Spine H2-IRL

Monday, April 8, 2024

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Grant number 22/RDD/812

About Energy Reform

Introduction

Energy Reform is a boutique consultancy with over 25 years' experience providing advanced modelling services and advice in support of the energy transition.

History

Born out of the leading-edge research at the Electricity Research Centre, headed by Professor Mark O'Malley at University College Dublin, Energy Reform has built a strong reputation for applying leading edge research in the area of renewables and energy system integration to real world problems.

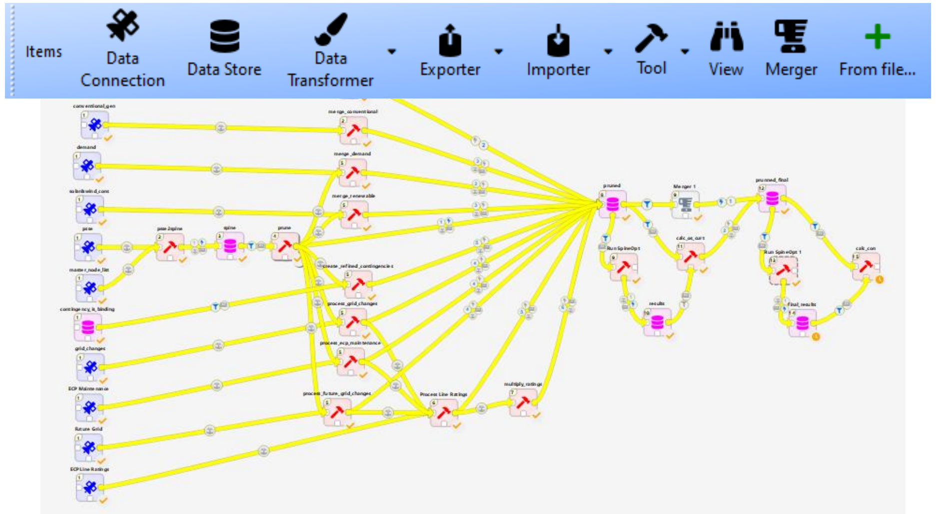
Highlights

- ER has been involved in numerous groundbreaking studies examining the impacts of high-RES-E scenarios in power and energy systems worldwide including the all-Island grid study and TSO facilitation of renewables study
- Represents Ireland on IEA Wind Task 25, "The design and operation of power systems with large amounts of variable renewable power" and co-authored best practices for renewable integration studies
- US Department of Energy Wind Research Program Peer Reviewer since 2016
- We have carried out numerous innovative modelling studies demonstrating the value of flexible technologies in supporting the energy transition resulting in over €115m grant funding for our clients
- Member of the research council of the Global Power System Transformation (G-PST)

The Spine Open-Source Framework for Energy System Modelling

Spine Toolbox

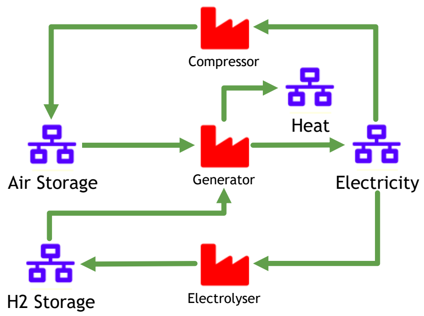
Comprehensive multi-tool and workflow management



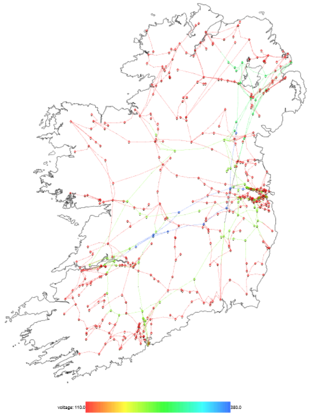
- Create and manage coherent, repeatable, complex workflows
- Manage, convert and manipulate data
- Store and access data in a centralised, problem independent
- Link models

SpineOpt

Richly featured and uniquely flexible energy system model



SpineOpt CAES Model



SpineOpt Irish Grid and Market Model

- Flexible structure allows technologies to be represented at an arbitrary level of detail
- Uniquely flexible approach to time and uncertainty giving finer control of model dimensions
- Methodologies to capture more scope and more detail
- Co-optimise investments, markets, operations and grid

Spine H2-IRL

Relevant Research Projects

Spine **Open-source toolbox for modelling integrated energy systems**

Designed from the ground up to address the workflow and modelling requirements of the energy transition.

