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Ireland's Energy Transition: Applying Systems Tools

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Chapter 1: Introduction

This Secretariat paper provides more detail on some of the systems thinking tools that informed the NESC Council Report No.172 Accelerating the Transition to a Sustainable Energy System (hereafter 'the Council report'). The Council report provides more detail on the context and purpose of the research and therefore this paper should be read alongside that report, which is available at www.nesc.ie.

1.1 Report Structure

This chapter provides details on the structure of this report and a brief introduction to systems thinking.

Chapter 2 presents details on how the Doughnut Economics concept (Andrew L. Fanning and Raworth, 2025) was translated or downscaled into a framing for the challenges facing the energy sector, the energy doughnut.

Chapter 3, describes the stakeholder participative approaches applied in the research, namely two participative workshops on energy systems and a roundtable on energy demand management.

Chapter 4 explains the Causal Loop Diagram tool and details how it was applied to four transition technologies in the energy sector.

Finally Chapter 5 briefly describes the outcome of the research.

1.2 NESC Energy Work Programme

In 2024, NESC undertook a programme of research to explore progress in, and implications of the energy transition for the economy, society and the environment. In April, 2025, NESC published the first Council report under this work programme, Ireland's Future Power System and Economic Resilience (National Economic and Social Council, 2025c). In July and August 2025, two further Council papers were published; 'International Trade Dependencies and the Energy Transition' (National Economic and Social Council, 2025b) and 'Connecting People to the Energy Transition'(National Economic and Social Council, 2025a). A series of secretariat and research papers have also been published over the course of 2025. This report is part of the series of secretariat reports. All the above reports are available at www.nesc.ie.

1.3 Systems Analysis

Systems analysis is not new but, as yet, it has rarely been formally applied in an Irish policy context. A systems analysis framework and tools were applied by the OECD to Ireland's passenger transport system in 2022 (Organisation for Economic Co-operation and Development (OECD), 2022) and its three-step framework informed the methodology and choice of tools applied in the Council report (see section 1.3.1). Within that framework, this report applies tools such as: participative stakeholder engagement to elicit stakeholders' expertise and insights; causal loop diagrams to identify dynamics driving relationships and outcomes; and doughnut economics concepts to frame objectives and inform a vision to identify potential for systems change. The following sections present the framework and tools, and provide a summary of their application to Ireland's energy transition.

1.3.1 OECD Transformational Change for Net Zero Framework

In 2022, the OECD applied its systems methodology framework to the Irish passenger transport sector. This analysis has been incorporated into official transport policy (Department of Transport, 2022). The OECD framework suggests that behavioural outcomes are largely a result of the system structure in which they are embedded and the mindsets that underlie that structure. It also suggests that government policies and interventions have been key influences shaping current systems and current mental models and that therefore, with appropriate policies, systems could be deliberately redesigned to trigger different behavioural outcomes and transformational change that would otherwise be unlikely to occur (OECD, 2022). Based on this framing a three-step approach to design a transformative climate strategy was developed and applied to Ireland as follows:

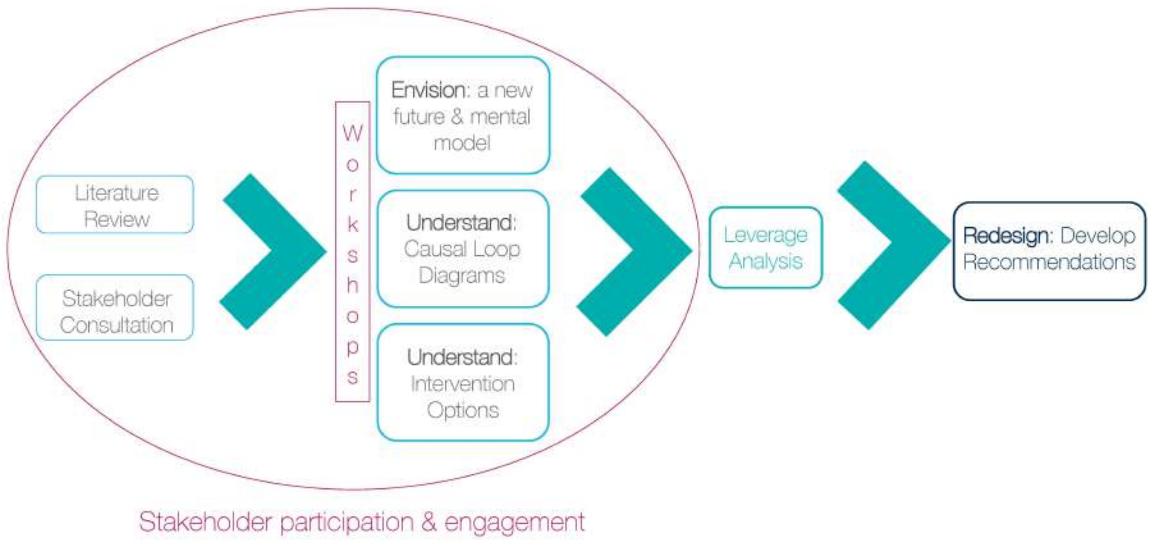
- '***Envision*** the goal(s) and the patterns of behaviours that a properly functioning system would foster,
- ***Understand*** why the current system is not achieving envisioned goals and patterns of behaviour
- ***Redesign*** systems to foster desirable patterns of behaviour and goals by prioritising transformative policy packages and processes.' (OECD, 2025a)

1.3.2 A Systems Methodology

Inspired by the OECD framework described in section 1.3.1, the Council Report applied a methodology combining systems tools such as envisioning, participative stakeholder engagement and causal loop diagrams to inform its research. Figure 1 illustrates the overall methodology. This paper describes how these tools were applied and the results thereof.

The doughnut economics framing (described in chapter 2) and participative approaches (described in chapter 3) were applied to develop key elements of **envisioning** a successful energy transition in Ireland. Stakeholder engagement, participative approaches and causal loop diagrams were applied to better **understand** the current energy system. Finally the doughnut framing, participative approaches, stakeholder engagement and the causal loop diagrams were applied to inform how to redesign and prioritise policies and actions to accelerate transformation to a sustainable energy system.

Figure 1: The systems methodology applied in this analysis



Source: O'Reilly, 2026.

Chapter 2: Applying Doughnut Economics to the Energy Sector

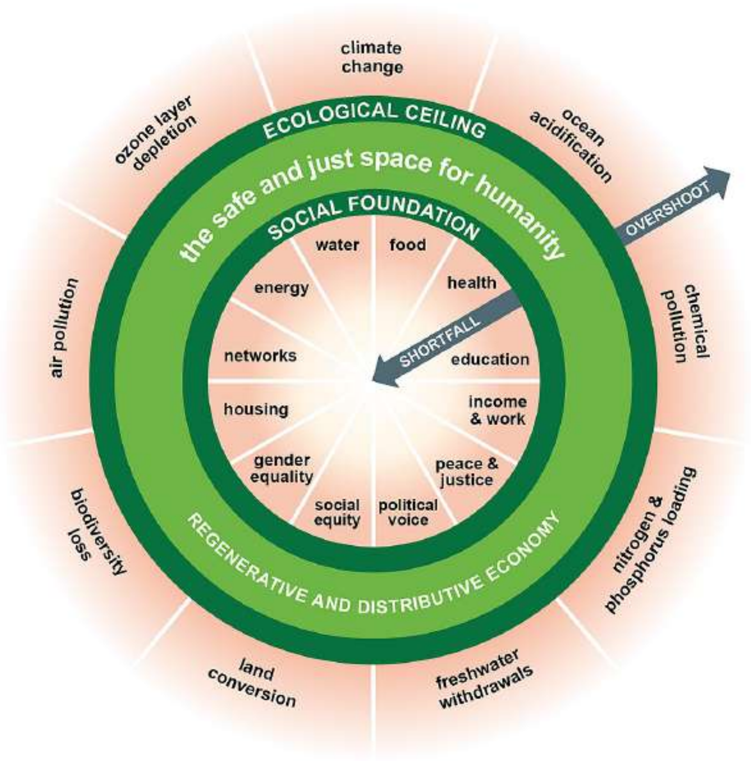
2.1 Energy Objectives & Doughnut Economics

The energy system provides essential services of heat, light, power, and transport through vectors such as electricity, gas and liquid fuels, but where does this energy system fit into our overall goals as a society? The Well-being Framework, adopted by the Government in 2023 has as an overarching vision 'enabling all our people to live fulfilled lives now and into the future' and a series of indicators towards monitoring outcomes (Department of An Taoiseach, 2023).

The doughnut economics model addresses the basic requirements for fulfilled lives now, through the social foundation, and into the future, through the ecological ceiling (Raworth, 2017). Both the Well-being Framework and the Doughnut Economics model address society or economy wide needs and constraints and are not aimed at sectoral analysis. The Well-being Framework is tailored to Ireland and is directed at aspirations such as subjective wellbeing whereas the Doughnut Economics concept, designed for global application, focuses on necessary conditions for a 'safe space for humanity'. Below, we present an application of the Doughnut Economics model downscaled to the energy system.

Doughnut economics, so-named for the diagram represented in figure 2.1, suggests that economies need to satisfy certain social foundational needs such as provision of adequate food. These represent a basic floor that must be met. At the same time, economies also have to operate within environmental constraints otherwise the earth systems on which we depend will be jeopardised. These constraints are presented as an ecological ceiling that should not be exceeded. While this theoretical model was developed for assessing whole economies whether at global, national, or local scales, it can inspire an adapted approach to assess the performance of a sector such as the energy system. The doughnut approach can also inform planning and policy development by acting as a reminder of the multi-dimensional objectives and constraints faced across society, the economy and the environment.

Figure 2: The Doughnut Economics Model



Source: Fanning and Raworth, 2025.

We took the 2025 doughnut economics model and assessed the relevance of each dimension of the social foundation and the ecological ceiling to the energy sector (A.L. Fanning and Raworth, 2025). The domestic social foundation analysis for Ireland is presented in table 1.[1] Not all the elements of the society-wide social foundation are directly relevant to the energy sector. In those cases where the performance of the energy sector is relevant, some common themes or characteristics become apparent.

1 An international analysis would also be a useful exercise to undertake as Irish energy choices have implications for the achievement of a safe and just space for humanity in other countries but this is not the focus of the present study.

Table 1: Assessing relevance of the domestic social foundation of the Doughnut Model to the energy sector

Indicator	Illustrated relevance to the energy sector	Supportive Energy Characteristics
Food	Energy is an important input to food production and preparation, from powering farm machinery to drying milk powder to domestic cooking and refrigeration. It is also crucial to transporting food, allowing some specialisation of production and access to a greater variety of foods. Therefore the price of energy and the efficiency of its use impacts food availability and quality.	Competitiveness of food industry Energy affordability Energy efficiency Land competition (an ecological ceiling)
Health	Excess winter mortality in Ireland illustrates a clear link between health outcomes and adequate energy for essential warmth (Institute of Public Health, 2022). Poor air quality driven by combustion has been shown to cause excess deaths in Ireland (Environmental Protection Agency, 2022). A reliable energy supply is crucial to the functioning of health services and many medical devices. Active travel supports good health. ost reductions due to VRE increase public support, which supports more ambition and investment.	Energy security Resilience to climate change Building quality/energy efficiency Air quality (ecological ceiling) Healthy energy use/sources
Education	Places of education rely on energy to function to provide a comfortable appropriate space for learning and connection to pupils, educators and the broader community. Microgeneration can be a source of income for schools.	Energy affordability Participation Connectivity
Income & work	The energy sector is a large employer while reliable energy provision is an essential input to economic activity.	Competitiveness Energy affordability Energy security
Social Cohesion	Energy deprivation exists in many poorer and other vulnerable households. The deprivation can be driven by energy prices, energy security, connectivity and energy participation. Energy deprivation can impact health and social inclusion.	Energy affordability Participation Connectivity
Energy	Energy itself is a segment of the doughnut and therefore the reliability and accessibility of energy are also important.	Energy security Energy resilience Energy affordability

Indicator	Illustrated relevance to the energy sector	Supportive Energy Characteristics
Equality	Energy costs can impact individuals and households differently depending on local transport infrastructure and the build quality (insulation or efficiency) of their home. Mobility poverty and energy poverty has been measured for Ireland. On the other hand, it has been found that some state supports for the energy transition primarily benefit wealthier households.	Participation Energy efficiency Connectivity Health Energy affordability
Housing	The manner of construction of housing has implications for energy demand and emissions. The quality of existing housing and efforts to retrofit the same also has implications for energy demand and emissions. The location of housing has a big influence on energy demand and overall efficiency and therefore the	Energy efficiency Energy affordability Competitiveness Healthy energy Connectivity
Connectivity	Connectivity can mean physical and virtual access to services, education, employment, opportunities for socialising and leisure. It can include modern information systems, spatial planning, and transport infrastructure all of which are closely tied to the energy system.	Energy affordability Healthy energy Energy efficiency Connectivity
Water	Energy is an important input to many water purification processes and therefore water supply can be vulnerable to power outages. Water is also a source of energy in hydroelectricity (e.g. Shannon) and pumped hydro (e.g. Turlough hill).	Energy security Energy resilience Energy affordability
Political voice	To what extent are people's voices heard in designing or guiding and implementing the energy transition? Do people have access to appropriate and adequate means to influence outcomes that are relevant to them? Do people have control over their own energy use?	Energy participation
Peace & Justice	In so far as the energy system can contribute to this dimension, it is closely related to political voice.	Energy participation

Figure 3 reflects how these features might be used to map the social foundations of a new 'energy system donut'.

Figure 3: Features of energy that support the social foundation

Source: O'Reilly, 2026.

The relevance of the different elements of the original doughnut's ecological ceiling were also assessed for relevance to the energy system with the analysis presented in table 2.

Table 2: Assessing relevance of the energy sector for performance against the ecological ceiling of the Doughnut Model

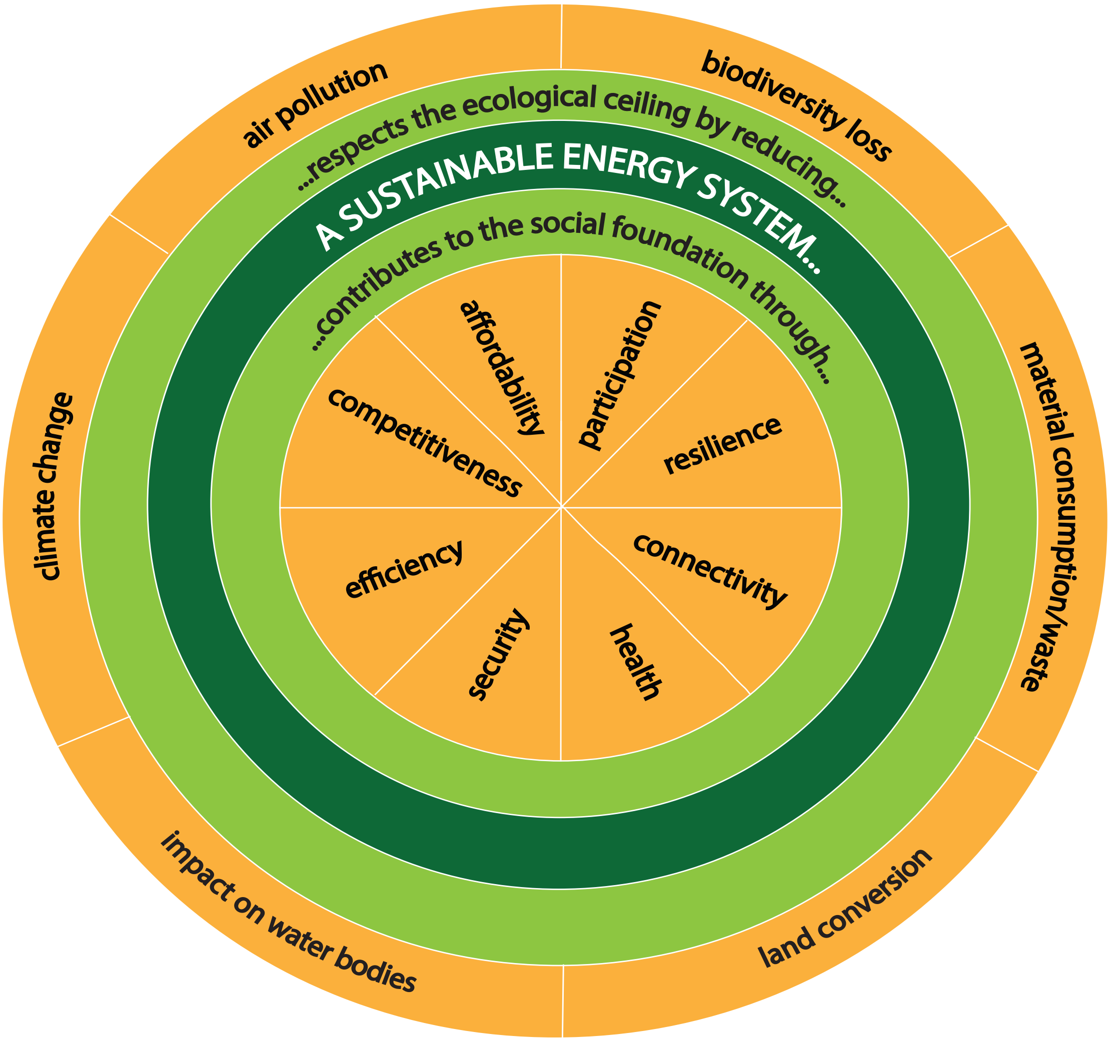
Criteria	Description/Comment	Relevance
Freshwater Disruption	Energy technologies such as hydro power, cooling of stations, pumped hydro energy storage can all involve either water extraction or the physical modification of natural water bodies (hydromorphology).	Relevant
Ocean Acidification	Energy's influence on ocean acidification is through its greenhouse gas emissions and therefore we fold this effect into a newly named planetary boundary 'impact on water bodies'.	N/A
Land conversion	Energy technologies of the fossil fuel or renewable variety both require landspace often converting land from low intensity agriculture. Land required for different energy pathways – industrial sites, biofuels, renewables, forestry, mines for minerals.	Relevant
Biodiversity Breakdown	Energy infrastructure can disrupt biodiversity habitats through land conversion or pollution. Some energy technologies, particularly could assist with provision of safe habitat (Molloy *et al.*, 2024).	Relevant
Air pollution	The burning of fuels for energy whether fossil, biofuel or hydrogen, always comes with air pollution which can be indoor or outdoor pollution.	Relevant
Nutrient Pollution	Increased biofuel use may lead to greater use of fertiliser, depending on application of biofuel standards. Manufacture of fertilisers is very energy intensive.	This is folded into impact on water bodies, air pollution, climate change and land conversion.
Ozone Layer Depletion	Not seen to have high relevance to energy activities in Ireland as the Montréal Protocol very effectively manages the phase out of ozone depleting substances in Ireland.	Where relevant, this is folded into air pollution.
Chemical pollution	Not clear that this is a current problem for energy sector activities and could be reflected under other categories.	Where relevant, this is folded into impact on water bodies and land conversion.

Criteria	Description/Comment	Relevance
Climate change	Greenhouse gas emissions	Relevant
Material Consumption/Waste	We introduce this additional category most obviously because of the rare-earth mineral consumption of many technologies, pointing to an ultimate need to manage material consumption and recycle materials. The same principles also apply to the use of more regular materials.	Relevant

Not all the elements of the ecological ceiling were deemed directly relevant to the electricity sector. A further element was identified for more direct analysis of the entire ecological impact; material consumption and waste. While these may have been represented in the land conversion element in the original doughnut, drawing it out for specific attention seemed warranted to facilitate and encourage circular economy considerations.

Based on this analysis, this section translates the original economy/society wide doughnut model to a sector specific model that includes the manner in which the energy sector contributes to the social foundation and also the planetary boundaries that can be implicated through energy sector activities. Figure 4 illustrates the resulting energy sector doughnut.

Figure 4: The Energy Doughnut



Source: O'Reilly, 2026.

The energy doughnut describes in the central circle, key criteria that energy needs to meet to support the social foundation. Performance could be marked from the centre of the circle reaching out towards the green circle representing the minimum levels required in those criteria. The outer circle describes the planetary boundaries that the energy sector must respect. Figure 4 is a useful summary of our energy objectives because it reminds us that environmental sustainability is not just about eliminating greenhouse gas emissions and that social sustainability is not just about affordability. The energy doughnut offers a clear illustration of the complex but interrelated space in which the energy transition operates. It highlights the importance of a policy response that recognises the wide range of policy goals and targets, as well as social, economic and environmental considerations, that must be taken into account when planning the energy transition. The doughnut can therefore serve as a useful prompt to design-in synergies and co-benefits to energy transition plans and policies while avoiding or reducing wider negative impacts, where possible.

Chapter 3: Stakeholder Participative Approaches

Stakeholders across the energy system were engaged with on a bilateral basis as part of this research, on the demand and supply side of the energy system, representing vulnerable groups, the environment, utilities, regulators, grid operators, planners, researchers, policy makers and the private sector.

Traditional engagement with stakeholders takes place in a sequential fashion. Stakeholders are met with bilaterally, or in a group, and given an opportunity to offer, in turn, their position on a topic. The researcher then gathers these discrete opinions and usually undertakes a desk-based approach to reconcile stakeholder views. This is a useful and important process but has some difficulties. Where stakeholders have been engaged with separately, stakeholders may not recognise the distance between the various positions and therefore might not understand if the reconciled outcome differs significantly from their own. Where issues are contentious, disparate stakeholders may not trust the outcome of the desk based (black box) reconciliation of their views. Finally, even when stakeholders are met in a group, unless prompted and enabled to think in different ways about their own needs and the needs of others, stakeholders' positions may not evolve or move.

Participative approaches elicit stakeholders' experience, expertise and views on a topic in new ways designed to have participants listen to each other and to develop shared insights. 'A shared understanding and alignment on the need to transform, … stakeholders' role in such transformation, … as well as the steps stakeholders could take to advance in that direction, are fundamental to launch a coherent process of systems change in the country' (OECD, 2022, p. 157). Participative approaches foster creative approaches, ownership of outcomes and importantly an openness to new solutions that deviate from participants' starting position.

Prof. Birgit Kopainsky of the System Dynamics Group at the University of Bergen assisted NESC with the design and facilitation of two participative workshops with stakeholders, employing systems tools, described in sections 3.1 and 3.2.

3.1 First NESC Energy Systems Workshop

The first workshop was held on November 19, 2024. The affiliations of the [40] participants are listed in Annex 5. The workshop focused on the envision and understand steps of the OECD systems framework (OECD, 2025a). The visioning work, which took place in the morning session, is described here. The afternoon session, explored dynamic drivers and effects through causal loop diagrams. The results of that session are reflected in chapter 4 on the Causal Loop diagrams tool.

Visioning

Ireland's Climate Change Assessment in 2023 noted that 'transformative outcomes can be realised through fundamental change that builds on visions of desirable futures and systems thinking that aligns immediate actions with long-term goals' (Moriarty *et al.*, 2023). Envision is the first step in the OECD's Transformational Change of Net Zero framework and asks us to explore what success look will look like (OECD, 2025a).

'Visioning is recommended when exploratory scenarios show that a place is not likely to be or become climate resilient[/proof] without dedicated action, meaning the current situation needs to change in an alternative, more positive direction. This is where we move from plausible to desirable futures. Desirable futures can only become reality when they are imagined: a concrete vision of what exactly a desirable future would look like helps to identify concrete actions that lead towards that future' (Van Den Ende *et al.*, 2022, p. 26).

Elaboration of a vision for energy would be useful to offer actors in the energy system more guidance in decision-making. 'This step sheds light on the shared goal(s) – or lack thereof – guiding policy decisions and invites policymakers to imagine and agree on "what could be"' (OECD, 2025b). It can also act as a public engagement tool to explain the changes and benefits that people can expect from the energy system. Infrastructural choices now could define the future of the energy system, incurring sunk costs in obsolete technologies or preparing the ground for transformation.

