retrofitting costs for households	SEAI, DCEE, D/Finance	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
3.4.1	Energy and the Built Environment	Water - Energy Conservation in Buildings	Examine awareness campaigns, educational initiatives, and financial incentives such as rebates or subsidies to support rainwater harvesting adoption.	Uisce Éireann, D/HLGH	2026-2030
3.5.1	Energy and the Built Environment	Building Energy Flexibility & Peer-to-Peer Trading	Revise the Microgeneration Support Scheme to integrate dynamic pricing.	DCEE, CRU	2026-2027
3.5.2	Energy and the Built Environment	Building Energy Flexibility & Peer-to-Peer Trading	Support SECs to pilot P2P using secure data-sharing mechanisms and digital platforms.	DCEE, SEAI	2026-2027
3.5.3	Energy and the Built Environment	Building Energy Flexibility & Peer-to-Peer Trading	Develop clear business models to incentivise suppliers and DSOs to support P2P, for example through transaction fees, supplier-enabled billing, or flexibility services.	DCEE, CRU, ESB Networks	2027-2030
3.5.4	Energy and the Built Environment	Building Energy Flexibility & Peer-to-Peer Trading	Update Smart Meter Data Access Code and GDPR-compliant frameworks to ensure trust and	CRU, DCEE	2027-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			transparency for P2P.		
3.5.5	Energy and the Built Environment	Building Energy Flexibility & Peer-to-Peer Trading	Establish a comprehensive legal and regulatory framework for P2P, supported by sandbox trials, explicit supplier responsibilities, and defined settlement procedures.	DCEE, CRU, SEAI	2030+
3.5.1	Energy and the Built Environment	Household Energy Deprivation	Prioritise targeted, full cost energy upgrades for low income vulnerable groups, specifically: Disabled people; lone parents; large families; working poor families; older people; young children; renters.	SEAI, D/Social Protection	2026+
3.5.2	Energy and the Built Environment	Household Energy Deprivation	Change the focus of the SEAI Sustainable Energy Community Mentors work to prioritise the most vulnerable households.	SEAI	2026+
3.5.3	Energy and the Built Environment	Household Energy Deprivation	Return to unit-based energy benefit v. cash-based subsidies (e.g. fuel allowance) to	D/Social Protection	

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			ensure minimum level of electricity/gas regardless of cost.		
3.5.4	Energy and the Built Environment	Household Energy Deprivation	Reserve access to SEAI grants to the most disadvantaged households for a period.	SEAI	2026+
4.3.1	Transport	Spatial Distribution of Household Private Transport Energy Demand	Integrate policy-relevant data within a bottom-up framework to generate high-resolution transport energy indicators, bridging national reporting and local planning.	D/Transport, NTA, Local Authorities, An Coimisiún Pleanála	2026-2030
4.3.2	Transport	Spatial Distribution of Household Private Transport Energy Demand	Integrate transport energy in urban and regional planning to mitigate the impacts of low-density, scattered, and car-dependent housing developments.	An Coimisiún Pleanála, Local Authorities	2026-2030
4.4.1	Transport	Preferences for Electric Light Vehicles Among SMEs	Redesign financial support, such as EV grants, Vehicle Registration Tax (VRT) relief, and reduced annual motor tax, to tie to	ZEVI, SEAI, D/Finance	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			measurable operational outcomes like improvements in range, energy efficiency, or reduced charging time.		
4.4.2	Transport	Preferences for Electric Light Vehicles Among SMEs	Prioritise depot and workplace charging, simplifying grid access and installation for SMEs. This rollout should be strategically aligned with the National Road Network EV Charging Plan (2024–2030).	ZEVI, SEAI	2026-2030
4.4.3	Transport	Preferences for Electric Light Vehicles Among SMEs	Implement service guarantees covering range and maintenance to further strengthen confidence, particularly among status quo-oriented firms.	ZEVI, D/Transport	2026-2030
4.5.1	Transport	Freight Assessment & Archetypes	Pursue cross-border cooperation and harmonised policies to effectively decarbonise HGV operations, specifically with	D/Transport	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			battery electric and hydrogen fuel cell electric HGVs in Northern Ireland, the UK & France.		
4.5.2	Transport	Freight Assessment & Archetypes	Support the uptake of hydrogen trucks for heavy goods operators, through rapid development and implementation of plans for infrastructure to facilitate fast refill of green hydrogen.	D/Transport, DCEE	2026-2030
4.6.1	Transport	Transition to Commercial Vehicle Electrification Policy	Focus rapid investment in nationwide high-power charging infrastructure for commercial vehicles to support improved Depot Charging to offset high installation costs, often requiring expensive grid upgrades.	D/Transport, ZEVI	2026-2030
4.6.2	Transport	Transition to Commercial Vehicle Electrification Policy	Invest in Optimisation Models that successfully optimise and share "behind-the-meter" charging capacity across commercial	D/Transport, ZEVI	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			sites (and potentially residential sites where appropriate) could significantly increase effective system capacity.		
4.7.1	Transport	Sustainable Aviation Fuels	Develop a national strategy to outline pathways for indigenous SAF production by developing the required facilities and securing 3 GW of dedicated offshore wind energy.	D/Transport	2026-2027
4.7.2	Transport	Sustainable Aviation Fuels	Support large-scale research and development into both DAC and biogas potential to ensure future SAF supply.	D/Transport, HEIs	2026-2030
4.7.3	Transport	Sustainable Aviation Fuels	Through a national SAF strategy, proactively address the significant cost impacts of domestic production to enable an equitable energy transition.	D/Transport	2026-2027
4.8.1	Transport	Transport Poverty	Expand the eligibility criteria for the school bus schemes and improve the	D/Transport, D/Education	2026-2030