The objective of the morning session on the vision was to elicit stakeholder views on what a zero carbon energy system would look like, how it would operate, and how people would interact with it, and to facilitate dialogue among energy system stakeholders to explore the extent to which visions of the future were shared.

The OECD (2022) study included a workshop with an envisioning exercise which was based around an exercise asking participants to visualise and draw the future scenario. Inspired by underlying aim of that exercise to envision a positive future, a new exercise tailored to the energy sector, which is hard to visualise, was developed for this study based on a narrative approach. Participants were invited to consider a positive future via five different entry points; households, urban, rural, a zero carbon business park and a zero carbon energy utility. Each group received a briefing sheet that set the stage for the visioning exercise. The introductory paragraph was identical for all five groups:

> Congratulations! It's 2050 and Ireland has achieved a zero carbon energy system with no fossil fuels. In fact the world as a whole has managed to limit climate change to under 2° degrees Celsius and Ireland was a leading light in this. Ireland's success in transition is known globally for achieving its energy transformation not only through a just transition but also enhancing wellbeing while respecting planetary boundaries and supporting a thriving natural world. Energy deprivation is a thing of the past in Ireland while the industry and entrepreneurial sectors are in good health. Ireland is well respected globally and has many friends across all countries (including the most vulnerable) due to the technical assistance it provides abroad on energy issues and

moreover due to Ireland's commitment to not export environmental problems but rather address them at home and through ethical trade with countries and communities internationally.

The remainder of the briefing sheet contained a vignette that described more specifically the scenario for each group and included prompts to think about; what are the behaviours, institutions, assets, transactions, market structures that will be current in 2050, what will the physical landscape look like? These scenarios and prompts were informed by the four lenses of the 'doughnut unrolled' exploring opportunities rather than just threats (Doughnut Economics Action Lab, 2022). The scenario was deliberately set in the long term and very positively framed to take stakeholders out of their day to day concerns and mindsets and to support creativity. The full vignettes are listed in Appendix 6. To assist discussions at the tables, participants were also provided with figure 4, the energy donut, as a reminder of the social and economic objectives and the environmental constraints and objectives faced by the energy system.

The following paragraphs describe the feedback from stakeholders in the respective breakout groups on the future energy system for their area.

Households in 2050

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

Rural areas in 2050

The 2050 vision for rural areas emphasises the importance of agriculture and food production and of social as well as economic benefits. These benefits were important to build community support the energy transition. There is a mosaic landscape with energy visible but agriculture still dominates, while space for biodiversity is also visible. The rural community benefits from a range of renewable energies including anaerobic digestion, onshore wind and solar. Solar is mainly on domestic and farm buildings as well as integrated with sheep grazing, with only some land dedicated solely to solar farms. Anaerobic digestion, with inputs supplied by farmers and local households, delivers a range of local economic opportunities e.g. energy, refined fuels, novel proteins and fertiliser. There is a mix of large and small AD plants, in a hub and spoke model, with some transport of materials across local areas replacing historic transport of fossil fuels. There is more sustainable mobility in rural areas, with more active travel and sustainably fueled/powered tractors and vehicles. Rural areas have more resilient infrastructure and they benefit from the energy infrastructure they host. Local benefits of the energy transition include energy self-sufficiency, export to grid, ownership opportunity, and district heating for villages.

Urban areas in 2050

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

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

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

Good planning has delivered a street scape that is child friendly, with biodiverse green space, that reduces travel demand, including through work from home policies, and supports the safety, convenience and comfort of sustainable travel. Infrastructure also incorporates biodiverse greenery. Roadside energy stations or parks act as charging hubs and sustainable fuel suppliers.[2] Public transport is electrified. Health is supported through cleaner urban air, the elimination of mould in buildings, green space and more walking and cycling.

Business parks in 2050

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

2 Author's note: these could usefully be seen as integrated with mobility hubs planned under the sustainable mobility plan.

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

Utilities in 2050

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

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

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

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

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

1st Workshop outcome

The outcomes of the workshop demonstrated there was a large appetite among stakeholders for a vision of what success looks like for the Irish energy transition that goes significantly further than technological change. One participant noted, to much agreement, that 'a successful energy transition requires a highly engaged society that does not exist in this form right now'. Common themes across the five envisioned scenarios, and in later discussion point to areas that need further development for Ireland's energy transition;

- Spatial dimension of energy transition
- New pricing models
- Community engagement
- Education
- Renewables back up
- Finance
- Planning

Finally, in a room of some 40 stakeholders from across the energy system, encompassing youth, energy users, vulnerable groups, utilities, developers, environmental NGOs, the over-riding sentiment was that there was no adequate plan for the whole energy transition.

3.2 Second Participative Systems Workshop

The second workshop held on April 8th, 2025, looked at the Understand and Redesign parts of the OECD systems framework (OECD, 2025a). The affiliations of the participants are listed in Annex 5. This workshop employed causal loop diagrams and the energy donut as part of the participant exercises. Participants were split into breakout groups for each of four technologies; variable renewable electricity, heat pumps, zero carbon fuels and district heating. Participants were invited to consider, discuss and offer feedback on the causal loop diagrams. They were subsequently invited to note ideas for interventions in the energy system to accelerate deployment of the respective technology and then discuss them in the group. An afternoon exercise invited participants to further elaborate and discuss a shortlist of ideas from the morning session. For this exercise, participants joined one of three breakout groups on variable renewable electricity, zero carbon fuels or heat. Participants were invited to think through the impacts of the suggested interventions based on the dimensions of the energy donut (figure 4).

2nd Workshop Outcome

The main outcome from the morning session of the workshop was based on causal loop diagrams. These outcomes are captured in chapter 4 Causal Loop Diagrams. Later in the morning, stakeholders were asked to individually write out their own policy suggestions and then to discuss and prioritise the collection of ideas in their breakout group. A shortlist of policies were discussed in the afternoon with some overlap between the breakout groups. The following policies or interventions were prioritised by participants for further consideration in the afternoon: coordinated planning; a plan for the energy transition; a citizens assembly on energy; local benefits to build support; planning; an integrated biorefinery/bioeconomy approach for anaerobic digestion; providing a domestic supply chain for fertiliser; and cross-energy stakeholder engagement with government on the transition. The following describes key points from the afternoon work.

Participants considered that a high level strategic plan was required for the energy transition that would cover electricity, transport and heat. The plan would need a vision to justify why it was worth pursuing. It should talk about benefits but in less abstract terms. The plan should take existing targets as given and offer more. It would need milestones and decision points to allow course adjustment if/when required. The plan should work alongside the National Development Plan and the National Planning Framework and should be very connected to industrial policy. Spatial planning with respect to settlements, population density, local connectivity will be critical elements in the plans with respect to where grids are situated, how transport is planned, where district heating or heat pumps are prioritised respectively and achievement of strategic co-location. The plan should address the economics and finance of transition and cover security of supply/resilience, affordability and competitiveness. The plan should not avoid the difficult choices but evolve or learn in response to experience or new realities. The plan should be informed by cross sector stakeholder engagement and public engagement, perhaps even a citizens assembly.

Participants felt that more was required on public engagement, including with communities. Some suggested that current engagement by government was focused on climate and tended to reach activists more than the broader population. Some suggested a citizens' assembly on the energy transition. Many thought that the real value of public participation would be to socialise a tangible vision and the benefits of transition.

Participants felt that more work was needed on local benefits to build support for the energy transition. It was noted that 'end of the wire' benefits are relatively easy to explain e.g. new jobs, bioeconomy, with security/resilience now a big selling point after Éowyn etc. However wire corridors tended not to see such benefits. Community benefit funds currently in place for windfarms should be evolved and extended to other energy infrastructure development. Some noted that provision of visible or tangible assets (such as domestic heat pumps or batteries) as benefits can offer more enduring public support than money off utility bills which can quickly fade in prominence. It was generally agreed that community funds should deliver communal infrastructure that all can benefit from and avoid supporting initiatives that only reach part of the community.

Planning and permitting were considered a priority. The Planning and Development Act (2024) was considered to offer some improvement (Government of Ireland, 2024). Some suggested that provision of official regional assessments for Environmental Impact Assessment and Appropriate Assessments could reduce the burden for individual planning applicants, meaning they would only have to cover local particulars of their case. There was a suggestion to look at emergency powers. Full transposition of the EU Renewable Energy Directive (RED III) was considered a priority by some (European Union, 2023).

Final discussion by participants emphasised again a key concern they had that 'the idea of having a master plan is absent'. There was further discussion on what is meant by a plan and it was concluded that energy needed a strategic plan or strategic vision that could offer sufficient confidence for the huge capital investments required to take place for the energy transition.

3.3 Energy Demand Management Roundtable

To move beyond the technological focus of the second Energy Systems workshop held in April 2025, NESC convened an Energy Demand Management Roundtable, held across two dates in May 2025 to consider energy demand management's role in the energy transition. The affiliations of attendees are included in Appendix 5. The format of the meeting was a series of open questions to participants to tease out fundamental understandings of energy demand management and its role (or not) in the energy system. A scene setter was provided by SEAI based on the National Energy Projections 2024 (Sustainable Energy Authority Ireland, 2024). SEAI outlined how growth in energy demand will mean technology change alone would no longer be sufficient for Ireland to meet its legislated 2030 energy and climate targets.

There were varied opinions on energy demand around the table, most notably in respect of whether the energy transition would ultimately lead to future abundance in zero carbon energy. However all participants agreed that at least in the short term and during the transition phase, zero carbon energy is not abundant. The question then arises, what is the best use of our limited energy resources (grid capacity, renewables, security, carbon budget allocation) during the transition phase?

Some participants pointed to a distinction between good energy (renewables) and bad energy (fossil fuels), between necessary energy use and frivolous or wasteful energy use, between well timed and poorly timed and finally between well or poorly located energy demand and supply. There was no consensus on the ability to define what might constitute frivolous energy use. Some at the roundtable noted that it could be inappropriate for government to make cultural or social judgements about what was important or unimportant energy use. However, there was agreement that good energy (renewables), necessary energy use and well timed energy use should be encouraged and/or supported, while bad energy (fossil fuels), wasteful energy use and poorly timed energy use should be discouraged. Appropriate location of energy connections to grids should also be encouraged. There was a sense from participants that the mechanisms and incentives to achieve this do not exist in the current system.

Pricing structures and the functional transparency of energy use needs to improve. One stakeholder noted that 'people in general don't make many conscious decisions about energy use'. Smart systems and automation can facilitate appropriate responses and behaviour by consumers. Regulations or peak charging could each play a role in reducing energy use at the worst times. However it is clear that at the same time, vulnerable consumers need to be protected.

Participants heard about the SEAI National Energy Projections indicating that existing and projected energy efficiency gains to 2030 will be balanced by increases in energy demand due to macroeconomic growth, transport energy growth and the addition of large new energy users to the Irish system, leading to an overall increase in final energy consumed by 2030 (Sustainable Energy Authority Ireland, 2024). One participant noted research by Daly (2024) finding that between 2017 and 2023, all additional wind energy generation in Ireland was absorbed by data centres (H. Daly, 2024). Some roundtable participants pointed to the risk of carbon leakage if large energy users were to locate in other jurisdictions that do not have robust plans for zero carbon emissions. Participants at the roundtable noted that not all energy use is appropriately priced and that data use spikes globally can increase energy consumption.

While the 'value' of some energy uses remained open to debate, roundtable participants agreed that it remains true today that a considerable quantity of energy is wasted. Addressing wasted energy should be the first priority of energy demand management. Many of the least efficient homes are using high emissions fuels such as solid fuels, peat or coal, which are very carbon intensive and also bad for indoor and outdoor air quality. Oil burning homes, concentrated in small towns and rural areas would be the next most carbon intensive on a like for like basis. Participants suggested that supports should be targeted first at both the most inefficient carbon intensive homes and the homes of the most vulnerable to achieve most benefits for public money. It was also noted that compact growth and sustainable mobility are further measures that can deliver significant energy demand reductions in transport.

Participants also discussed demand flexibility and response as another aspect of energy demand management. Demand flexibility and response encourages the shifting of energy demand from times of low renewable energy and/or peak demand to times of high renewable production and/or low demand. The CRU National Energy Demand Strategy was briefly discussed (C.R.U., 2024). The strategy focuses on: smart services and dynamic tariffs to deliver flexibility from domestic and smaller business customers; increasing the potential for demand response from larger users and storage installations by providing efficient market signals and mechanisms; and on requirements for flexibility from new large energy user connections.

Participants generally agreed that in the context of technological change being insufficient to meet targets for energy transition (in respect of legislated carbon budgets or EU targets for renewable energy and energy efficiency), there is a tension between economic policy and climate policy that needs to be publically acknowledged and addressed. A roundtable participant suggested that energy demand growth is not driven so much by industry as by consumption trends, noting that there is a 'tension between consumption and climate action and where industrial policy drives consumption, how much of that is value?'.

The question of large energy users was not resolved at the roundtable, however it was noted that such policy questions should not be left to individual decisions on planning permission or be left solely in the hands of the regulator. Government should take its leading role. It was also raised that grid operators lack the legal basis to make more nuanced decisions on connections that could otherwise respond to local network conditions, sectoral emission ceilings, and arising interdependencies between gas and electricity grid connections particularly where there are commitments for demand flexibility and sustainability from large energy users.

Finally the roundtable participants emphasised the urgent need for progress. It was generally felt that Government needs to try many things, to innovate and be prepared to make mistakes, learning in pursuit of the transition. A moonshot project or 'investment in the big opportunities' was discussed as being required to catalyse an accelerated transition and public support for the transition. Large government investment in offshore wind or district heating was discussed. It was noted that district heating could deliver direct social benefits.

3.4 Participative Approaches Outcomes

Across all the stakeholder engagement, there is a sense that when difficult choices need to be made, they are not made, leaving developers, industry stakeholders and the public uncertain about how to proceed or whether to invest. These choices can relate to defining the roles of different technologies that seem to be competing, clarifying the role of distributed and community solutions versus centralised solutions, growing energy demand while risking legislated targets. The fog in the electricity system transition identified by NESC extends across the whole energy transition (National Economic and Social Council, 2025c). Nevertheless, stakeholders can see a way forward if the Government would light the way. Tough choices made, would clear the route for exploiting synergies across the energy system and allow the development of robust business models for essential technologies currently falling behind. More clarity would also facilitate early planning on how to protect vulnerable households during the transition and in the future.

When we drill down into how energy transition will be achieved, spatial planning comes out as a key component of the energy transition both in terms of its 'development control and permitting' function as well as its 'forward planning' or place-making function. Stakeholders were not convinced the sector had sufficient tools to achieve strategic location of demand and supply. Opportunities for cooperation and shared learnings with Northern Ireland were noted, as well as areas where coordination is crucial.

Finally, public support for the energy transition and how to achieve it was a key theme. It was seen that people generally had little awareness of energy in their life until something goes wrong and that this means support for necessary infrastructure and changes is hard to achieve. A positive and tangible vision to help the public understand the changes they can expect in their lives and benefits to be achieved through the transition was seen as important. Increasing the public's understanding through better communication and engagement was seen as important. This could be enabled by energy education in schools, and making better use of available and usable data. Familiarity and support could be built through demonstration projects, community initiatives, and deployment of micro-generation and micro energy storage.

Chapter 4: Causal Loop Diagrams

A key aim of systems analysis is to understand how the various parts of a system respond to change in any individual part. Sharpe et al (2025) states that:

> Navigating the transition successfully requires an awareness of its dynamics. Change is often non-linear; cause and effect are disproportionate; system interactions can be complex and unpredictable. As a result, interventions can achieve much more or much less, than their intended outcomes. These dynamics can be understood in terms of feedback loops. (Sharpe *et al.*, 2025, p. 4)

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

We developed causal loop diagrams through consideration of the literature and insights from early stakeholder engagement. We then explored the causal loop diagrams with stakeholders and experts at two workshops in November 2024 and April 2025 (as outlined in sections 3.1 and 3.2). Feedback received at these workshops was incorporated into the causal loop diagrams discussed in the sections below. **Note:** Figures 5-27 are credited to O'Reilly, 2026. Figures 28-34 are credited to Gursan et al, 2024 and O'Reilly, 2026.

4.1 Introduction to Causal Loop Diagrams

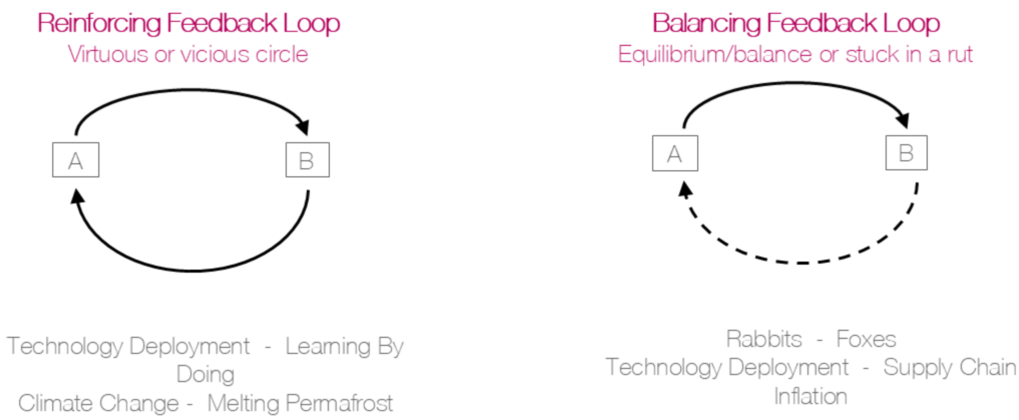
Causal loop diagrams (CLDs) start from a problem statement or research question: what are the drivers of X, where X is a variable that can increase or decrease. This 'main variable' of the CLD could be deployment of a technology (as we explore below), it could be hospital waiting lists, obesity or college graduates. Building the CLD then involves gathering the other variables impacting the main variable and defining the relationship between the two. The CLD also then looks at the drivers of drivers, and their relationships. It also gathers impacts of variables in a similar way. These can all be gathered from literature, data analysis and/or stakeholder consultation.

The CLD represents two types of relationship between variables; a relationship where variables move in the same direction i.e. where one increases the other increases and vice versa; and a relationship where if one variable increases, the other variable decreases and vice versa (*System Mapping Academy Welcome*, 2025). We employ the notation of a solid line arrow where variables move in the same direction, with the direction of the arrow denoting the direction of causation. A broken line arrow denotes a relationship where the variables move in the opposite direction as illustrated in figure 5.

Figure 5: Causal Loop Diagrams Representing Relationships between Variables

When many causal relationships have been mapped out, we often discover some feedback loops where a change in one variable leads to a chain of impacts that return to impact that first variable. Feedback loops come in two categories: reinforcing feedback loops and balancing feedback loops represented in figure 6.

Figure 6: Causal Loop Diagrams: Feedback Loops



A reinforcing feedback loop is a sequence of causal effects that reinforces an initial development. A balancing feedback loop is a sequence of causal effects that drive the system behaviour towards a steady state, a goal or a limiting condition. These feedback loops can involve many variables. Feedback loops or causal chains are a key feature of complex systems and are strong drivers of outcomes. They have a big role in determining how successful interventions in a system are at achieving desired outcomes.

The causal loop diagrams in the following section have been informed by literature, stakeholder consultation and participative workshops with stakeholders held in November 2024 and April 2025. They do not represent fixed realities. In fact, it is often the case, that to achieve different outcomes we should explore how we can change the fundamental relationships or rules of the system which could mean changing an arrow, removing or inserting a new arrow. Therefore the following diagrams represent a starting point for further consideration dynamic drivers in technology deployment in Ireland and how to accelerate the energy transition.

Using Causal Loop Diagrams

At the second participative systems workshop held in April 2025, after taking note of suggestions on improvements to the CLDs, participants were invited to consider where interventions might take place in the energy system, with reference to the CLD in front of them. Potentially influential variables were identified by exploring which variables had a greater number of causal connections (outward arrows) to other areas. Areas that are difficult for government to change or that only change very slowly, were marked as 'frozen' areas (e.g. areas governed by EU law). Areas with potential for change were identified mostly where government had capacity to impact the influential variables directly or indirectly.

4.2 Variable Renewable Electricity Deployment

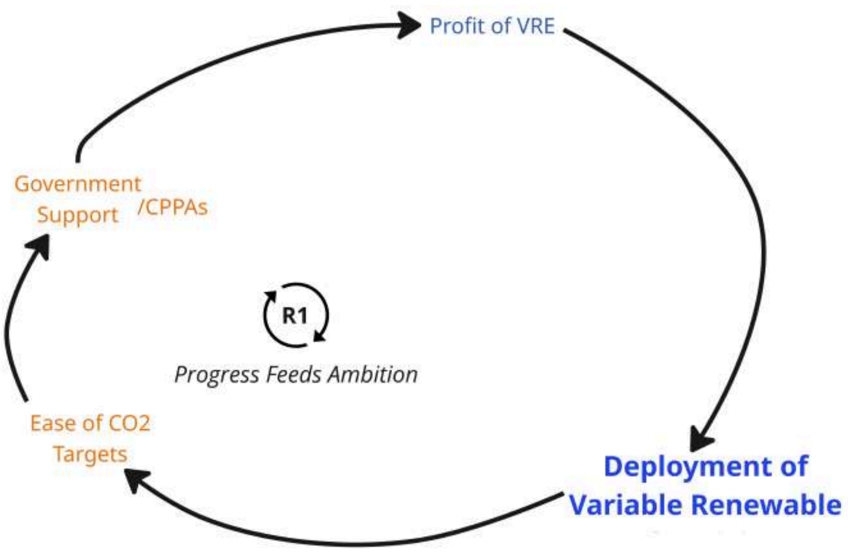
The development of causal loop diagrams and their respective feedback loops for variable renewable electricity (VRE) has drawn on stakeholder consultation with industry experts, direct input and feedback from stakeholders at participative workshops, and also draws on a seed diagram from (Kopainsky, 2024a) based on (de Gooyert *et al.*, 2016). A more detailed causal loop diagram for the deployment of VRE is contained in Annex 1. It describes the main drivers of and constraints on deployment of variable renewable electricity. The diagram illustrates how any intervention in the electricity system is likely to have a variety of knock on impacts elsewhere the system.

We focus here on six feedback loops, four of which were balancing feedback loops, pointing to a need to unlock constraints to allow cascading impacts and acceleration of deployment to occur. In this section we explore the feedback loops in a more simplified form based on materials prepared for the April 2025 NESC Energy Systems Workshop by Aidan Sliwkowski in 2025.

Progress Feeds Ambition

This reinforcing feedback loop describes how increased deployment of variable renewables leads to greater ease in meeting greenhouse gas emission reduction targets, leading to greater levels of ambition which acts to further deployment. Figure 7 illustrates the dynamic. An increase in deployment of variable renewable electricity (VRE) leads to greater ease in meeting CO2 reduction targets. This leads on the one hand to more government support or ambition, which leads to an increase or improvement (in certainty/duration/conditions) in government subsidies. This supports improved expectations for revenue streams of VRE which acts to increase profits which supports more deployment of VRE. The greater ease of meeting CO2 reduction targets, also leads to more Corporate Power Purchase Agreements (CPPAs) which is another avenue of improving expected revenue streams for VRE, supporting an increase in the deployment of VRE.

Figure 7: Variable Renewable Energy Feedback Loop: Progress Feeds Ambition



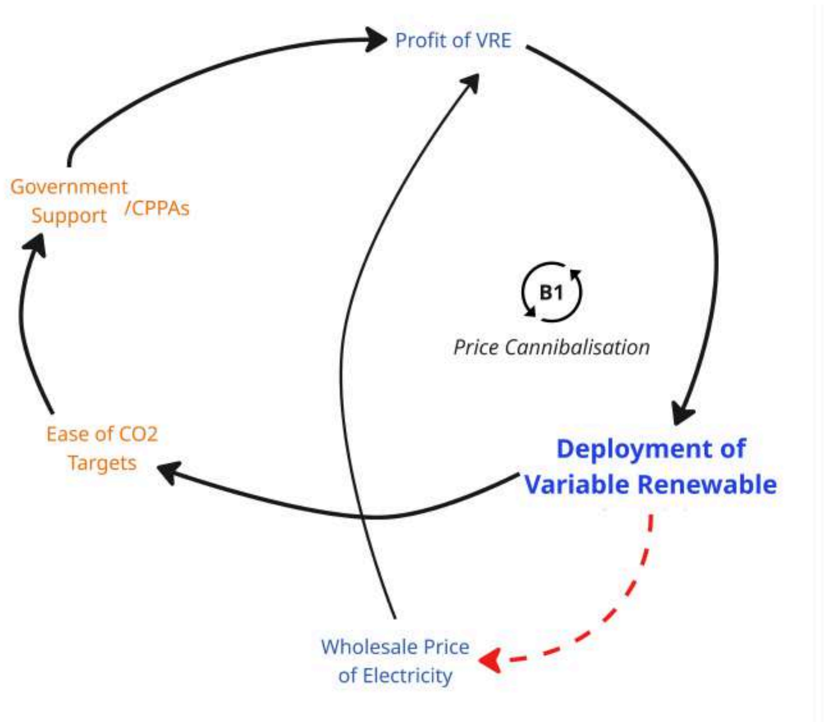
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Interventions: This is a desirable feedback loop. It's effect can be accelerated by an enabling environment for CPPAs and by improving government support and subsidies. This doesn't have to mean increased subsidies per unit. Action to simplify procedures and improve certainty, as appropriate, can also help to increase profitability of VRE deployment. Overall we can see that this dynamic is already in effect, with high government and corporate ambition for renewable electricity however it is being counteracted by other constraining dynamics. In this situation it will be most effective to try to address other constraining dynamics.

Price Cannibalisation

In the absence of government subsidies (RESS/ORESS) for VRE, or long duration corporate power purchase agreements, increased deployment of variable renewables leads to price cannibalisation balancing feedback loop. As the deployment of VRE increases, the *wholesale price of electricity* decreases. This is due to greater quantities of renewable electricity being supplied to the grid (at times of high wind and solar output) whether demand is there or not because the variable or operational costs of renewable electricity production are so low. Thus, high levels of VRE deployment means an increase in the occasions when the supply of renewable electricity exceed the demand, leading to wholesale prices near zero or curtailment of production (Wade *et al.*, 2024). Failing other sources of income, this would lead to a decrease in *revenue* for the VRE and therefore reduced deployment. This is illustrated in figure 8.

Figure 8: Variable Renewable Energy Feedback Loop: Price Cannibalisation



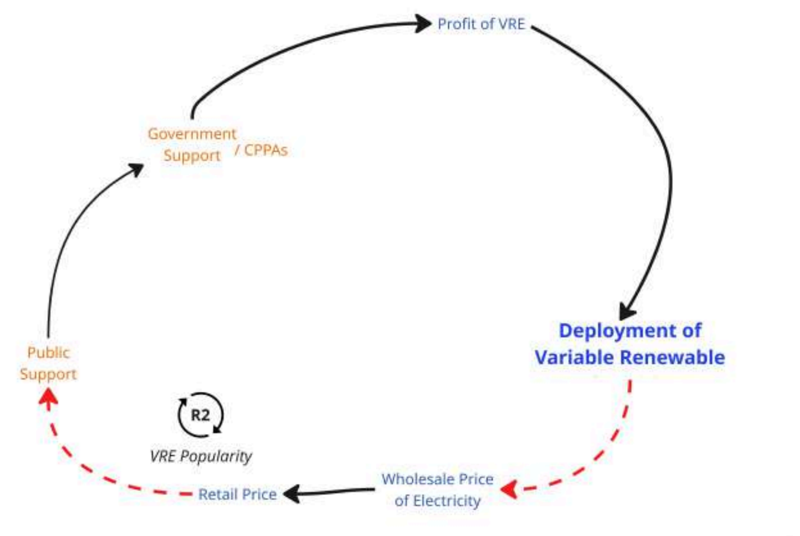
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Interventions: With our aims to increase VRE deployment, this is an undesired dynamic. It is mitigated by existing government supports and the regular holding of RESS and ORESS auctions. However, it does suggest long term lock in to renewables support. Every country transitioning to an electricity system based on variable renewables will eventually encounter this problem. It is possible to at least partially disrupt this dynamic if electricity demand responds to availability of renewables. This can be achieved through energy storage technologies like batteries or through behavioural change by shifting the timing of energy intensive activities. Demand response dynamics are discussed further below. Exploring alternative market incentive structures could fundamentally disrupt this dynamic but an effective design is not yet obvious. Ireland would need to work with EU partners to develop solutions in this space. Due to the particular characteristics of the Irish case as a relatively small and isolated system, specific Irish research on this topic should also be supported to enable effective participation in EU discussions (Wade *et al.*, 2024).

Renewable Energy Popularity

This effect, represented in fig 9 describes how the dampening effect on price of more renewables in the electricity system can increase public support for renewable energy. Cosmo et al (2016) found that 'overall, wind decreases costs through its effect on the electricity price' (Cosmo *et al.*, 2016). As described in the previous feedback loop, increased deployment of renewables leads to a reduction in the *wholesale price of electricity*. Everything else being equal, this would lead to a reduction in the retail price. The resulting cost savings to consumers act to increase public understanding and support for renewables, which increases government support which supports further increases in VRE deployment. However there are other dynamic effects at play as we will see in the next feedback loop.

Figure 9: Variable Renewable Energy Feedback Loop: Renewable Energy Popularity



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

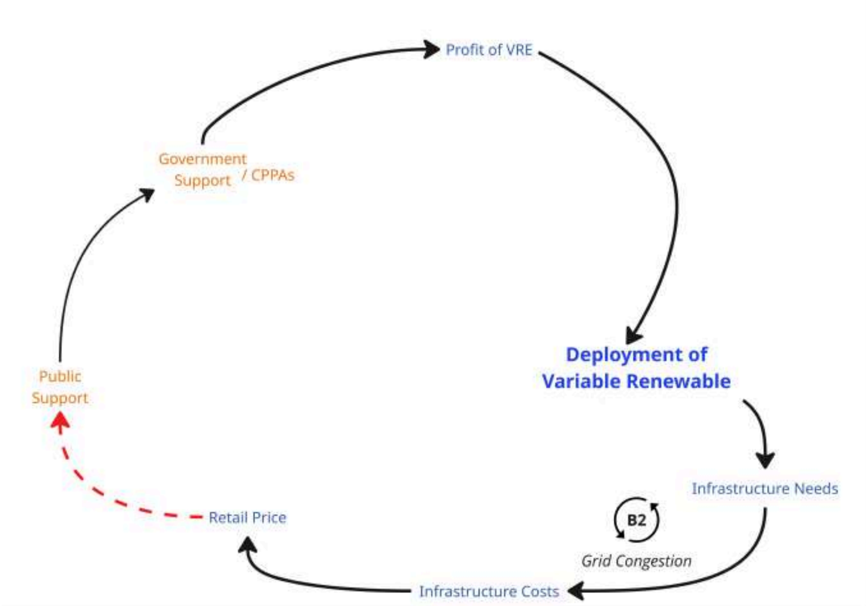
Interventions: This is a desirable dynamic which could be accelerated by greater public awareness of the role renewables play in our current and future energy system. The weakest link in this feedback loop currently is the link of the falling wholesale price to a falling retail price. Other factors can work to increase the retail price which means that the public would not see an immediate material benefit from renewables. Microgeneration and community renewable projects and private wires potentially offer a chance to benefit from lower renewable prices without retail pricing. Such direct interactions with renewables can increase public support for their deployment. It will also be important to limit where possible the impact of other factors in increasing the retail price. The next feedback loop *grid congestion* is particularly relevant in this regard.

Grid Congestion

This balancing feedback loop describes how grid congestion can act as a constraint on deployment. An increase in deployment of VRE leads to an increased need for investment in grid and energy infrastructure. This leads to an increase in grid costs which raises the retail price of electricity. An increased price of electricity (all else being equal) reduces public support for renewable energy deployment. This can make increasing government support for further renewable energy deployment more difficult. The IEA (2023) notes that 'The acceleration of renewable energy deployment calls for modernising distribution grids and establishing new transmission corridors to connect renewable resources – such as solar PV projects in the desert and offshore wind turbines out at sea – **that are far from demand centres** like cities and industrial areas [emphasis added]'(International Energy Agency, 2023, p. 7). DCEE noted in its Electricity & Gas Networks Sector Climate Change Adaptation Plan in 2019 that:

> the Distribution System only needs reinforcement when the loads on it exceed its peak capacity. Increasing the volume of energy through the network has little cost. This means that where peak capacity is to be exceeded there is a choice between adding Network reinforcement or changing when the peak loads are used, so that a choice between whichever is the more economical option can be made.
> (Department of the Environment, Climate and Communications, 2019, p. 20)

Figure 10: Variable Renewable Energy Feedback Loop: Grid Congestion



Note:
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Interventions: Because the electricity grid was designed and built around conventional (synchronous) generation, we cannot avoid all the infrastructure needs arising from renewables (non synchronous) generation deployment. However, there are a number of factors we can control. The quote above from the IEA immediately suggests that one factor driving infrastructure requirements is the distance between sites of renewable generation and centres of energy demand. More strategic spatial planning could reduce this distance through a prioritisation of demand and supply connections and the strategic location of new centres of demand close to the best renewable resources.

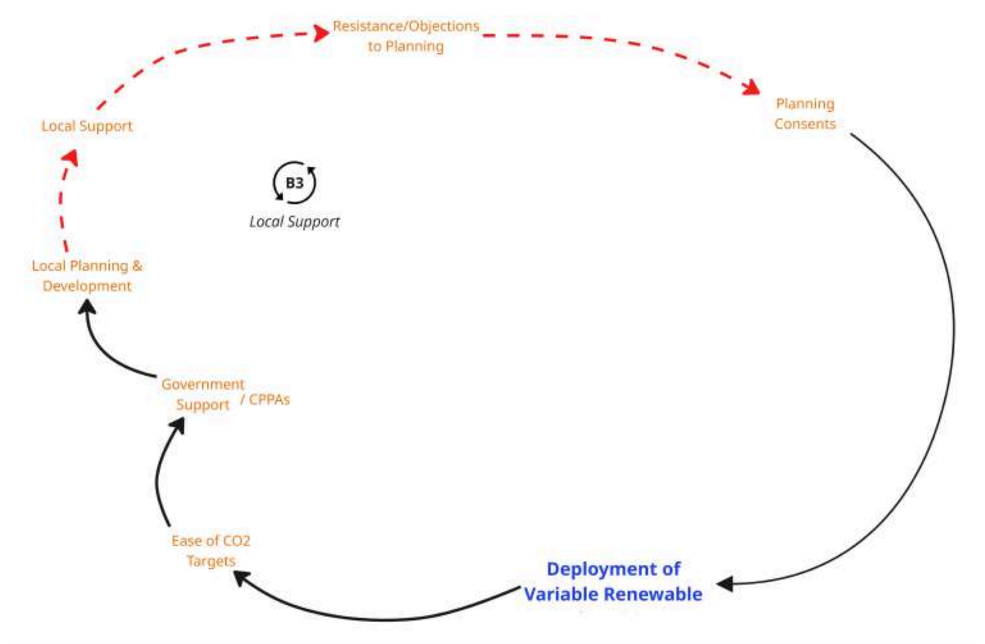
The review of costs following storm Éowyn suggests another area where infrastructure needs could be controlled. The electricity system is already used to a risk management approach, apparent in the system level Loss of Load Expectation (LOLE) target (National Economic and Social Council, 2025c). NESC also identified how homes in Sweden are expected to have capacity to survive 72 hours without network services (NESC, 2025). Storm impacts cannot be completely eliminated. It may be more cost effective to consider a downscaled LOLE or resilience type indicator and target for isolated rural areas and to have some decentralised resilience efforts through deployment of micro batteries and accessible micro-generation to homes, SMEs and community centres that are capable of providing supply in isolation from the grid.

More broadly, demand response across time might also reduce infrastructure needs. Technological innovation employing smart solutions have great potential. Regarding the translation of infrastructure needs to costs that appear in retail bills, innovative thinking on finance should be explored. New sources of finance could be considered, e.g. from the EU or the private sector, or new financial models or instruments could be considered to reduce cost burdens.

Local Support

This balancing feedback loop describes how an increase in VRE deployment leads to an increase in resistance and objections to planning which undermines further deployment in VRE. As discussed for previous feedback loops, an increase in *deployment of VRE*, increases the *ease of CO2 targets*, which acts to increased *government support*. This leads developers to submit more *local planning and development applications*. Hallan and Gonzales (2020) found that accumulating landscape changes worried all stakeholder groups in their study (Hallan and González, 2020). For a given local area, an increase in planning applications reduces the *local certainty* about the final outcome for their area, e.g. in terms of number and placement of the renewables and what the final costs and/or benefits will be overall. This uncertainty can reduce *local support* and ultimately lead to more *resistance and objections to planning*. This acts to reduce or at least delay provision planning *permissions* which leads to a decrease in VRE deployment.

Figure 11: Variable Renewable Electricity Feedback Loop: Local Support



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

NESC found that support is strong for renewable energy, retrofitting and clean energy systems. A KPMG (2025) survey of a representative sample of more than 1000 people in Ireland, found 78 per cent and 72 per cent support for offshore and onshore wind respectively (KPMG, 2025).[3] However, Bell *et al.*, (2013) found a body of literature identifying a 'social gap' between general support for renewables and support for a particular renewables development which can be driven by different concerns such as altruistic feelings of place protection and place based attachment with the evidence also suggesting that self-interested nimybism plays only a minor role (Bell *et al.*, 2013).

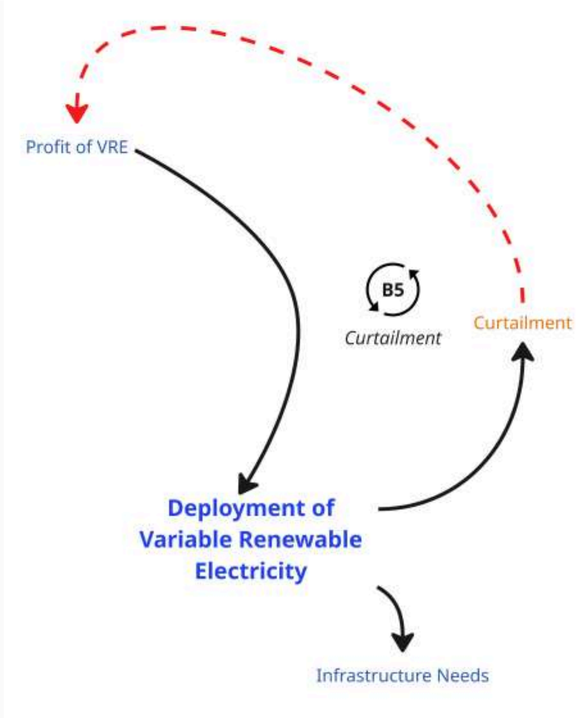
Intervention: The key link in this dynamic is between the increased local applications, local certainty and support. Better public engagement is important but if there is a diversity of projects, the aggregate picture of local development is unclear, which would undermine confidence. A plan led approach to renewable development should support greater local certainty about expected outcomes, with attendant increase in local support. This is potentially the outcome from the revised National Planning Framework regional targets for renewable energy and the accompanying requirement for Regional Renewable Energy Strategy and County Renewable Plans. However this approach needs to be combined with appropriate local consultation.

Another means of building local support is to increase levels of community projects and local or community ownership. Kienbaum et al (2023) found research from several countries demonstrating a positive impact of local or community ownership on attitudes to development (Kienbaum, Farrell and Grimley, 2023).

Curtailment

This feedback loop describes how, everything else being equal, the more variable renewable electricity sources you connect to the grid, the greater the extent of *curtailment* will be. Greater curtailment, reduces the *profit of VRE*, which acts to undermine further *deployment of VRE*. Curtailment is the deliberate 'switching off' of variable renewable electricity generation when supply exceeds demand either on a national basis, or on a local basis where there is insufficient grid capacity to deliver that excess generation to centres of demand. It occurs in time periods of high production but low demand. It can also occur due to the availability of cheaper electricity imports over interconnectors.

Figure 12: Variable Renewable Electricity Feedback Loop: Curtailment



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

Intervention: Enhancing grid capacity to deliver electricity from areas of renewable production to areas of electricity demand would reduce curtailment rates. The North-South interconnector would be one example where there is potential to reduce curtailment rates in the northwest. Demand response to shift demand over time to when more generation is available could act to reduce curtailment. This can be achieved with batteries on the grid or held by consumers, or through behaviour change. NESC previously outlined how EnergyCloud makes use of excess renewable electricity, that would otherwise be curtailed, to provide hot water in disadvantaged homes (NESC, 2025). Batteries co-located with renewables could help renewable operators avoid lost revenue from curtailment, so that they shift supply to the grid to when it is more profitable. Finally, increasing co-location of energy demand with renewable supply could also work to reduce curtailment alongside other measures.

VRE Causal Loops and Potential Interventions

When we add the above feedback loops together, despite the simplification exercise, we already see a very complex system, where single interventions can have many impacts. The more complex diagram from which this was derived is available in Annex 1.

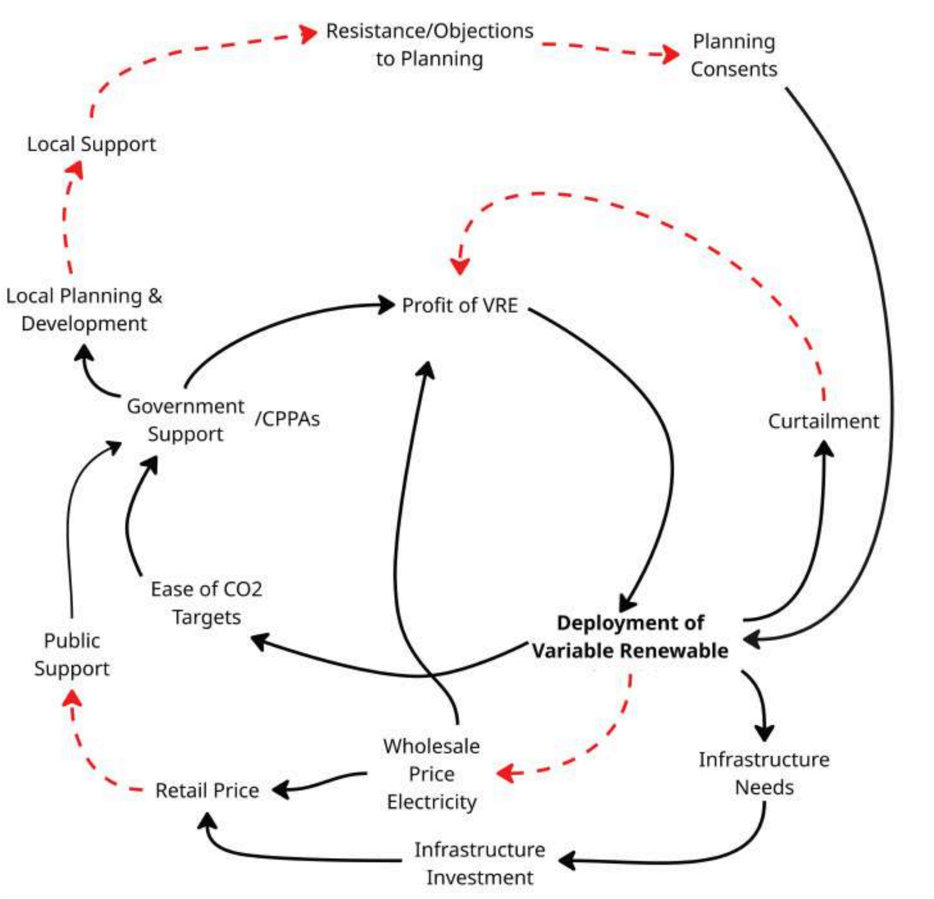
Positive developments have already occurred in recent years. RESS and ORESS schemes have been delivered. Corporate power purchase agreements (CPPAs) have increased in number and complexity in Ireland with Pexapark (2025) noting a 125 per cent increase in deal numbers from 2023-2024, and Ireland entering the top ten European countries by deal count for the first time (Pexapark, 2025). Increased administrative resources have been committed to the planning system. We need to ensure that cascading positive impacts from these developments are not blocked by other drivers.

In the second participative workshop, stakeholders were brought through the causal loop diagram for VRE, identifying the dynamics and barriers. The concept of leverage points in a system was explained (D. Meadows, 1999). Stakeholders were then asked for 'action ideas' to unlock greater progress in deployment in light of the illustrated dynamics at play. The stakeholder suggestions represent further avenues for disrupting negative dynamics and supporting positive dynamics in the deployment of wind and solar renewables.
The action ideas collected can be broadly categorised around spatial planning, finance and investment, pricing and incentives and local or community efforts and are listed in Table 3.

Table 3: Stakeholders' action ideas collected at April 2025 NESC Energy Systems Workshop

Category	Action Ideas
Spatial planning/development management	Simplify planning and consents for renewables and interconnectors, spatial planning for renewables, all-Island spatial energy plan
Finance and Investment	Battery storage fund, risk sharing of investments with government, invest in skills, grid capacity, repairing existing assets
Pricing and incentives	Battery storage incentives, engage EU to factor dispatch down into price coupling, accurately price grid costs in RESS bids, government backed PPAs
Local or community efforts	Use curtailed wind for local benefit, community benefit fund

Figure 13: Variable Renewable Electricity: Simplified System Feedback Map



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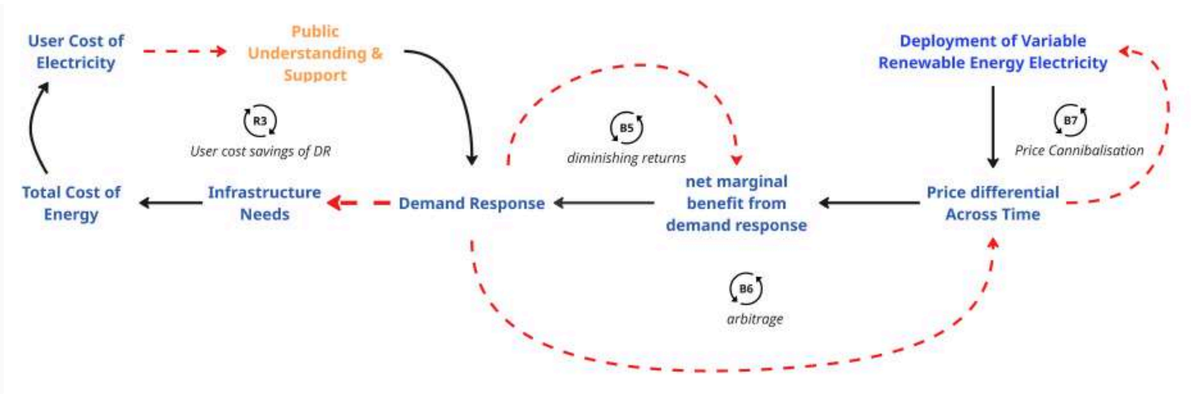
Demand Response Dynamics

An important extension to the map above would be consideration of demand response. Demand response can represent an activity to shift demand over time usually to match renewables availability. In this way, demand response can reduce the effect of the grid congestion feedback loop on overall VRE deployment. We consider demand response in the general sense here to cover e.g. behaviour change or battery/energy storage investment. A reinforcing feedback loop applies where an increase in demand response leads to a decrease in the user's cost of electricity, which leads to which leads to greater public understanding and support for demand response, which leads to more uptake of demand response.