No.	Chapter	Section	Insight / Recommendation	Stakeholders	Timeframe
			integration between it and public transport.		
4.8.2	Transport	Transport Poverty	Expand the Safe Routes to School Programme to increase active travel among young vulnerable transport users.	D/Transport, NTA, D/Education	2026-2030
4.8.3	Transport	Transport Poverty	Extend access to TFI Local Link Community Car Scheme to address limited coverage and waiting lists.	NTA, D/Transport	2026-2030
4.8.4	Transport	Transport Poverty	Extend access to TFI Local Link beyond rural areas to peri-urban areas where there is a lack of public transport (e.g. North-West or South-west Dublin) to reduce forced car ownership in suburban and peri-urban areas.	NTA, D/Transport	2026-2030

10. Acknowledgements

The editorial team gratefully acknowledges the assistance and expertise of the NexSys research team in the creation of this report. NexSys contributors to this Roadmap include (in alphabetical order):

Prof. Aisling Reynolds-Feighan, University College Dublin
Alireza Etemad, University College Dublin
Allison Kelly, University College Dublin
Prof. Andrew Keane, University College Dublin
Dr. Bidisha Ghosh, Trinity College Dublin
Dr. Charlene Vance, University College Dublin
Dr Ciarán Mac Domhnaill, University College Dublin
Dr. Conor Sweeney, University College Dublin
Dr. Daniel Cassidy, Economic and Social Research Institute
Dr. Divyanshu Sood, University College Dublin
Dr. Eoin Syron, University College Dublin
Prof. Fabiano Pallonetto, Maynooth University
Prof. Gerald Mills, University College Dublin
Glenn McNamara, University College Dublin
Hugo Jacque, University College Dublin
Dr. James Carton, Dublin City University
Prof. James O'Donnell, University College Dublin
John Doody, University College Dublin
Kamran Khammadov, University College Dublin
Prof. Lisa Ryan, University College Dublin
Mary Gallagher-Cooke, University College Dublin
Dr. Mohsen Kia, University College Dublin
Dr. Monika da Silva Pedroso, University College Dublin
Dr. Muhammad Waseem, Maynooth University
Prof. Neil Hewitt, Ulster University
Nadiya Saba, University College Dublin
Dr. Nessa Winston, University College Dublin
Dr. Oliver Kinnane, University College Dublin
Orla Dingley, University College Dublin
Pardis Asgharisemnaei, University College Dublin
Dr. Pranay Kumar, University College Dublin
Dr. Régis Delubac, University College Dublin
Dr. Sarah Launius, University College Dublin
Dr. Shuo Zhang, University College Dublin
Dr. Sweta Malik, University College Dublin
Dr. Terence O'Donnell, University College Dublin
Dr. Tim Persoons, Trinity College Dublin
Dr. Vikram Pakrashi, University College Dublin

NexSys is funded by Research Ireland Grant no. 21/SPP/3756 (NexSys Strategic Partnership Programme). Observations and recommendations in this report are those of the author(s) and do not necessarily reflect the views of NexSys affiliated research organisations or industry partners.

Any correspondence or queries in relation to this report can be addressed to terence.odonnell@ucd.ie