However, a balancing feedback loop of arbitrage also applies. In the current business model or under existing market rules, if the price differential over time (e.g. peak/non peak) of electricity increases, more demand response will be implemented (as the benefits of doing so have increased). However, as demand response increases its effect of shifting demand over time, the price differential of electricity over time will decrease, diminishing the motivation to undertake further demand response efforts. Wade et al (2024) note this impact but suggest that the price differential is unlikely to reach zero (Wade *et al.*, 2024). Nevertheless they also note that there are insufficient signals for demand response in the Irish electricity market, meaning there is likely to be insufficient signal for the required level of investment in energy storage (at micro or grid level) and insufficient signal for behaviour change or temporal shifts in e.g. manufacturing. We can see a similar feedback take place where, as demand response increases, the easy options for shifting electricity consumption are exploited first, so that further demand response becomes more difficult. This means that everything else being equal, further increases in demand response become less likely.

Figure 14: Variable Renewable Electricity Feedback Loops: Demand Response Dynamics



Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
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Box 1: Zero Carbon Demand Response

Demand response has benefits for management of the electricity grid as discussed above, however its environmental benefits are much reduced where demand response is not zero carbon. We discuss above demand response based on behaviour change or use of energy storage like batteries. These do not entail increased greenhouse gas emissions from the energy system and in fact might reduce overall energy system emissions by allowing more efficient operation of the electricity system.

However, if demand response in the electricity sector is delivered by energy switching to more polluting sources, this acts to increase overall emissions in the energy system. For this reason, demand responsive industries are those that can either rely on energy storage or that can stop and start or at least substantially reduce their activity levels for limited periods on request. In future there may be opportunities to offer demand response by switching to zero carbon fuels but this is not available at scale at present.

Variable Renewable Electricity Conclusions

Constraining dynamics in the system can act to hold back deployment of VRE. If we can tackle these constraints, positive feedback loops such as learning by doing can be allowed to accelerate deployment rates. Public understanding and support, infrastructure needs, and local outcome confidence are three influential areas ripe for further exploration.

Infrastructure needs and grid congestion can be driven inter alia by a temporal or spatial mismatch between energy demand and supply and physical quality characteristics of the electricity such as frequency. Demand response can address some of the mismatch between supply and demand but without specific incentive structures in place, its delivery potential is limited. Demand response through fuel switching to higher carbon energy sources should be discouraged, unless it can be demonstrated that it serves to reduce system wide emissions. Spatial mismatch between demand and supply leads to grid bottlenecks and congestion. Addressing this spatial mismatch must be linked with local outcome confidence and local engagement.

4.3 Heat Pump Deployment

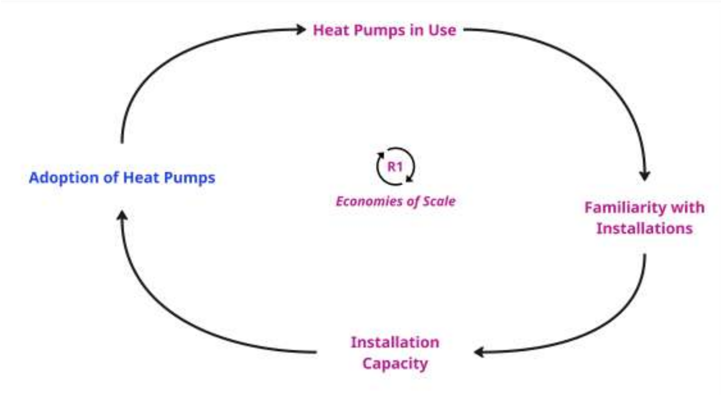
These causal loop diagrams are built on a 'seed structure' developed by Kopainsky (2024) for participative exercises in the NESC Energy Systems workshop held in November 2024 (Kopainsky, 2024a). The seed structure was informed by (Siemer, 2024).

The diagram describes the main drivers of and constraints on deployment of heat pumps. Five feedback loops were identified. Most of these were reinforcing feedback loops, pointing to the potential for well designed interventions to lead to cascading positive impacts.

Economies of Scale

Sharpe et al (2025) describe reinforcing feedbacks of clean technology development and diffusion. Increased adoption of heat pumps, while increasing the number in use, also increases familiarity with installations. This leads to an increase in installation capacity which leads to more adoption of heat pumps. SEAI has seen this where one stop shops for retrofit and heat pump installation now number 24, after beginning with just three in 2022 (Sharpe *et al.*, 2025).

Figure 15: Heat Pump Feedback Loop: Economies of Scale



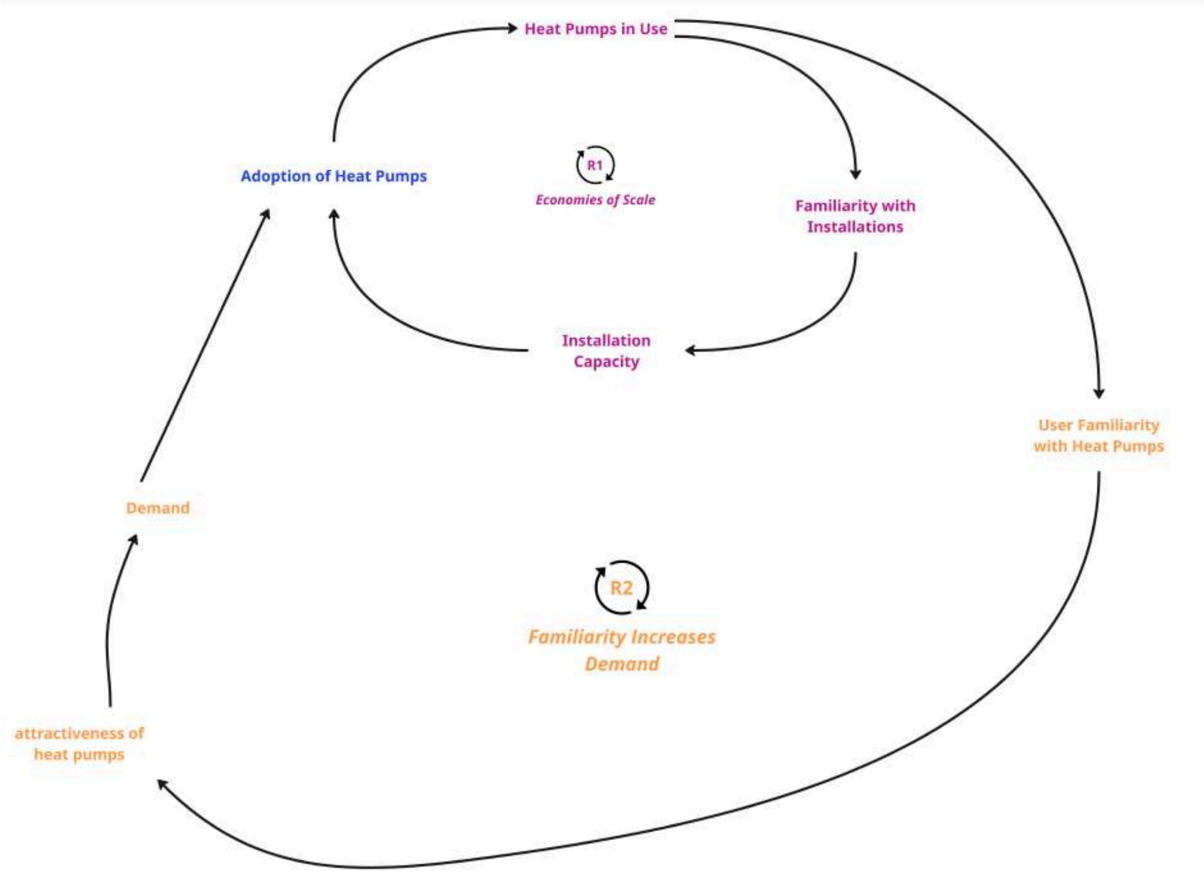
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Intervention: This feedback loop is already in operation. Continued support for heat pumps and training for installers are important interventions here to maintain and accelerate this desired feedback loop.

Familiarity Increases Demand

More heat pumps in use, leads to public familiarity with heat pumps, which increases the attractiveness of heat pumps, increasing demand. This leads to more adoption of heat pumps and therefore more heat pumps in use. Everything else being equal, lack of familiarity with heat pumps creates a knowledge hurdle for people or businesses to cross before potentially making a decision to invest in a heat pump.

Figure 16: Heat Pump Feedback Loop: Familiarity Increases Demand



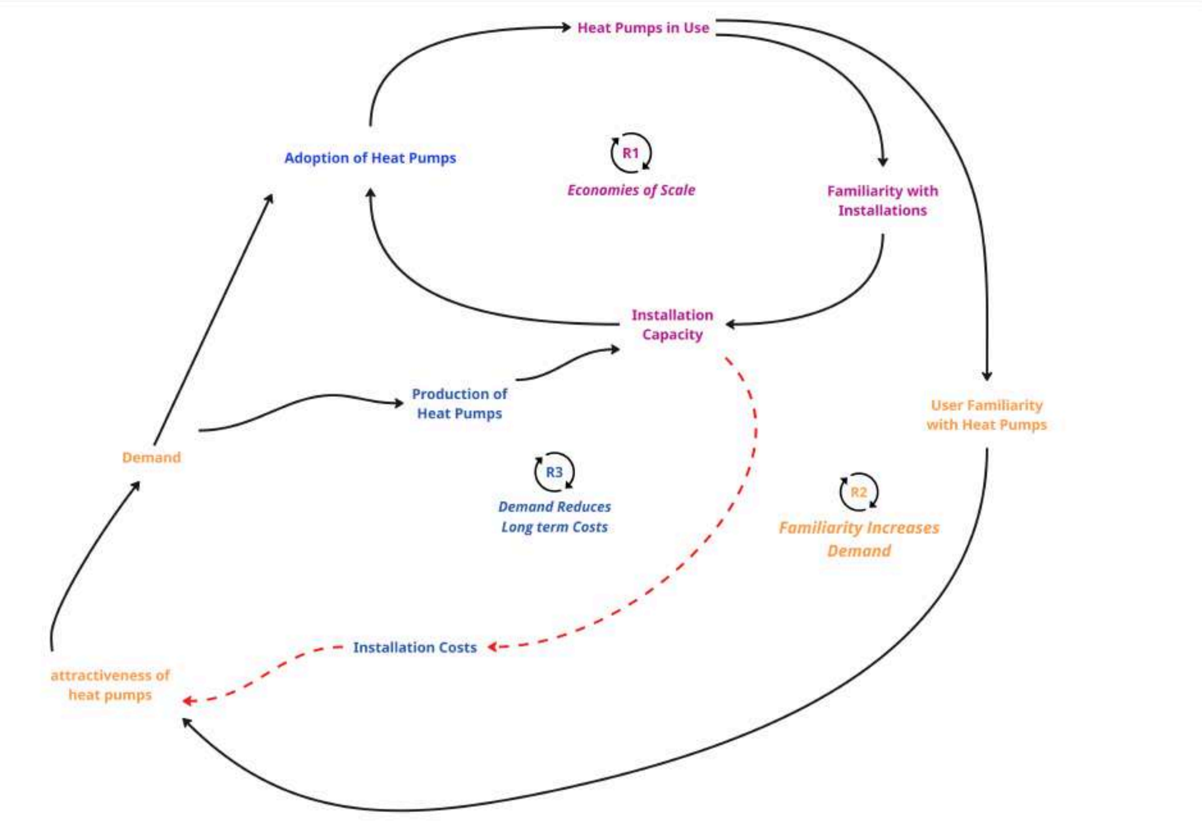
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Intervention: This reinforcing feedback loop is in effect but familiarity with heat pumps is still relatively low. Lack of knowledge on how to operate heat pumps by some existing owners leading to poor performance unfortunately can disrupt this effect. Demonstration houses and buildings, and more advice available for heat pump users on how to appropriately run their heat pump would accelerate this virtuous circle. NESC recommended an action point that 'consideration should be given to increased public engagement around heat pumps and demonstrating them in action (NESC, 2025).'

Demand Reduces Long Term Costs

An increase in *demand* for heat pumps leads, over time, to greater *production of heat pumps* or a scaled up supply chain, which increases *installation capacity* leading to a decrease in upfront costs. This further increases *demand*.

Figure 17: Heat Pump Feedback Loop: Demand Reduces Long Term Costs



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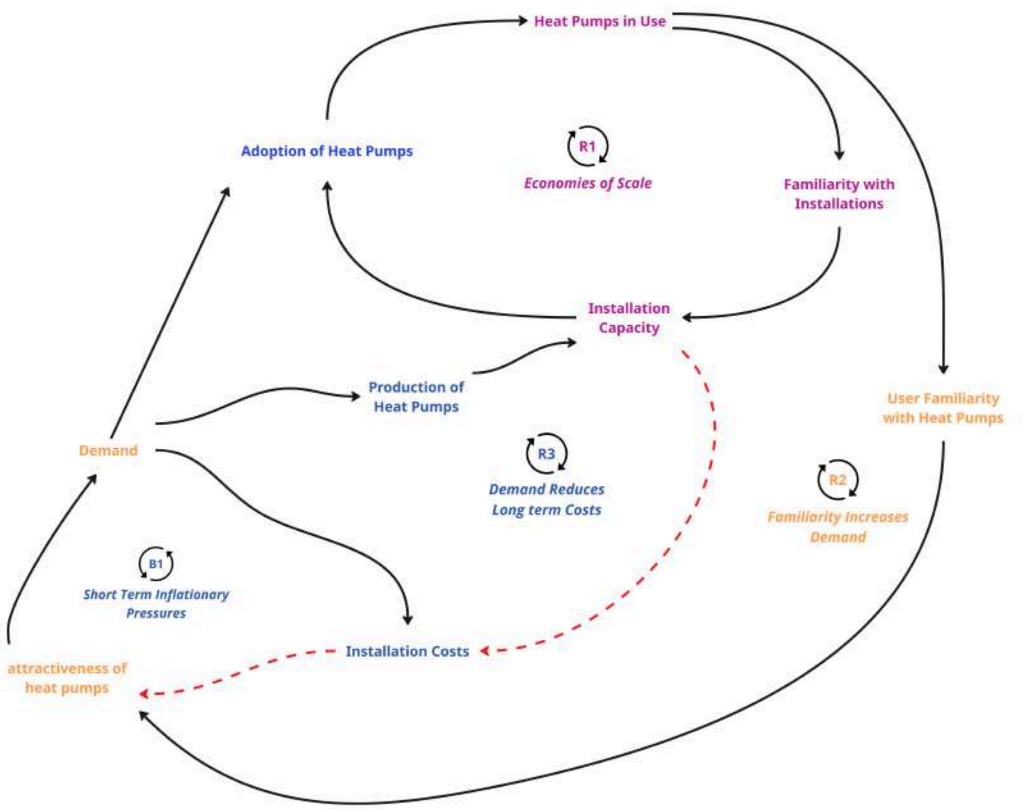
Red dashed arrows: represent relationships where the named variables move in opposite directions, all else being equal.

Short-term Inflationary Pressures

In the short-term if demand exceeds installation capacity, the cost of installation can increase. This increase in cost, reduces the demand for heat pumps.

Figure 18: Heat Pump Feedback Loop: Short Term Inflationary Pressures



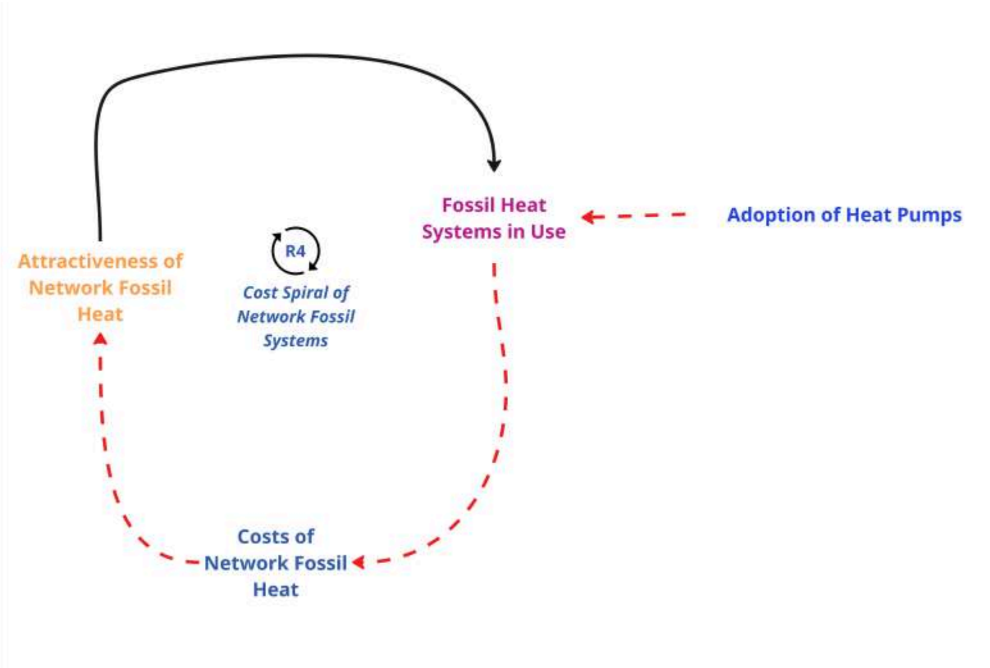
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Intervention: Confidence in continued public support for heat pumps creates the confidence for private investment in the production and supply chain for heat pumps. Continued support for training of trades-people for heat pump installation will also assist greater capacity for installation which acts to reduce inflationary pressures.

Cost Spiral of Network Fossils

The adoption of heat pumps implies a process of 'ex-novation' or movement away from fossil heat systems. These are directly competing technologies and the success of one, impacts the success of the other. Figure 19 illustrates how *adoption of heat pumps* leads to a reduction in *fossil heat systems in use*, including networked gas supply. In the long term, as customers leave a network, the network costs are spread over a smaller based, leading to *costs of network fossil heat* increasing due to increased network costs. This reduces the *attractiveness of the networked fossil heat*, which acts over time to reduce the fossil heat systems in use.

Figure 19: Cost Spiral of Network Fossil Systems



Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
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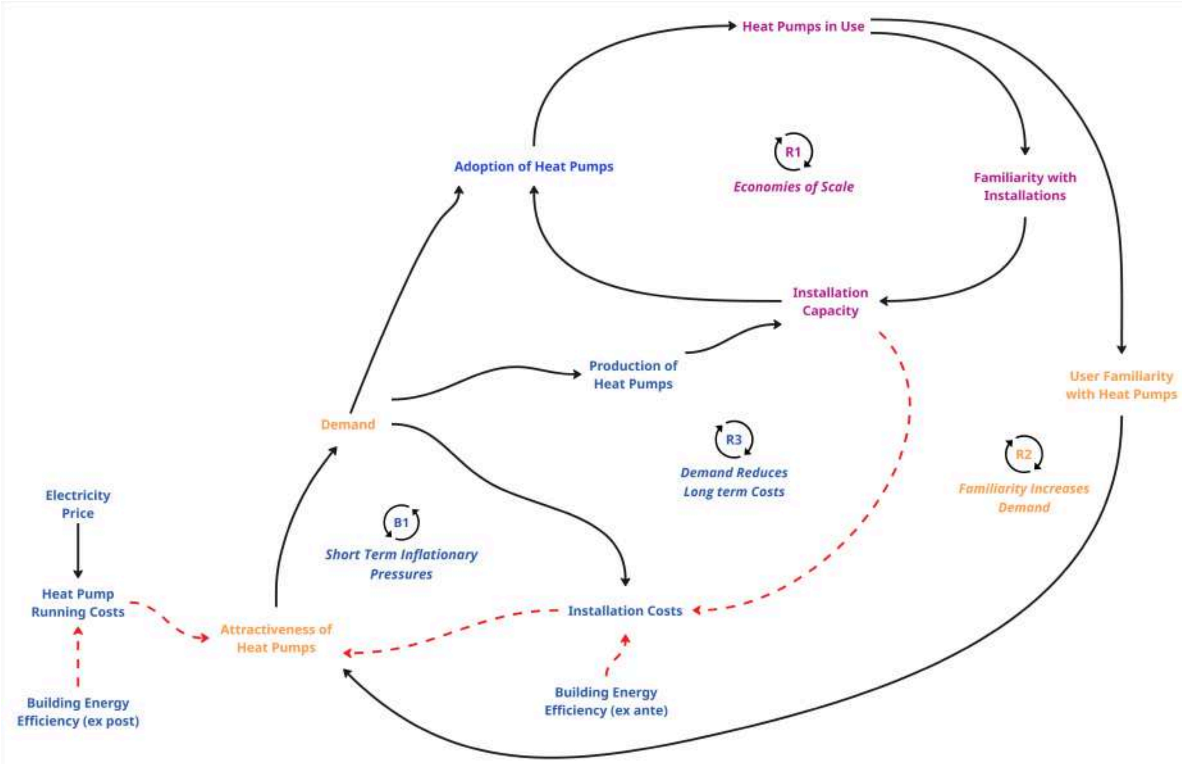
Intervention: This dynamic operates to support the energy transition once it is under way. Increasing connections to the gas grid would cause this dynamic to undermine the energy transition, as increased connections would lead to reduced costs which would increase the attractiveness of fossil heat. Therefore, further connections to the gas network should be considered strategically as to whether they support or undermine the energy transition. The gas grid also needs to be supported to become zero carbon. Finally, it is crucial to ensure that low income households are not caught in a poverty trap where they are unable to switch to a heat pump but face increasing energy network costs as more affluent users leave the network.

Heat Pump Installation and Running Costs

Installation and running costs are important factors influencing the attractiveness of heat pumps. Installation costs are influenced by installation capacity, including the supply of heat pumps. In the space heating context it is also particularly influenced by the building energy efficiency before installation/retrofit of the property as many buildings require an energy efficiency retrofit before a heat pump is a feasible option and also to meet criteria for heat pump grants. However the building energy efficiency after installation is very influential on the operational or running costs of the heat pump which is influential in its attractiveness for adoption. Electricity prices are another key feature in determining operational costs of a heat pump and its attractiveness for adoption. Appropriate use and settings are important to efficiency and running costs. Finally, the comparative price of fossil fuels are also influential on the attractiveness of heat pumps. At a global level, a constraining feedback loop applies whereby as more end uses are electrified, global demand for fossil fuels weakens and the price falls. This acts to reduce the attractiveness of electrification options.

Figure 20: Heat Pump Drivers of Attractiveness



Note:
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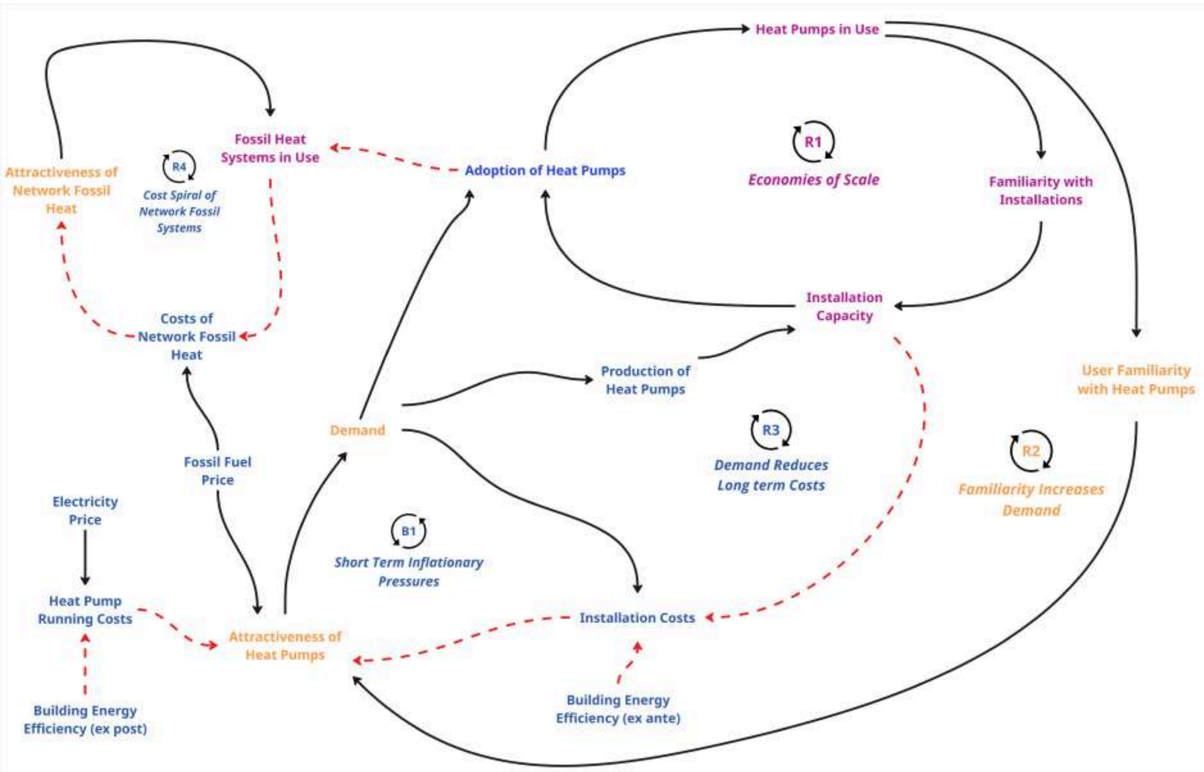
Intervention: The price of electricity is an important determinant of operational costs for all heat pump applications. Therefore high or volatile electricity prices can undermine efforts to electrify. Carbon taxes improve the comparative cost levels of electric heat pump versus fossil fuel options regardless of international market movements. Appropriate installation and advice on efficient operation are crucial to support the attractiveness of heat pumps. Support for building fabric retrofit is important but for some older buildings, particularly in urban areas, other solutions like district heating may be more economic.

Heat Pump Causal Loops and Potential Interventions

Figure 21 presents the feedback loops and drivers altogether. It is useful to note that this diagram would link with the previous causal loop diagram on variable renewable electricity whose activities influence the price of electricity.

Annex 4 includes the more detailed Causal Loop Diagram for heat pump deployment, developed at the first Energy Systems workshop in November 2024 with stakeholder input that shows more drivers of different variables in the feedback loops. The stakeholder diagram found influence in the stringency of heat pump readiness assessment (which drove costs of installation) and trusted advisors as driving familiarity and efficient operation of the heat pump. Positive change is already occurring in installation capacity and familiarity (SEAI, 2025).

Figure 21: Simplified Heat Pump Feedback Map



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

In the second participative workshop, stakeholders were brought through the causal loop diagram for VRE, identifying the dynamics and barriers. The concept of leverage points in a system was explained (D. Meadows, 1999). They were then asked for action ideas to unlock greater progress in deployment in light of the illustrated dynamics at play. The stakeholder suggestions represent further avenues for disrupting negative dynamics and supporting positive dynamics in the deployment of wind and solar renewables. The action ideas collected are represented in Table 4. These were not necessarily all discussed by workshop participants and therefore represent individual contributions. The stakeholder suggestions represent further avenues for supporting and accelerating beneficial dynamics in the deployment of heat pumps.

Table 4: Stakeholder action ideas on heat pumps from NESC Energy Systems Workshop April 2025

Category	Action Ideas
Spatial planning & development management	Map future energy plans for local areas
Finance and Investment	Training and incentives for installers and trusted advisors
Pricing and incentives	Means tested subsidies
Public engagement, local or community efforts	A network of community energy advisors; dedicated energy advice service for landlords; advertising at the end of energy bills; a communication campaign
Policy Development	Heat pump/district heating planning integrated with GNI planning for pipeline decommissioning or extensions

Some stakeholders and energy experts at a roundtable on energy demand management suggested that air source heat pumps should be prioritised for rural homes, while retrofits of the worst performing homes should be subsidised at a much higher rate than other homes or even paid for outright especially where coal and peat are still in use.

Heat Pump Conclusions

Deployment of heat pumps has increased but not yet fast enough to meet Government targets. Upfront costs and running costs are key concerns for potential users, as described by (NESC, 2025). Heat pumps are still competing with existing fossil fuel heating systems and their benefits need to be made obvious to potential users. Trusted intermediaries can help explain the benefits. Further work to address upfront costs will be important whether through grants for retrofit or installation or through financial access measures will be important. It will also be important to demonstrate reliably low or at least competitive running costs into the future.

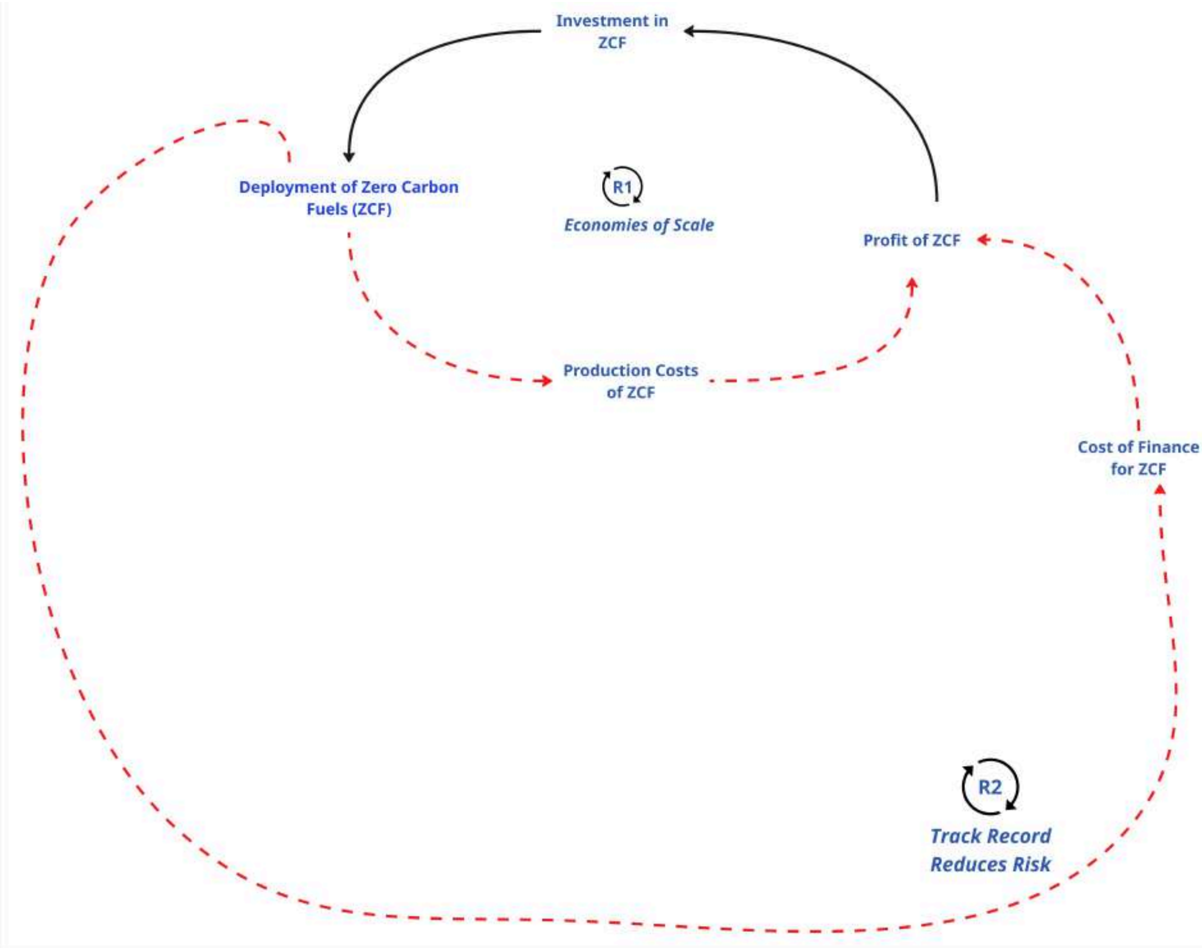
4.4 Zero Carbon Fuels

The analysis and graphics in this section were inspired by the seed diagram provided by Kopainsky (2024) and materials prepared by Aidan Sliwkowski for the second NESC Energy Systems Workshop in April 2025.

Economies of Scale and Track Record

As in the previous sections, we use the economies of scale reinforcing feedback loop (figure 22), as identified by Sharpe et al (2025) as the foundation of our feedback loop map, where increased *deployment of ZCF* leads to reduced *production costs of ZCF* which leads to increased *profit of ZCF* which supports increased *investment in ZCF* which supports more *deployment of ZCF*. To this we add the track record effect (Sharpe *et al.*, 2025). Waidelich and Steffen outline how 'relatively immature technologies with a limited track record are less attractive for loan providers' (Waidelich and Steffen, 2024). This also applies to investors. Reluctance to invest or give a loan translates to higher *costs of finance* if any is available. High costs of finance reduce development viability, reducing the number of developments that go ahead/*investment in ZCF* which reduces further deployment of ZCF. While both these reinforcing feedback loops can be activated in a virtuous circle, with limited development of biofuels or green hydrogen, this feedback loop is currently reinforcing stasis.

Figure 22: Zero Carbon Fuels Feedback Loops: Economies of Scale and Track Record Reduces Risk



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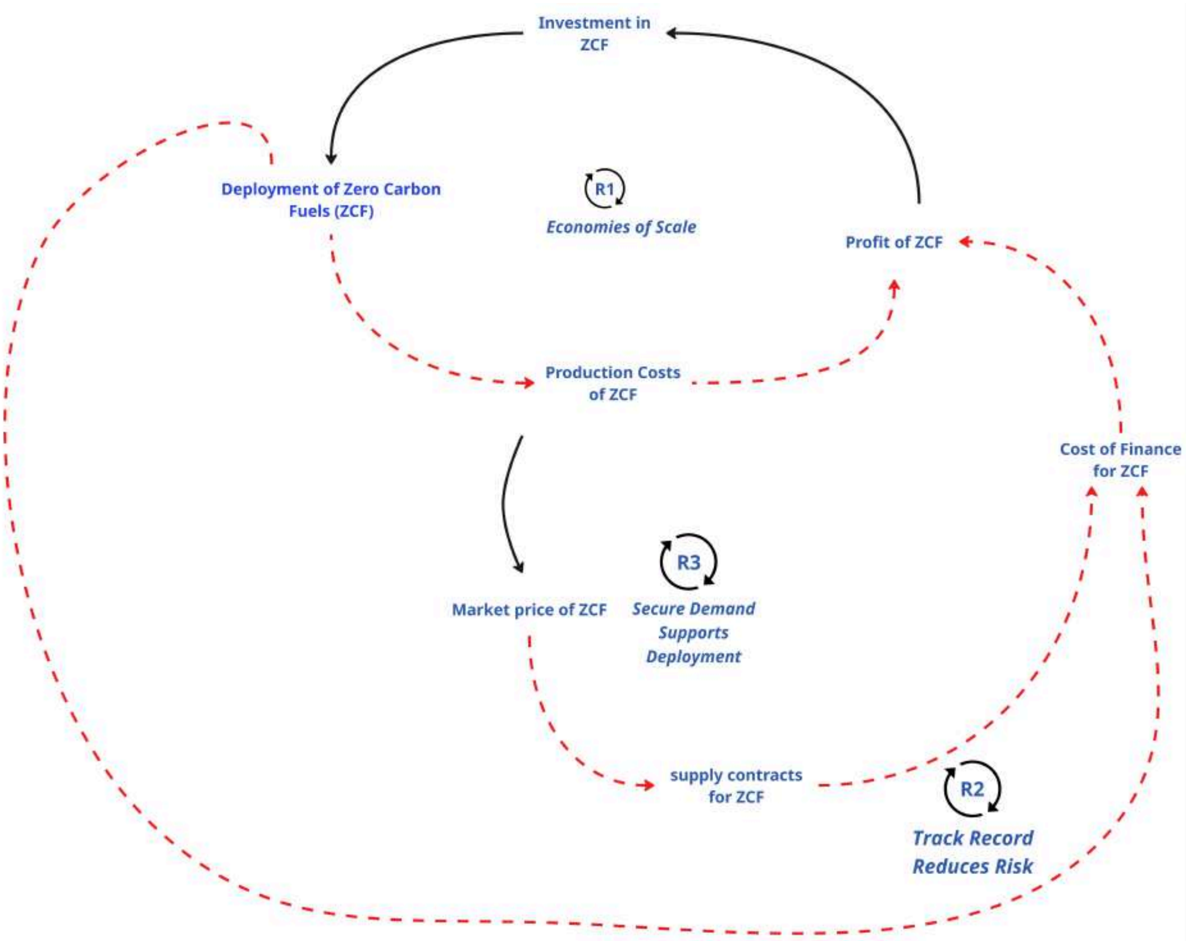
Secure Demand Supports Deployment

Similarly to the track record feedback loop, the cost and availability of finance for domestic ZCF deployment depends on the developer's ability to demonstrate ability to generate a steady return over a number of years. The primary way to demonstrate future return is to point to reliable demand for your product, often by securing contracts for supply. If *deployment of ZCF* increases such that *production costs of ZCF* reduce, the *market price of ZCF* should also see a reduction. This increases the possibility of securing *supply contracts for ZCF*, which reduces the *cost of finance for ZCF*, which can lead to more investment in ZCF and therefore further deployment of ZCF.

Figure 23: Zero Carbon Fuels Feedback Loop: Secure Demand Supports Deployment



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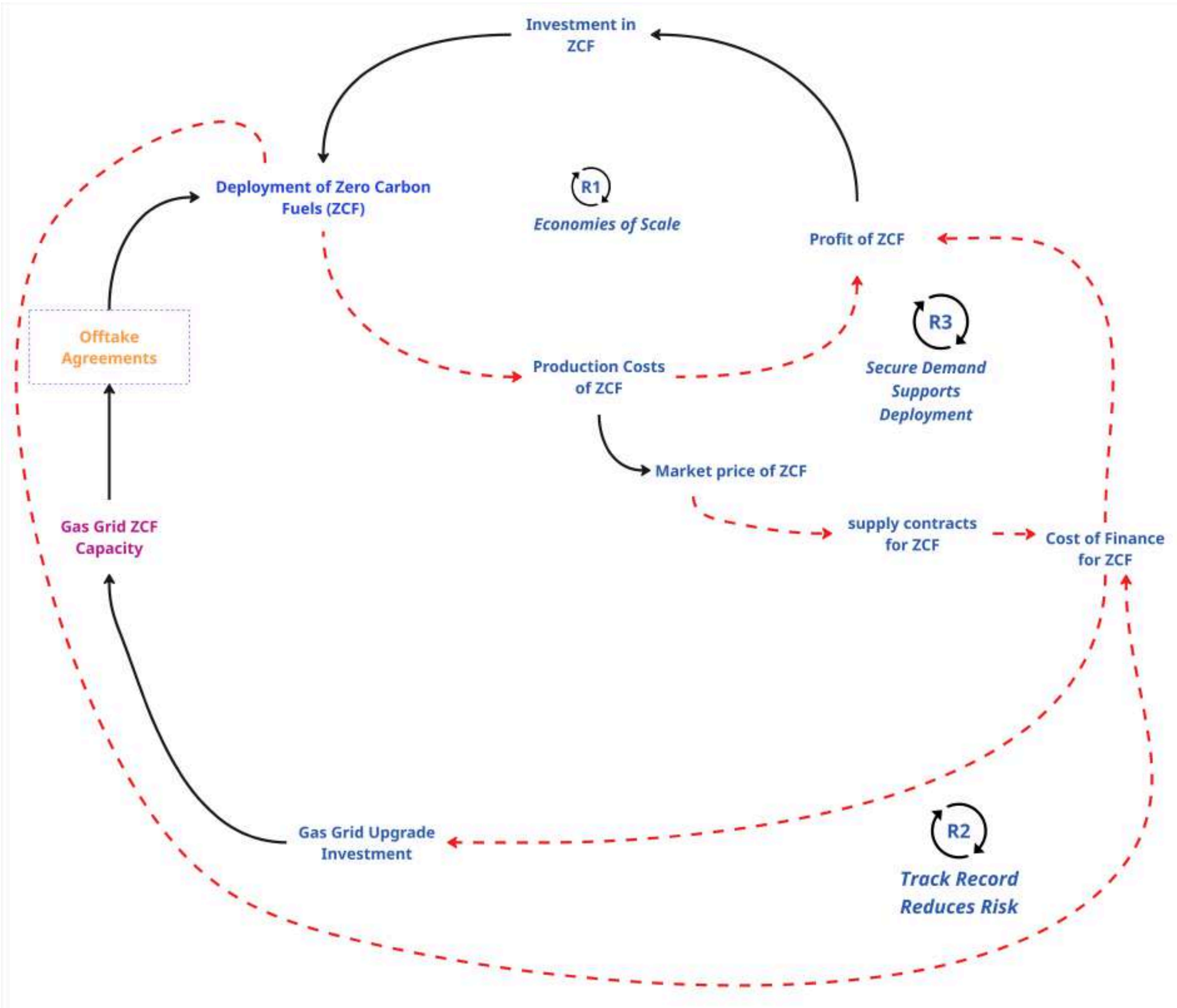
Intervention: As we will explore under 'path dependencies', zero carbon fuels not only have to compete against fossil fuels which are cheaper but also often electrification. This does not create confidence in future returns. If investments in gas grid readiness were undertaken, offtake agreements, e.g. where the gas grid commits to inject or utilities commit to purchase a set quantity of ZCF, could demonstrate a robust level of demand which would improve investment conditions for ZCF. This could unlock the desirable reinforcing feedback loops of reducing costs and further deployment. This intervention is illustrated in figure 24.

Figure 24: Zero Carbon Fuels Intervention: Grid Investment and Offtake Agreements

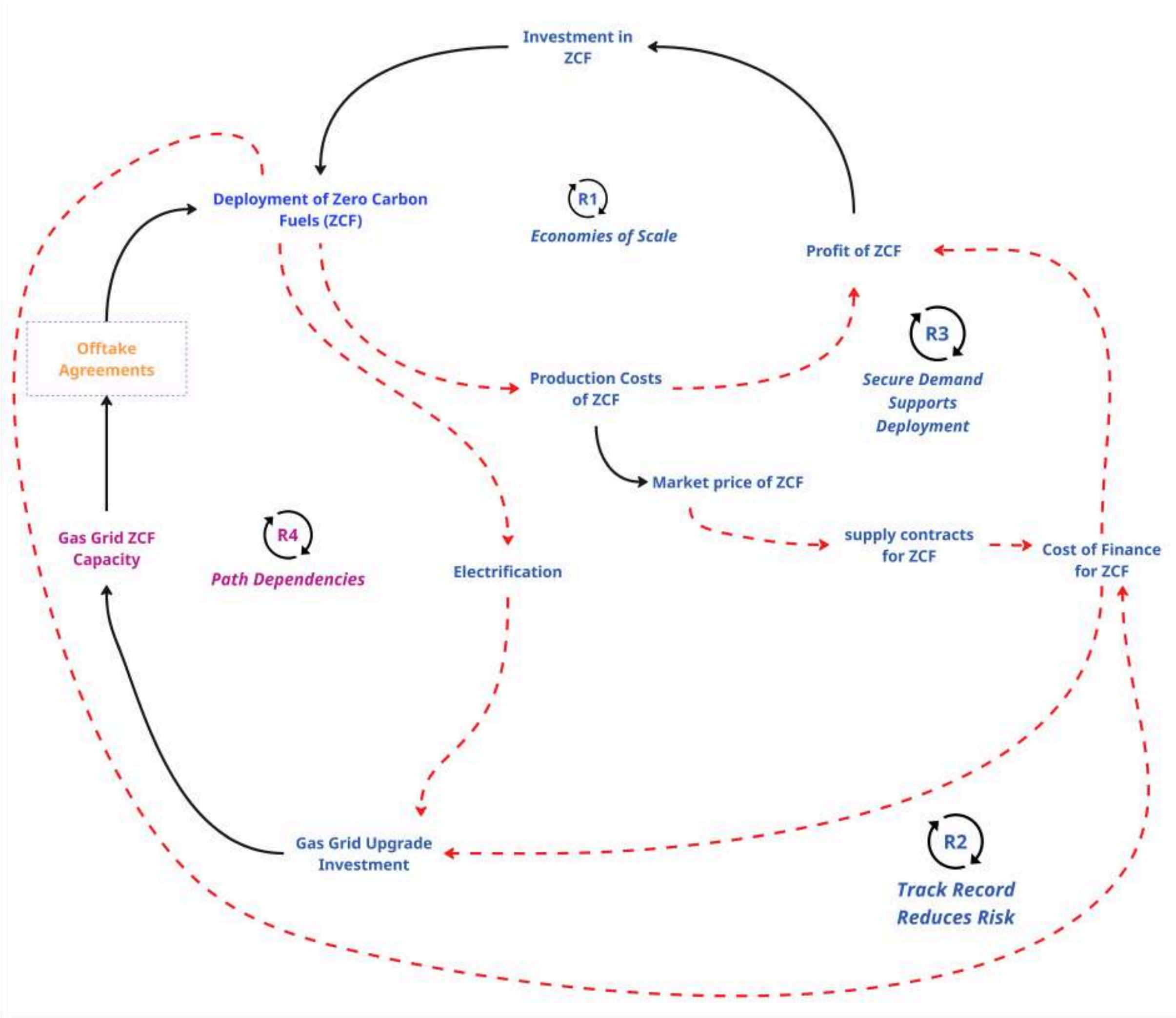


Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Path Dependencies

An increase in *deployment of ZCF* could lead to less *electrification*, which would increase the demand *gas grid upgrade investment*. This would increase the *gas grid ZCF capacity*, which would support more *offtake agreements* which would lead to more *deployment of ZCF*. We could also see the level of electrification influencing deployment dynamics through increasing *supply contracts for ZCF* in the feedback loop 'Secure Demand Supports Deployment'. These are similar to a feedback loop identified by Sharpe et al (2025); 'success to the successful; path dependence in technology choice' (Sharpe *et al.*, 2025).

Figure 25: Zero Carbon Fuels Feedback Loop: Path Dependencies



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

Intervention: Governments often aim to 'avoid picking winners'. However, as technologies are not perfect substitutes, it might reduce overall costs of the energy system to clarify technologies' respective roles, where already understood, to avoid over or under investment. Sharpe et al (2025) note that 'a policy intended to be technology neutral will typically advantage whichever technologies are more mature, or more supported by existing infrastructure and market structures… The reinforcing feedbacks [of path dependency] will tend to amplify this advantage over time'. They suggest that 'instead governments can aim to … align or adjust policies to influence technology outcomes deliberately rather than accidentally' (Sharpe *et al.*, 2025, p. 11).

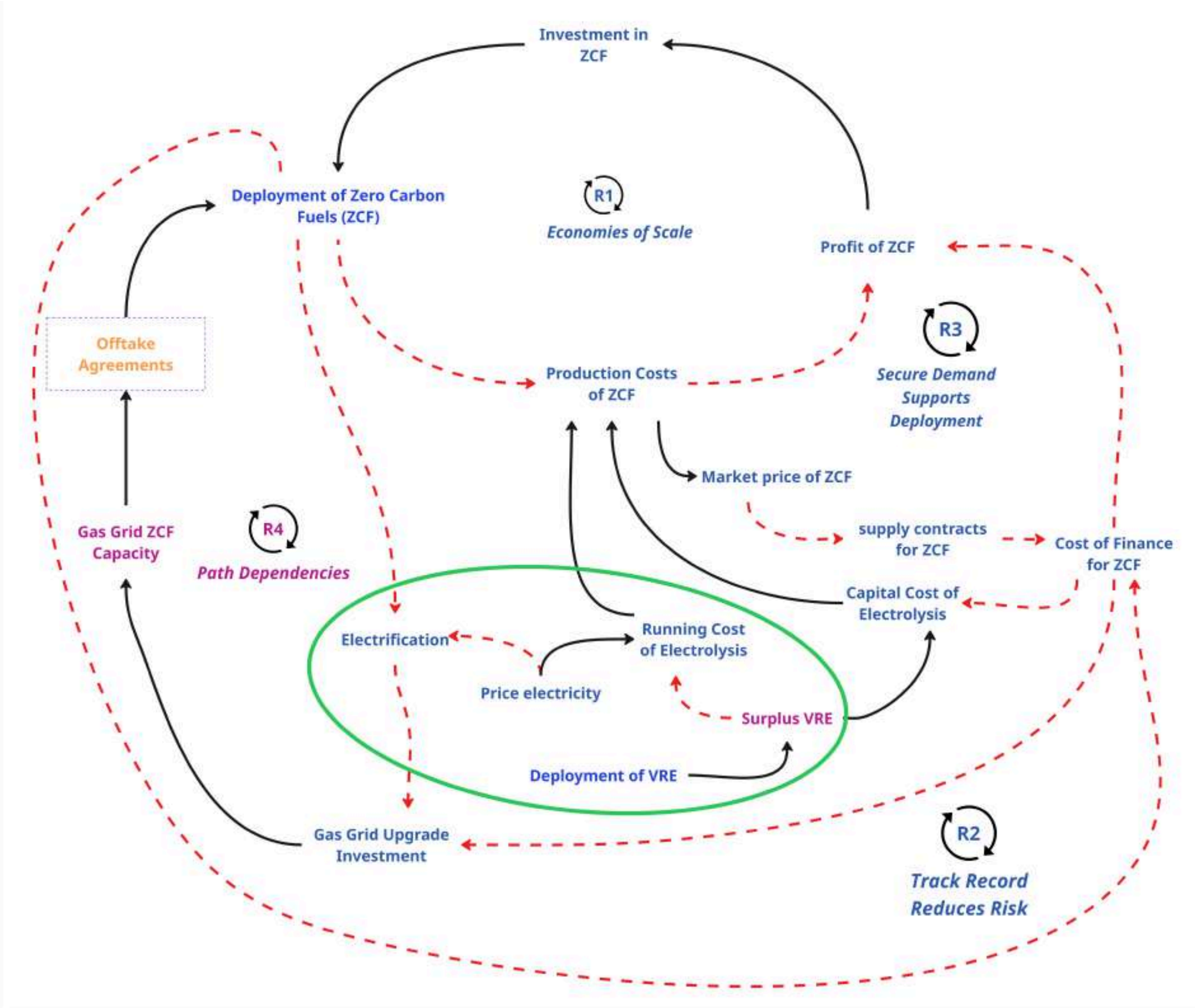
Zero Carbon Fuels Causal Loops and Potential Interventions

Figure 26 brings together the main drivers of and constraints on deployment of zero carbon fuels which broadly include biofuels and green hydrogen. Four reinforcing feedback loops were described. We have focused so far on the potentially beneficial side of these reinforcing dynamics. However, if we take a starting point with R1 'Economies of Scale', where you have low or stagnant *deployment of ZCF*, *production costs of ZCF* remain high, the *profit of ZCF* remains low and therefore *investment in ZCF* remains low which does not support further *deployment of ZCF*. This points to a need to kickstart initial deployment to unlock cascading impacts. The diagram also notes path dependency where there is a real or perceived competition between zero carbon fuels and electrification options.

It is important to consider the links of this technology to the others. Figure 26 highlights in the green circle where development in ZCF is linked to developments in variable renewable electricity and heat pumps. Through the use of electrolysis, powered by renewable electricity, this technology links back to the deployment of variable renewables. Surplus renewable electricity, priced close to zero, would reduce the operational or variable costs of green hydrogen. However, reliance on surplus renewable electricity implies cutting back green hydrogen production when electricity prices are high. This has the effect of increasing the capital costs per unit of output for green hydrogen.

Back up for VRE is expected to be a large share of the demand for zero carbon fuels in future, and so ZCF also links with VRE deployment through the 'demand for ZCF' variable. Zero carbon fuels deployment is also related to the deployment of heat pumps and EVs (the electrification options), as competing technologies (Gas Networks Ireland (GNI), 2024; Khammadov, Syron and Ryan, 2025). Market uncertainty with respect to the scale of future market share for a technology has an impact on risk and certainty and therefore on the cost of finance, impacting the supply chain for each of the technologies in question. Clarifying the future role, even where the forecasted volume/quantity of sales is lower, can still create more certainty for the development of a robust business case.

Figure 26: Zero Carbon Fuels Simplified Feedback Map



Note:
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We need to unlock cascading beneficial impacts by shifting the reinforcing feedback loops from stasis into scale up. This analysis identifies offtake agreements, supply contracts, and cost of finance as leverage points with potential to deliver change.

In the second participative workshop, stakeholders were brought through the causal loop diagram for ZCF, identifying the dynamics and barriers. They were then asked for action ideas to unlock greater progress in deployment in light of the illustrated dynamics at play. The stakeholder suggestions represent further avenues for kickstarting good dynamics in the deployment of ZCF. The action ideas recorded in table 5 were broadly categorised under: spatial planning and development management; finance and investment; pricing and incentives; public engagement local and community efforts, and policy planning.

Table 5: Stakeholders' action ideas from NESC Energy System Workshop April, 2025

Category	Action Ideas
Spatial planning & development management	Implement renewable 'go to' areas to reduce permitting time; integrate bio-refining with anaerobic digestion; compulsory purchase order of sites for anaerobic digestion biomethane plants near the gas grid; fine futile objections;
Finance and Investment	Support for development of new transmission infrastructure guarantee offtake for the zero carbon fuel government support for pilot projects
Pricing and incentives	A Renewable Energy Support Scheme (RESS) for biomethane
Public engagement, local or community efforts	Subsidise local households' energy where an AD plant is seeking planning permission; information and education pack for primary school teachers; develop a counter narrative regarding what can't happen if we don't have zero carbon fuels; centralised communications, r sources and guidelines to combat misinformation
Policy Development	Government to engage with key energy stakeholders together (gas, electricity, grids, government etc); develop definitions and targets

Box 2: The Future of Zero Carbon Fuels in Ireland

The Future of Zero Carbon Fuels in Ireland. Source: (Khammadov, Syron and Ryan, 2025)

The cost of hydrogen per the EU Hydrogen Bank pilot auction in 2024 was between €174 to €405/ MWh. For comparison, the fourth RESS auction provisional results showed a weighted average price of onshore wind at €90.47/ MWh. The National Biomethane Strategy estimated costs of producing biomethane at between €120 to €150/MWh.

The total energy value of gas consumption (natural gas, biofuels and hydrogen) is expected to drop from 2023 levels by about 20 to 30 per cent by 2050, assuming CAP 2030 and 2050 targets are met. Industry is expected to be the greatest customer of gas by 2050, followed by the electricity sector and then transport.

Residential and commercial/public sector demand for gas is expected to drop significantly as they are anticipated to have cheaper decarbonisation options available to them. Consumption of gas by the electricity sector is also expected to reduce from current levels. Khammadov et al note 'A shift to a flexible supply [to balance variable renewables] is likely to reduce the running hours of conventional thermal capacity significantly, which requires thorough transition management.'

Some research has examined the potential capital costs of hydrogen powered electricity generators. Most heavy duty gas turbine models are designed to handle hydrogen levels of 30-50 per cent by volume. Some gas turbines on the market are capable of handling pure hydrogen but with implications for air pollution.

While the capital cost of a 2 GW combined cycle gas turbine (CCGT) would be around €2.6bn, retrofitting the same capacity for hydrogen would cost between €0.3 to €0.8bn.

Khammadov et al (2025) note that 'An evaluation is needed to determine the adaptability of Ireland's gas turbines for retrofits that enable hydrogen-readiness'.

Source: Khammadov *et al* (2025).

Zero Carbon Fuels Conclusions

The overall use of gas (of any kind) is expected to fall over the course of the energy transition. However, it still will have an important role to play in the transition, offering a decarbonisation option to those areas where electrification will remain unfeasible or uneconomic. As with most technologies, it needs initial deployment to initiate positive feedback loops of track record and learning by doing. Offtake commitments or injection commitments by the gas grid could also activate positive feedback loops. Zero carbon fuels will be more expensive than existing fossil alternatives and indeed electrification options, therefore appropriate supports tailored to zero carbon fuels' anticipated future role will be important. Clarifying that future role will also be important.

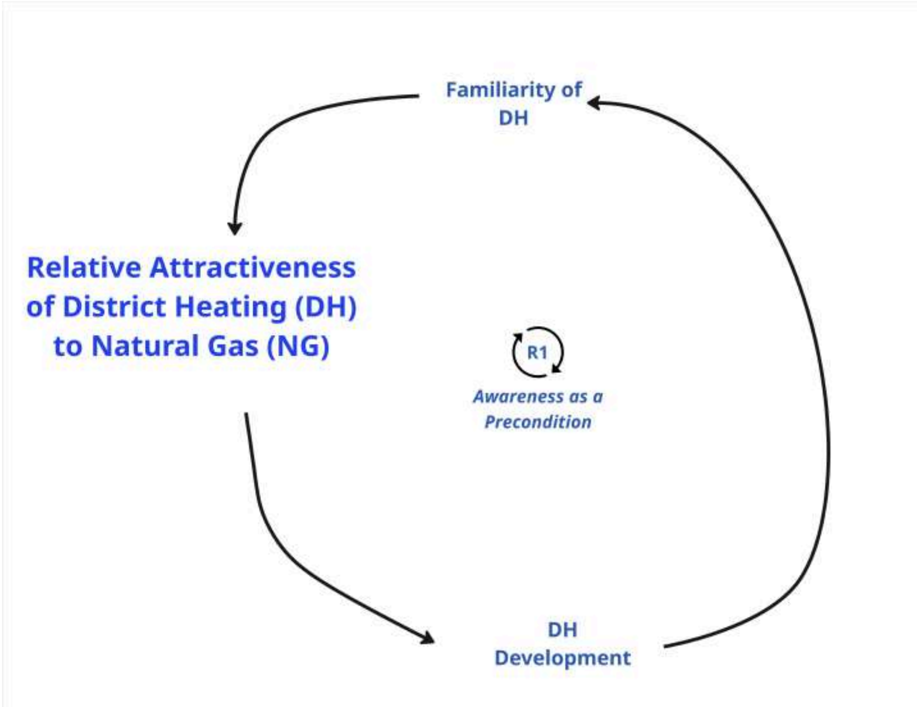
4.5 District Heating

The causal loop diagrams in this section are adapted from Gürsan et al (2024) and informed by feedback from stakeholders at the second NESC Energy Systems Workshop based on a 'seed structure' developed by Kopainsky (2024) for participative exercises in the NESC Energy Systems workshop held in November 2024 (Gürsan *et al.*, 2024; Kopainsky, 2024b). The full causal loop diagram informed by stakeholders is available in Annex 3. The Gursan et al (2024) CLD is based on a case study for deployment of district heating in a dense neighbourhood Rotterdam. Rotterdam already has district heating in some neighbourhoods but other buildings are mainly heated by network natural gas supply. The studied neighbourhood consists of buildings that are 'pre-war era with low thermal insulation'. Following the approach adopted by Gursan (2024) we set natural gas against district heating as the competing options for heating buildings. District heating is only economically feasible in areas with sufficient density of heat demand. In Ireland, such areas are likely to coincide with areas currently supplied by the gas network (S.E.A.I., 2022).

Awareness as a Precondition

Interestingly one of the biggest disparities between the Gursan et al (2024) analysis and the work by stakeholders at the NESC workshop is the importance ascribed to familiarity to drive deployment of district heating. Neither awareness nor familiarity appear as drivers in the Gursan CLDs (Gürsan *et al.*, 2024). Due to low levels of awareness of district heating in Ireland, we include familiarity with district heating as an important driver for the relative attractiveness of district heating to natural gas. We represent a further simplified version of the Sharpe et al (2025) learning by doing feedback loop where familiarity with district heating increases the relative attractiveness of district heating to natural gas, which in turn increases deployment (see figure 27) (Sharpe *et al.*, 2025). Any increase in deployment, starting from a low base, will increase familiarity with district heating in Ireland.

Figure 27: District Heating Feedback Loops: Awareness as Precondition



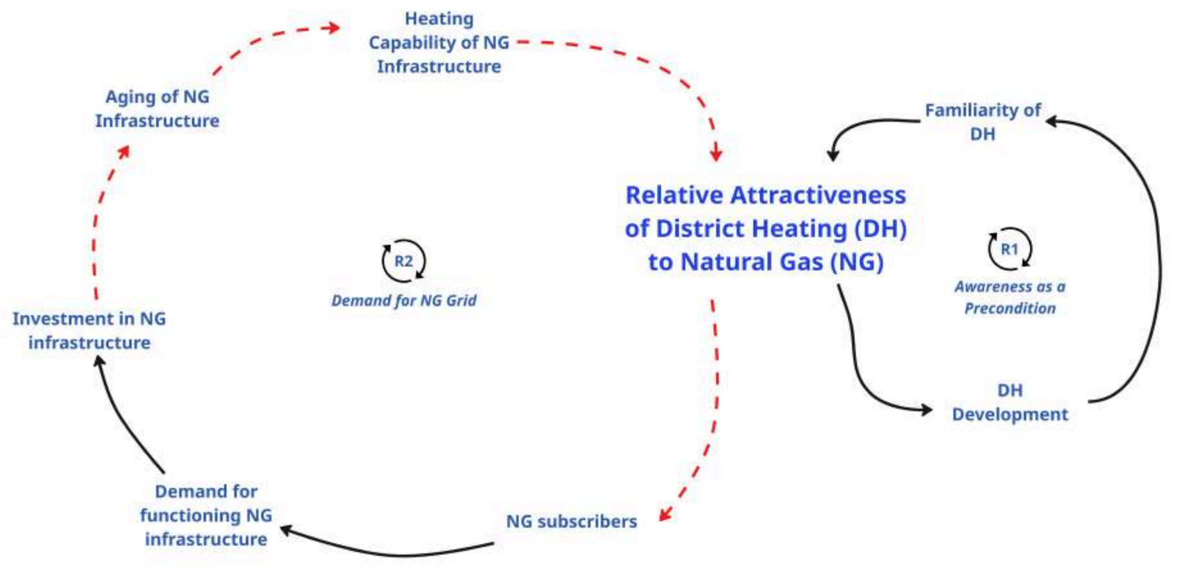
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.

Intervention: There is very little awareness in Ireland about district heating. The government should work with local authorities and representative organisations to raise awareness, starting with the policy and advocacy communities and stakeholder organisations on the advantages of district heating. Businesses need to be made aware that district energy solutions are a viable and available option in Ireland for development in the near term. It is hard to raise awareness among the general public without being able to point to existing residential provision of district heating in Ireland. This is where advocacy and stakeholder organisations can act as trusted intermediaries to communicate the benefits to the public to build support for development of schemes.

Demand for Gas Grid

In this model, networked natural gas and district heating are competing technologies. If the *relative attractiveness of district heating to natural gas* increases, the number of '*subscribers*' or customers of the gas network decreases. This decreases the *demand for functioning gas infrastructure*, leading to less *investment* and therefore *aging infrastructure*. The consequent reduction in the *heating capability of the gas network* decreases its attractiveness relative to district heating (Gürsan *et al.*, 2024).

Figure 28: District Heating Feedback Loops: Demand for Natural Gas Grid and Awareness as a Precondition



Note:
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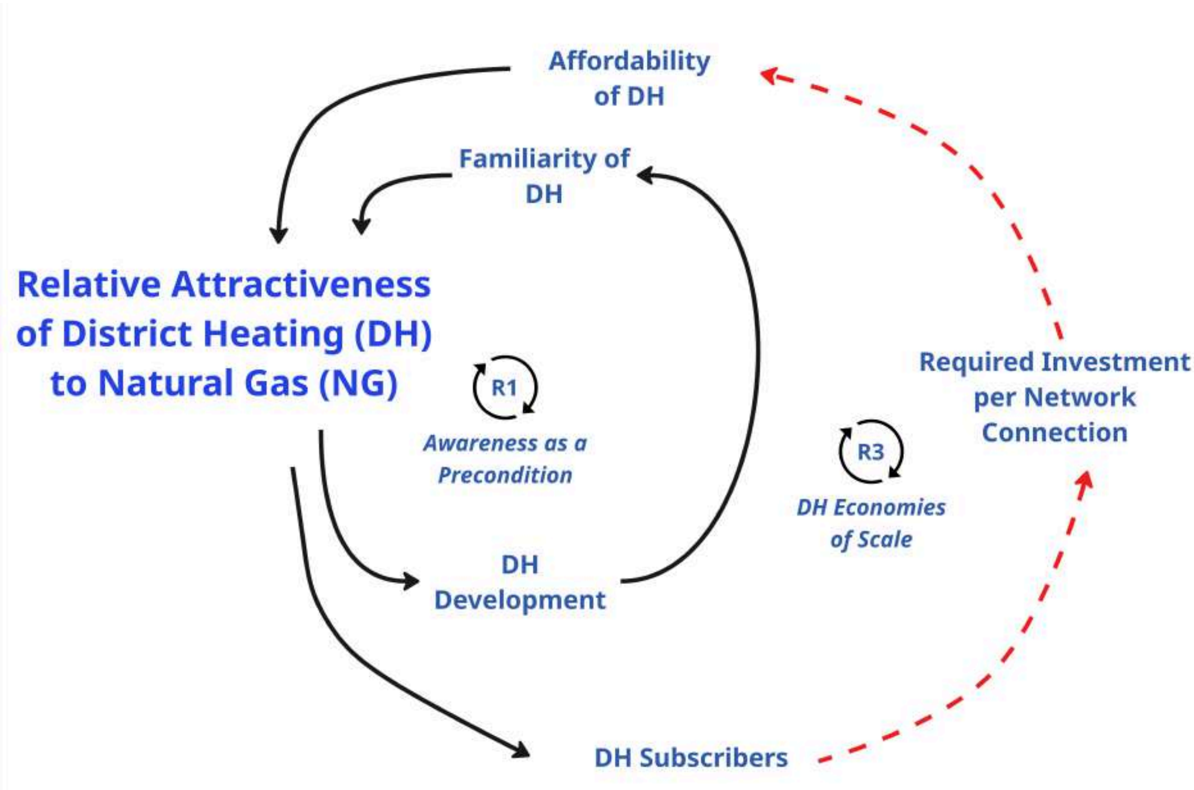
Intervention: This dynamic would seem to favour energy transition once the movement away from the networked gas supply has begun. However, this movement is not yet visible. A further concerning dynamic in this regard is highlighted under energy poverty below. It is important to be clear on the implications of the energy transition for the gas grid and its business model. This dynamic suggests that when the energy transition is underway, the gas network could deteriorate. This highlights the importance of being clear what is expected from the gas network in future and then having a plan in place to ensure the network can and does fulfil its future role.

R3. District Heating Economies of Scale

Similar to the other technologies, reinforcing feedbacks of clean technology development and diffusion identified by Sharpe et al (2025) apply here. Increased relative attractiveness of DH compared to natural gas, leads to an increase in subscribers (Sharpe *et al.*, 2025). This splits the network costs over a wider base, reducing the required investment per network connection. The reduced network costs lead to greater affordability of DH which acts to further enhance its relative attractiveness. Figure 29 illustrates the feedback.

Figure 29: District Heating Feedback Loop R3: Economies of Scale



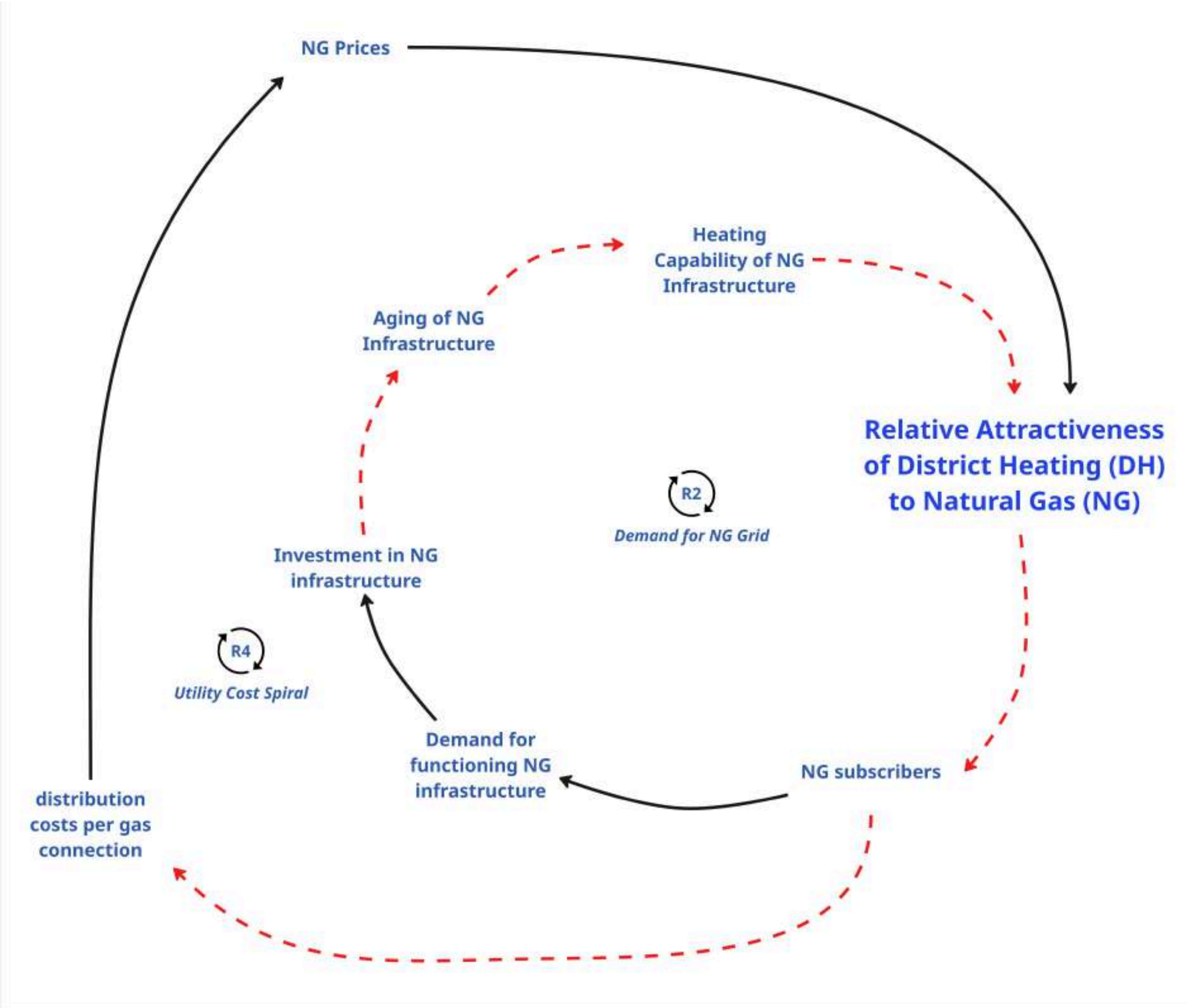
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Intervention: This dynamic clearly can't be activated unless and until a DH scheme is available. DH subscribers are not just households and small businesses but can also include 'anchor tenants' like large public buildings, hotels or businesses with a high heat demand like food. Such connections or subscriptions could offer a quick route to economies of scale. In the absence of existing district heating schemes, developing familiarity among the broader business community with district heating as a potential affordable zero carbon heat option could build demand which could offer more confidence to developers.

R4. Utility Cost Spiral

As seen previously in the heat pump causal loop diagram, *increased attractiveness of district heating* (and subsequent deployment) leads to reduced gas *subscribers* which increases the *distribution cost per gas connection* leading to *NG price* increases which reduce the *relative attractiveness* of those systems.

Figure 30: District Heating Feedback Loop: Utility Cost Spiral



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

This effect was identified by Sharpe et al (2025) as a the complex feedback of fossil fuel decline where they note the impact of reverse economies of scale, network effects and capital flight.

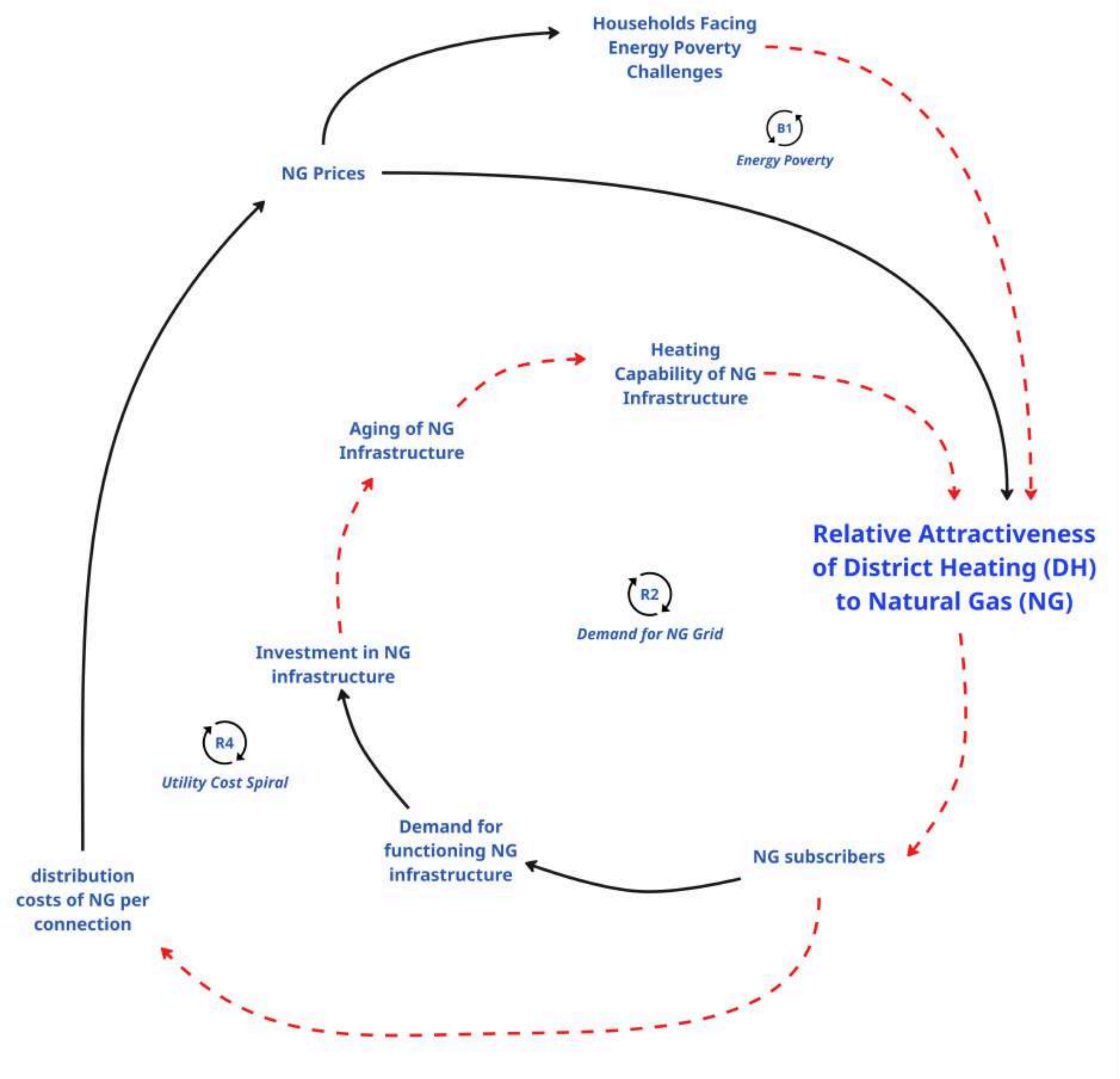
Intervention: The gas grid will be reshaped by the energy transition and a new business model will have to develop. This points to the need to integrate the planning for the future of the gas system with other energy transition plans.

B1. Energy Poverty

Gursan et al (2025) identify an energy poverty trap where limited capital or even disposable income makes it difficult for vulnerable households to make the changes required to shift their supply from one heat supply to another. As gas prices rise, such vulnerable households are even further constrained from changing. Figure 31 describes an energy poverty loop where the departure of *gas subscribers* from the grid leads to increased *gas prices* which leads an increase or worsening of households facing energy poverty challenges, which limits their ability to switch from heat supply to another. While more affluent households leave gas in bigger numbers it gets harder for poorer households to do the same, leaving them facing greater energy costs. This energy poverty feedback loop applies even moreso to households where district heating will not be available and heat pumps are the best decarbonisation option. In these cases, the cost of switching is much higher and therefore the energy poverty trap would be more acute.

Intervention: Gursan et al (2025) suggest specific supports to poorer households to facilitate changing heat supply. It would also be important in any DH scheme to keep initial connection charges as low as possible to encourage a broad take-up.

Figure 31: District Heating Feedback Loop: Energy Poverty

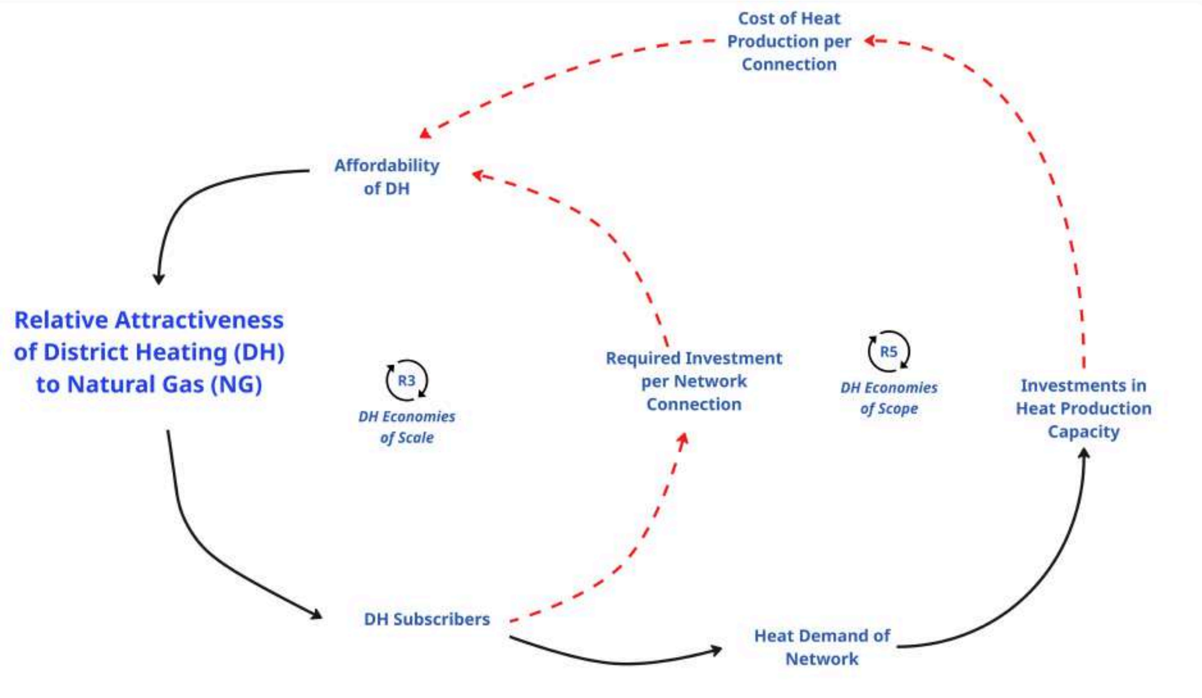


Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Economies of Scope

As a district heating network grows, it reaches sufficient size to requires further investment in heat production. This offers opportunity for the district heat operator to diversify heat sources. Diversification of heat sources gives the operator greater opportunity to take advantage of price variations between and within markets over time, with potential for significant cost savings (Gursan *et al*, 2024).

Figure 32: District Heating Feedback Loop: Economies of Scope



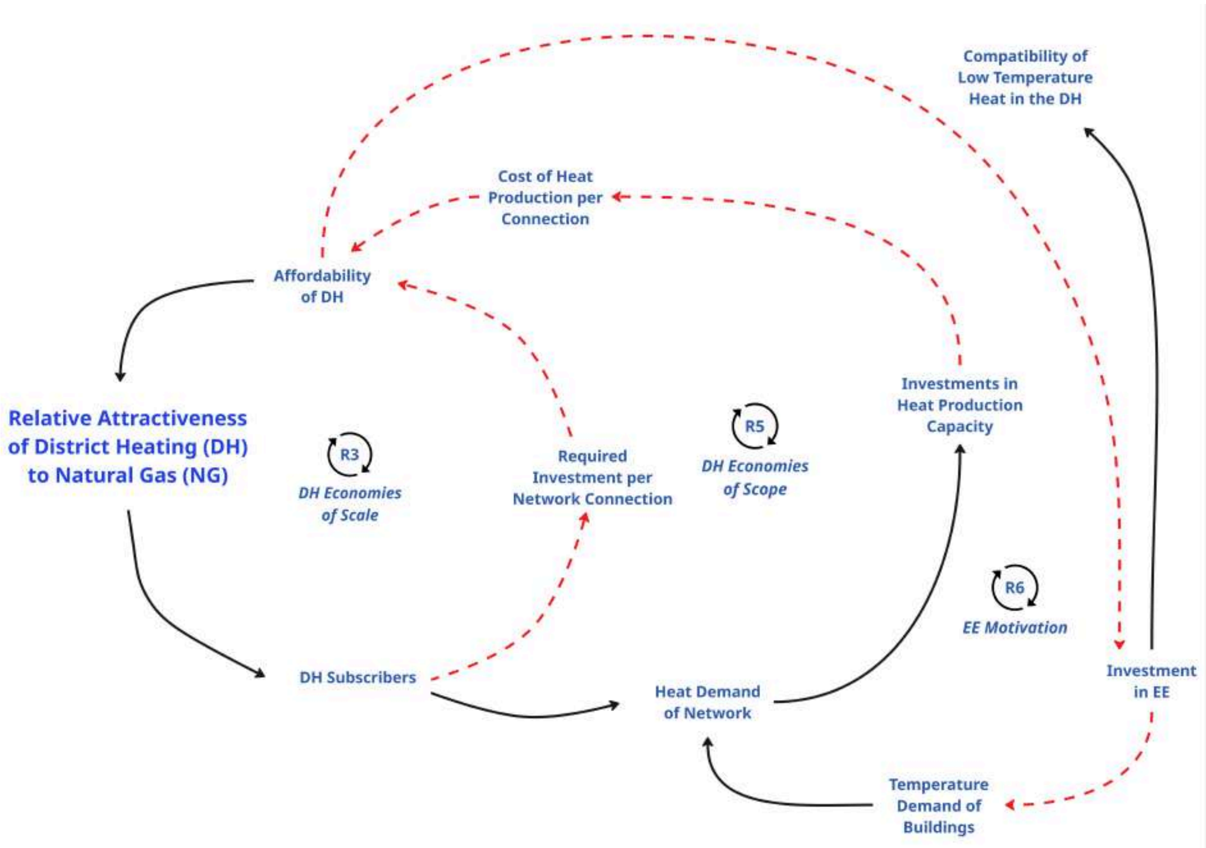
Note:
Solid black arrows: represent relationships where the named variables move in the same direction, all else being equal i.e. if the origin variable increases, the destination variable at the end of the arrow increases.
Red dashed arrows: represent relationships where the named variables move in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

Intervention: DH schemes should be encouraged to grow to sufficient scale to diversify heat sources. This would have benefits beyond the DH system, where DH could potentially supply great levels of demand response in the electricity system.

Energy Efficiency Motivation

A district heat operator benefits from greater density of heat demand over their network area. All else being equal, a greater density of heat demand allows more affordable district heating. The more affordable a connection's heat supply is, the less likely that customer is to invest in energy efficiency. This is a reinforcing feedback loop. However, the ability of a district heating system to employ some renewable energy heat sources which only supply low temperature heat, is constrained by the capacity of connecting customers to use low temperature heating systems. Typically older homes which have not been retrofitted require high temperature heat solutions, whereas new buildings, conforming to Near Zero Energy Building (NZEB) standards are designed to take low temperature heat solutions (Gürsan *et al.*, 2024; The Housing Commission, 2024).

Figure 33: District Heating Feedback Loop: Energy Efficiency Motivation



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

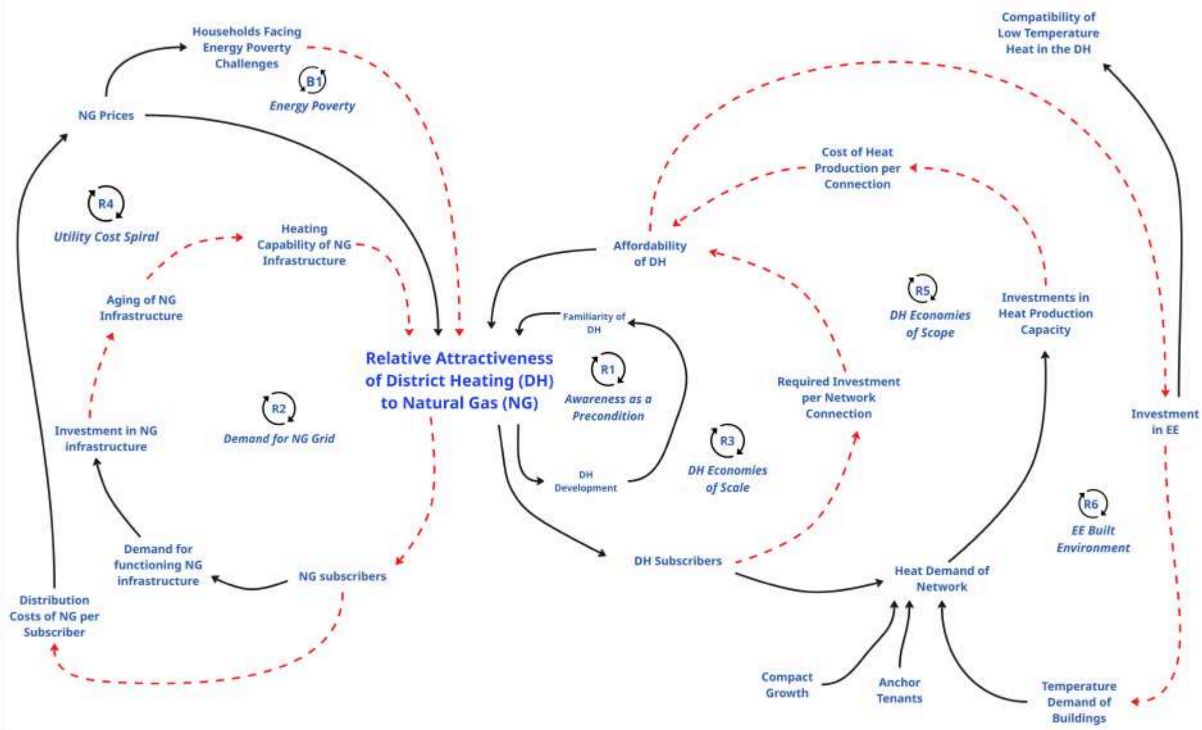
Intervention: Households should continue to be encouraged and supported to improve their energy efficiency of their dwelling. High heat demand from poor quality buildings can limit the heat source options for DH operators leading to missed cost savings. Finally, poor building fabric associated with poor insulation levels has implications for the health of those living and working in those environments and leads to higher energy costs.

Simplified District Heating Feedback Map

There are two further influential variables worth noting; compact growth and anchor tenants. Compact growth is a necessary condition for a viable district heating system. The deployment of the heat distribution network in district heating is a defining part of the costs. Gursan et al (2025) note that 'each heat network ... project requires a minimum number of connections and consumers to compensate for the investments [in] the heat network. Large district heating networks offer better business cases and cash-flow profiles for network operators' (Gürsan *et al.*, 2024, p. 6). Anchor tenants such as large public buildings like hospital or manufacturers with large heat demand like food processors, can increase the viability of district heating by increasing the density of heat demand over the network area, thus allowing more affordable prices which further encourages more subscription (S.E.A.I., 2022).

We noted earlier distinctions between the Gursan et al (2024) analysis based on a Rotterdam case study and the causal loop diagram for district heating in Ireland discussed with stakeholders at the second NESC Energy Systems workshop (see annex 3). The first distinction, covered under 'awareness as a precondition' above was that familiarity was not a variable in the Dutch model but was considered very important in the Irish model. A further distinction is the role of public and government support, including financial support which was included in the Irish model. Government support was not a central feature of the Dutch model, though it was noted as important for breaking the energy poverty trap. Government support was also a noted possibility in the Dutch model to incentivise district heating adoption or to incentivise energy efficiency improvements in buildings. The Irish model noted alternative zero carbon heat systems as a further competing technology, which links this technology back to heat pumps. The deployment of heat pumps reduces heat demand and therefore impacts the cost per unit of district heating supply. Therefore, again we have a situation where two technology solutions for the energy transition, heat pumps and district heating, are in competition with each other though they are seen by SEAI Heat Study (2022) as best fitted to different use cases. The earlier adoption of heat pumps in urban areas could undermine the case for the more efficient district heating solution in later years. A further link is the potential for district heating system to take surplus VRE as a heat source and moreover to offer demand response flexibility to the electricity grid due to the many options it could use to store energy as heat. Finally, there is also potential for district heating to be a customer for zero carbon fuels, depending on costs and local availability of distribution.

Figure 34: Simplified District Heating Feedback Map



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

In the second participative workshop, stakeholders were brought through the causal loop diagram for district heating, identifying the dynamics and barriers. They were then asked for action ideas to unlock greater progress in deployment in light of the illustrated dynamics at play. The stakeholder suggestions represent further avenues for kickstarting good dynamics in the deployment of district heating. The action ideas recorded in table 6 were broadly categorised under: spatial planning and development management; finance and investment; pricing and incentives; public engagement local and community efforts, and policy planning.

Table 6: Stakeholders' action ideas collected at April 2025 NESC Energy Systems Workshop

Category	Action Ideas
Spatial planning & development management	A plan led approach to building and housing development; spatial alignment of Large Energy Users or Data Centres with district heating demand and embedded in planning hierarchy
Finance and Investment	Have a demonstration project supported by government, the government to provide capital funding for initial projects.
Public engagement, local or community efforts	An awareness campaign
Policy Development	Developing a net zero vision and energy transition master plan, refine the heat decarbonisation roadmap integrating cost and local elements policy clarity on future of fossil fuel boiler (phase out)

It is notable that stakeholders did not suggest or prioritise measures around pricing and incentives as important for district heating deployment. This is possibly because district heating has been demonstrated as a viable option in many different cases across Europe where heat demand density was sufficient. Stakeholders noted the potential of district heating to offer many social and environmental benefits. Because of its potential, if appropriately set up, to deliver reliable low cost heat to households as well as business participants in the Energy Demand Management Roundtables (see section 3.3) thought it could be a good candidate for public investment to demonstrate the benefits of the energy transition to the public.

4.6 Conclusions

District heating is a familiar technology in many European jurisdictions but not in Ireland. District heating, if well designed, can offer advantages of, zero carbon heat sources, reliably low cost heat, potential to offer demand response to the electricity system and/or to be a customer for zero carbon fuels, and the opportunities for lower cost decarbonisation of commercial heat demand. Fiscal support or subsidy is not necessarily an ongoing requirement for the operation of district heating but it is likely to be necessary to initiate positive feedback loops of learning by doing, familiarity and economies of scale and scope. District heating relies on the co-location of a sufficiently dense heat demand with a heat source. Therefore compact growth and strategic spatial planning are both important to enable deployment of district heating.

Chapter 5: Taking Forward Results from Systems Analysis

5.1 Findings from Applying the Systems Tools

The energy transition involves more than just technology change, it requires new approaches to how we live and do business within a sustainable world. This paper applied this approach to explore the potential for systems thinking to offer new insights to the energy transition. The tools applied have delivered a fresh perspective on Ireland's energy transition that is shaped by stakeholder contributions and informed by the latest research.

The fog in the electricity system transition identified by (National Economic and Social Council, 2025c) appears to extend across the energy transition. There is a sense that when difficult choices need to be made, they are not made, leaving developers, industry stakeholders and the public uncertain about how to proceed or whether to invest. Many transition technologies are currently competing with each other and experiencing the effects of path dependency.

We explored the system dynamics of four energy transition technologies through causal loop diagrams. We found that district heating and zero carbon fuels could both achieve economies of scale to some degree if deployment would get started. Both technologies in an Irish context are hampered by lack of a business model, though the district heating has been demonstrated as a robust utility option in jurisdictions across Europe.

Heat pumps, district heating and zero carbon fuels are seen to compete with fossil heat options and each other for demand. However each technology has a distinctive core use-case. Upfront costs and costs of finance arose directly or indirectly for all the technologies. Clarifying the roles of potentially competing technologies could reduce costs for all by reducing real or perceived risk of investment. Developing a coherent plan for the whole energy sector that outlines respective roles for different technologies, behavioural and institutional change and outline timeframes for these, could also act to change relationships across the system, moving from perceived conflict or competition, to the development of synergies and coherent strategies.

When we drill down into how energy transition will be achieved, spatial planning comes out as a key component of the energy transition both in terms of its 'development control and permitting' function as well as its 'forward planning' or place-making function. Though it is not represented as a variable in the causal loop diagrams, grid congestion and infrastructure needs are driven in part by the spatial and/or temporal mismatch between energy demand and energy supply. The spatial distribution of technology deployment is not uniform but the system as a whole lacks sufficient tools to guide location of energy demand and supply. While in the district heating map, heat density is also driven by spatial planning through the required network investment per connection and compact growth.

Changing market rules or pricing structures to provide new incentives, whether for specific actions, timing, or locations could have transformative potential. Renewable energy is not even distributed over space or time. Neither is consumption. Decades of energy infrastructure investment have defined a concentration of assets in different locations that would take a long time to change. These need to be reflected in strategic planning and decision making. Paying attention to the spatial dimension of the energy transition and using place based approaches is crucial, not only for a just transition, but a competitive transition where strategic co-location can also deliver advantages for commercial and industrial decarbonisation. Spatial awareness in the energy transition also means developing opportunities for cooperation and shared learnings with Northern Ireland, as well as identifying key areas where coordination is crucial, such as infrastructure congestion.

NESC (NESC, 2025) has already noted the power of energy communities and microgeneration to change attitudes towards energy and build support for the energy transition. Bringing the potential benefits of the energy transition into focus through a reframed and elaborated tangible vision of life and business after a successful transition could help engage the public and stakeholders. Finally, public support for the energy transition and how to achieve it was a key theme. It was seen that people generally had little awareness of energy in their life until something goes wrong and that this means support for necessary infrastructure and changes is hard to achieve. Increasing the public's understanding through better communication and engagement was seen as important. The systems analysis tools suggest that finance, pricing and incentives, spatial planning, public support, knowledge and engagement, and the future of fossil fuels were important areas for further development and enquiry. It further suggests that the interaction between different transition solutions across the energy services of transport, heat and electricity need focused attention.

5.2 Conclusions of the Research

The results of the analysis described above informed the NESC Council Report No.172 Accelerating the Transition to a Sustainable Energy System, which is available at www.nesc.ie. That report's conclusions are summarised here.

The Council recommends five approaches designed to support coherence, reduce frictions, and realise the broader benefits that will cement public support for the energy transition.

Recommendation 1: Create a Cross-Government Energy Framework

To realise synergies and avoid siloed thinking, create a Cross-Government Energy Framework that addresses heat, transport and electricity together in a coherent manner, integrating existing strategies and plans for different policy objectives such as climate, energy poverty, affordability and energy security, and for different energy vectors such as electricity, gas and biofuels. The framework should aim to reduce uncertainty for energy users and investors. It should be consistent with the National Climate Objective and the Climate Action Plan but also integrate the broader social, economic and environmental objectives associated with energy, as captured in the energy doughnut (Chapter 2).

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

Some research suggests that public support for the energy transition could trickle up rather than down – in other words, that good experience locally can build support for national action. Government has already outlined plans for Green Energy Industrial Parks to act as a future end use for renewable energy, particularly offshore wind. These plans should be more ambitious, designing-in broader benefits including greater decarbonisation potential and tangible benefits for local communities. This can include provision of local amenities, district heating extended to complementary businesses on site and to the local community, space for nature, sustainable mobility infrastructure connecting industrial parks with local communities and population centres, and durable employment opportunities.

Recommendation 3: Develop A New Focus on Energy Demand

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

Recommendation 4: Increase Energy Literacy and Public Engagement

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

Recommendation 5: Build Distributed Resilience

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

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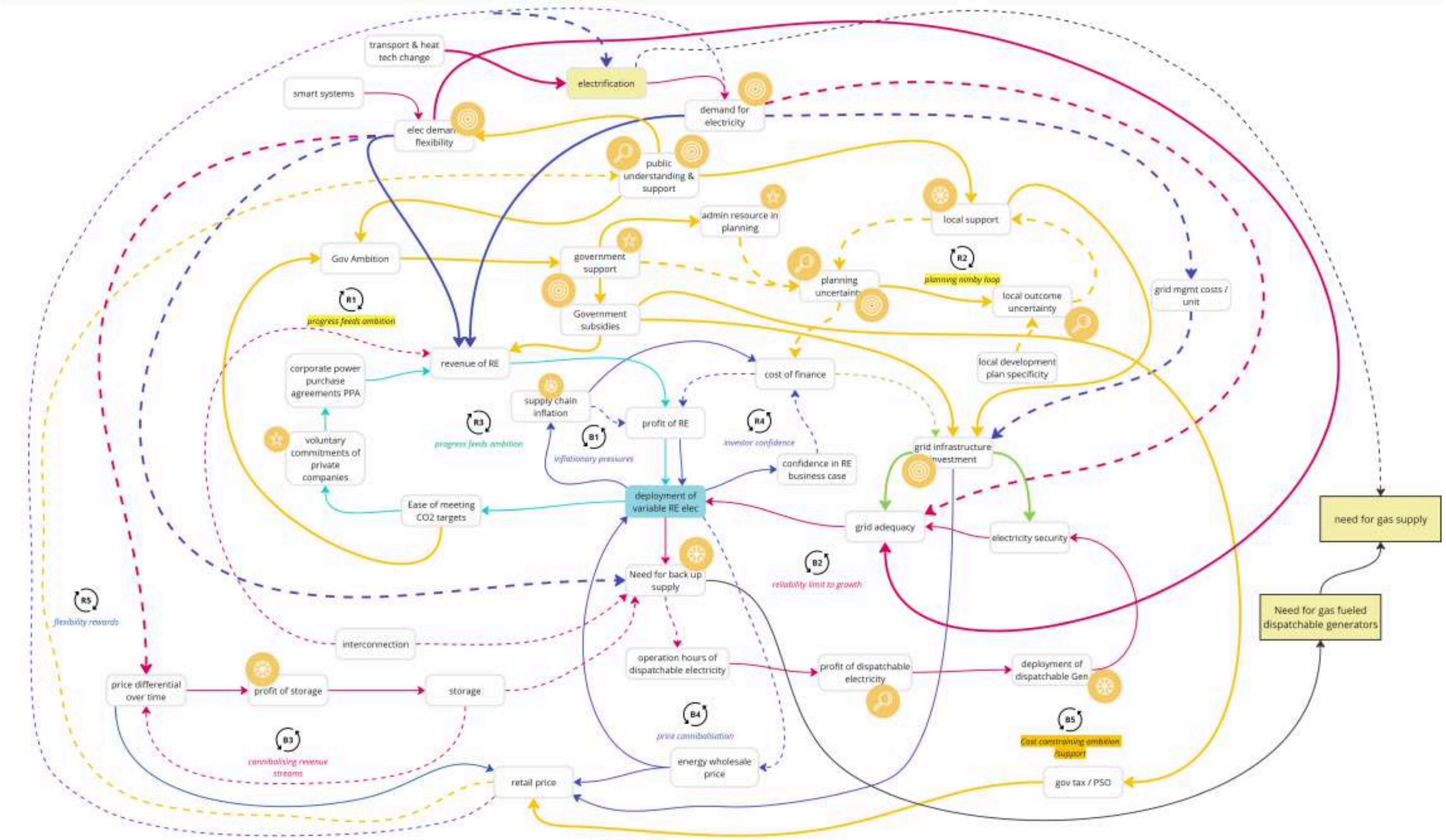
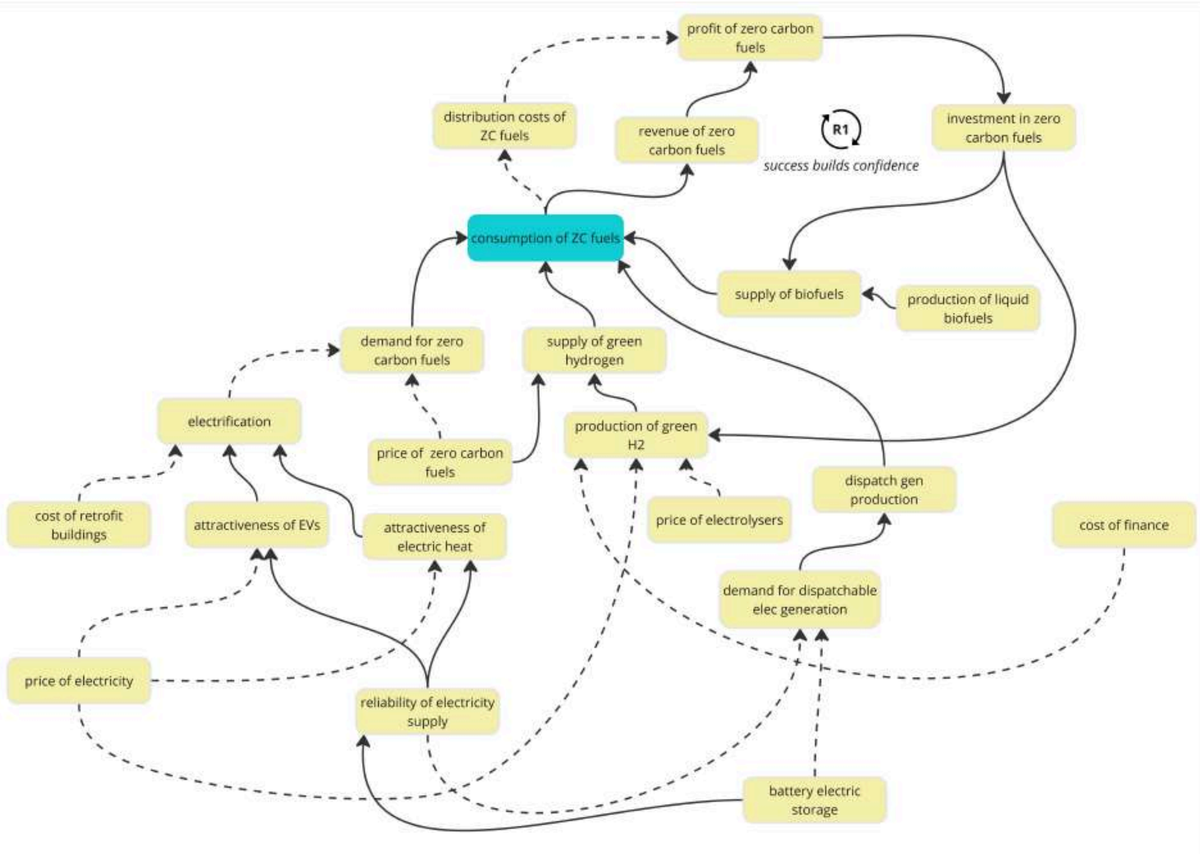
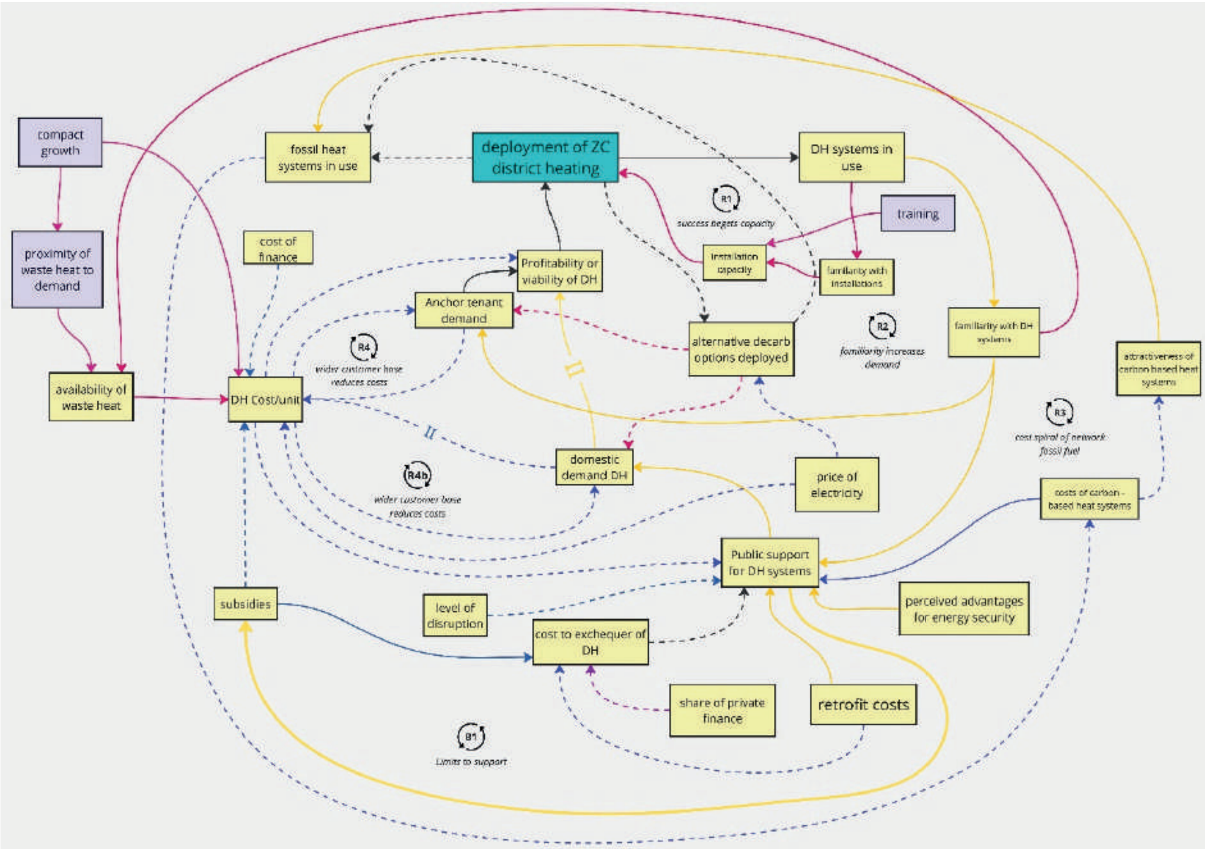
Annex 1: Detailed Variable Renewable Deployment Map



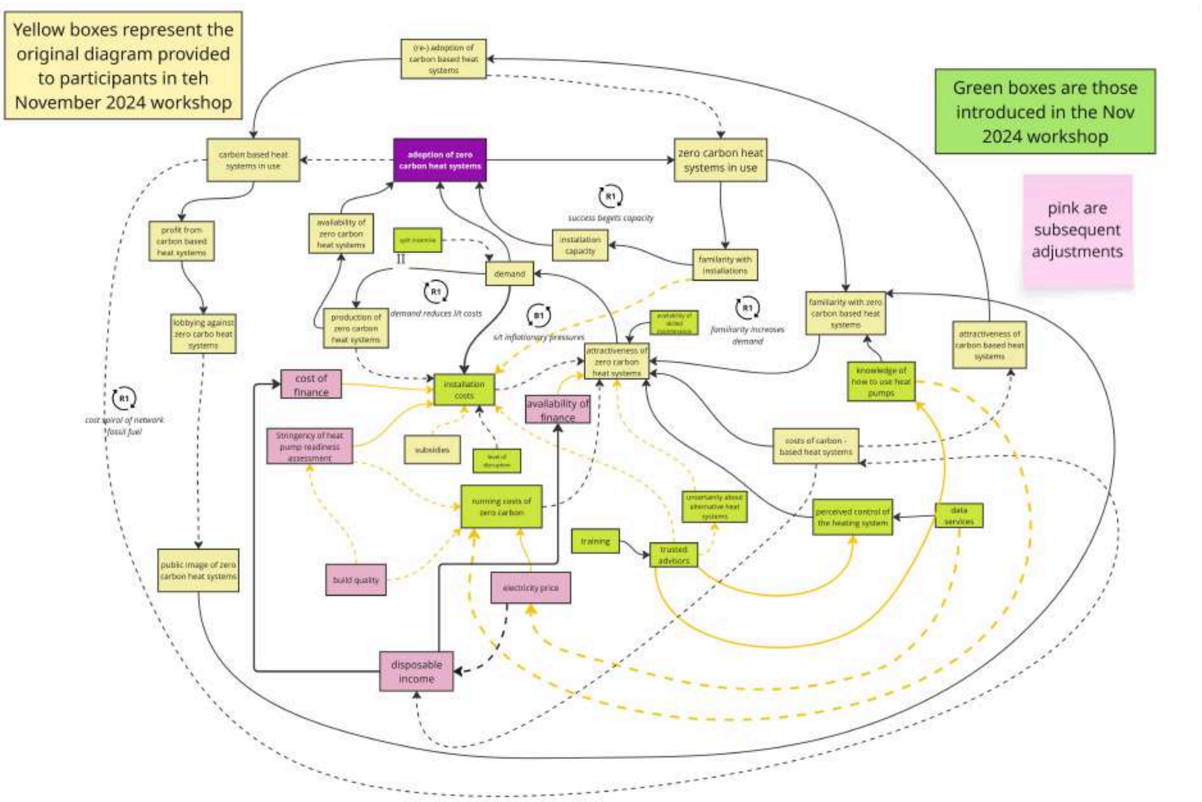
Annex 2: Zero Carbon Fuels Map



Annex 3: District Heating Detailed Map



Annex 4: Heat Pump Deployment Map



Annex 5: Workshop Participants' Organisations

First NESC Energy Systems Workshop November 2024, Dublin

Bord na Móna
Climate Change Advisory Council
Secretariat
Dublin City University
Department of Environment, Climate
and Communications
Demand Response Association of Ireland
Department of Enterprise, Trade and
Employment
Department of Public Expenditure, NDP
Delivery and Reform
Dublin City Council
Electricity Association of Ireland
EirGrid
Electricity Supply Board (ESB)
Friends of the Earth
Gas Networks Ireland
Irish Business and Employers
Confederation
Irish Cooperative Organisation Society
Industrial Development Agency (IDA)
Ireland
Irish Doughnut Economics Network/BDT Consultancy
LeBruin Private
National Youth Assembly
National Economic and Social Council
Northern Ireland Housing Executive
Orsted
Progress Ireland
Sustainable Energy Authority of Ireland
Social Justice Ireland
System Operator Northern Ireland
(SONI)
Trinity College Dublin
The National Participation Office
University College Cork
University College Dublin
University of Bergen

Second NESC Energy Systems Workshop April 2025, Dublin

Bord na Móna
Climate Change Advisory Council Secretariat
Dublin City University
Department of Environment, Climate and Communications
Demand Response Association of Ireland
Department of Enterprise, Trade and Employment
Electricity Association of Ireland
EirGrid
Electricity Supply Board (ESB)
Friends of the Earth
Gas Networks Ireland
Irish Business and Employers Confederation
Irish Cooperative Organisation Society
Industrial Development Agency (IDA) Ireland
Irish Doughnut Economics Network/BDT Consultancy
LeBruin Private
National Economic and Social Council
Sustainable Energy Authority of Ireland
Social Justice Ireland
System Operator Northern Ireland (SONI)
University College Cork
University College Dublin
University of Bergen

Energy Demand Management Roundtable: Participants' Affiliations

NESC
Social Justice Ireland
Demand Response Association
Department of An Taoiseach
Department of Enterprise, Trade and Employment
Friends of the Earth
SEAI
DCEE
Feasta
CRU
Department of Transport
Independent expert
UCD

Annex 6: Workshop Vignettes

Congratulations! It's 2050 and Ireland has achieved a zero carbon energy system with no fossil fuels. In fact the world as a whole has managed to limit climate change to under 2O degrees Celsius and Ireland was a leading light in this. Ireland's success in transition is known globally for achieving its energy transformation not only through a just transition but also enhancing wellbeing while respecting planetary boundaries and supporting a thriving natural world. Energy deprivation is a thing of the past in Ireland while the industry and entrepreneurial sectors are in good health. Ireland is well respected globally and has many friends across all countries (including the most vulnerable) due to the technical assistance it provides abroad on energy issues and moreover due to Ireland's commitment to not export environmental problems but rather address them at home and through ethical trade with countries and communities internationally.

Households

You are an environment and energy journalist from Iceland taking unpaid leave in Ireland for a year and plan to earn some money by sending home to an Icelandic newspaper some lifestyle articles about Ireland over the course of the year. You have now been living in Ireland for a couple of months. You have sorted out your accommodation (there were a lot of nice, fairly priced options), and you have sorted out your utilities; media, heat, power etc. This has been an eye opening experience. You find it interesting because, although it is very different, it is easy to manage despite the advanced technologies. You decide to prepare a lifestyle article about energy in Ireland from an individual perspective and how one connects with, uses and contributes to the system throughout the day and across the seasons. You note the features that ensure minimal planetary impacts, perhaps even some positive impacts, and other features that protect vulnerable users. Some features are fun and other features make you feel like you are part of the Irish community.

Task: Prepare a 3 minute pitch for your lifestyle article to the Icelandic editor who you will meet in VR later today. Tell your editor, are energy features in an Irish home visible, how you pay for your energy, is energy affordable? Your editor is also interested to know whether you feel any obvious or subtle constraints on how much or when you use? Is the energy supply reliable throughout the day or even in bad weather?

If it helps, you can situate your journalist in a real or made up location in Ireland. You can assume that Iceland's energy system is supported entirely by geothermal and dispatchable zero carbon electricity.

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Rural

You are a lonely planet journalist, travelling around Ireland in 2050. You are interested in environmental and energy issues (everyone is these days) – you come across so many examples of how countries took different routes to decarbonisation, some with more success than others. You have arrived in a rural location that seems to embody how enviable Ireland's zero fossil fuel, zero carbon energy system is. You can see it in the landscape in front of you. Zero carbon solutions are woven seamlessly into a countryside that is both productive and rich in nature. Of course, a lonely planet article in Ireland is not complete without some reference to the locals and the social fabric of the place. People here seem to have a good life and are proud of their locality and their role in the energy system.

Task: You have a phone call with your editor later today. Your editor has never visited Ireland but is an energy system enthusiast. What do you tell your editor about what you have seen and heard? Is energy production and infrastructure visible in the landscape? If so, how is it compatible with agriculture, other land uses and a thriving natural world? Who benefits from energy production and how? How are ongoing technology and energy costs paid for? What makes the locals proud of their locality and their role in the energy system? Do the locals play an active or passive role in the national or local energy system? Is energy affordable?
You can choose a real or made up location for your story.

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Urban

You are a journalist with the Dallas Tribune, visiting one of Ireland's cities in 2050. You are excited about this trip because this city is legendary for its great atmosphere and 'the craic'. However, your real focus for the article you are writing is the social and environmental fabric of the city. You want to give readers a sense of what makes this great city 'tick' and the energy system seems to be a fundamental part of it. Interest in energy is really high at the moment because some countries were more successful in achieving a 'good decarbonisation' than others like Texas. The people in this city seem to be protected from the fluctuations in global energy markets. They have adapted to relying on variable renewable energy in interesting ways and can still support a thriving society and economy. The concept of reliability seems a little different here, while energy users also take some responsibility in the energy balance. Public buildings like hospitals are interesting case studies because of course a reliable energy and heat supply is vital but how they managed that here is really innovative.

Task: You set up a call with your editor to pitch what is so interesting about the energy system in this city. Your editor doesn't know anything about Ireland, so you'll have to start with the basics. Is the energy system visible in the city? Do urban dwellers and businesses have an active role or passive in energy? Do urban dwellers and businesses have the traditional relationship with utilities, seen in other countries, or are there new models of heat and power provision here? Do vulnerable users have extra protections or does the energy system protect vulnerable users by design?

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Business Park

You are an employee of the IDA. A space has become free in Ireland's landmark business park. There is already a waiting list of applicants, so advertisement is not necessary to fill the slot. However, with a view to maintaining Ireland's reputation on the international stage, your manager has tasked you with preparing a blurb for the business park, outlining how efficient and attractive it is as a location for business. A key part of 'the offer' is how well the zero carbon, zero fossil fuel energy system works for this business park – this is a strong selling point for Ireland these days as not every decarbonised energy system works so well. Added selling points include the ease of setting up in Ireland, and how the business park actually supports local nature. The business park is a favourite among circular economy enthusiasts (the trainspotters of 2050), so it will be important to include something on that. Of course these days, it is usual to talk about businesses being heat suppliers or consumers or sometimes both. Explain the mix of enterprises currently in the energy park and how that affects/effects the local energy system and its efficiency.

Task: Your manager wants you to prepare a '3 minutes to camera' vlog today.
If it helps you can choose a location for your business park and discuss how the success of the business park's energy system is connected to the local community, services and environment whether that is a coastal location, the 'sunny south east', close to interconnectors, close to renewables, close to centres of employment/residential etc.

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Energy Sector

You are senior management in one of Ireland's energy utilities. You have been invited for a rare in-person global trade conference on improving the operation of zero carbon energy systems around the world. The conference convenors want you to explain the success of the business model in Ireland and the expertise that we share across the world. Ireland is seen as a leader in effective zero carbon energy systems with happy consumers, happy suppliers and thriving nature. Energy deprivation has been eliminated. Your international colleagues want to know how it all works? How do you earn enough revenue to keep the energy system in tip-top shape? How have you maintained sufficient reliability of the system, including for critical customers like hospitals and vulnerable customers without falling back on fossil fuels? You should also explain for your international colleagues how the Irish energy sector is different or similar to other countries in terms of size, concentration, distribution, number of participants and outline the advantages and challenges in the current make up.

Task: You will be speaking to an energy sector audience so you can get a little bit technical but need to bear in mind that since AI translation was outlawed in 2042, you will need to be mindful of jargon. Also the conference organisers, in their wisdom, have put you in the slot just after lunch, so you will need to keep people awake. Maybe if you give a good presentation, you'll get a better slot next time.

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