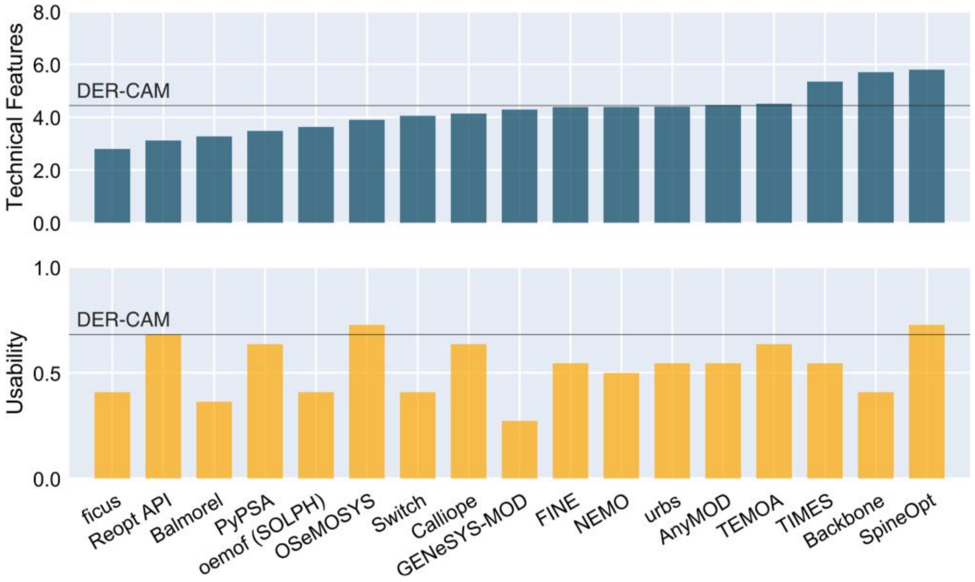
- Ran from 2017 to 2021
- 5 Partners
- Budget €4m over 4 years.

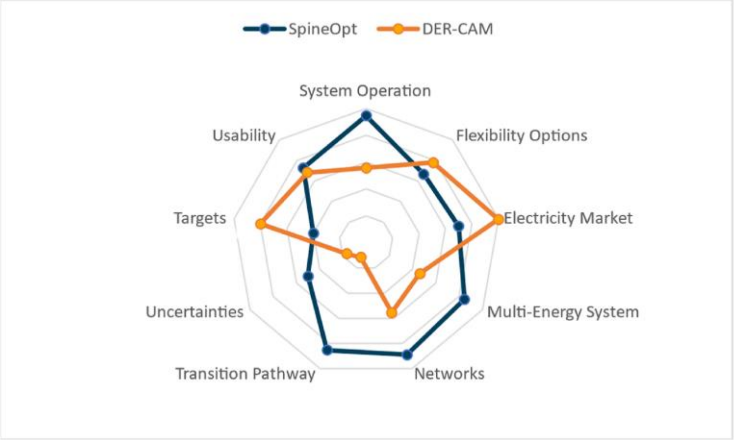
mopo **Comprehensive, fast, user-friendly and thoroughly validated open-source energy system planning framework**

Focus on usability, performance, reliability and data.

- From 2023 to 2027
- 15 Partners
- Budget €6m over 4 years.

Independently ranked the most capable, usable tool for energy system planning





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Review

Critical review of energy planning models for the sustainable development at company level

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ABSTRACT

Companies in the manufacturing, service and transport infrastructure sectors will play a key role in the sustainable transition of the energy system implementing innovative technologies at full industrial scale. However, developing long-term investment plans is a challenging task, complicated by the volatility of energy markets and the uncertainties induced in the policy landscape by the recent energy crises. In this respect, mathematical models can support the transition of industrial systems, steering the planning process. In this work, we review and evaluate the suitability of available models to serve this purpose. The availability of modelling tools for local energy planning has already been assessed by several works. However, the tools which are most frequently employed at this scale are generally unable to characterise the evolution of the energy system in the long term, they have a focus on the operational aspects of the system, and are, in many cases, proprietary. By contrast, all the models examined in this review are open source, and the investigated set also features tools able to capture long-term dynamics. Our results provide evidence that several tools could offer valuable insights to the planning process. Nevertheless, a trade-off between the representation of long-term dynamics and the modelling of key aspects of the energy system of a company is, to date, inevitable. The best compromise is offered by a small group of multi-scale tools, able to conjugate a long-term perspective with a detailed modelling of the operational aspects of the system.

1. Introduction

The 26th Conference of the Party held in 2021 in Glasgow (COP26) witnessed an unprecedented participation of the private sector. After the release of the Sixth Assessment Report of the IPCC, it has become clear that the joint effort of the public and private sectors is needed to keep global temperature from rising above 1.5 °C. As the engagement of businesses increases, it is expected that more and more companies will have to commit to net-zero emission targets in the near future [1]. While this is already a reality in the UK, where listed companies will have to publish their net-zero strategies by 2023 [2], the call for the development of Corporate Determined Contributions made by the WBCSD at COP26 also points in this direction [3].

One key action companies can take to directly reduce their carbon footprint is revisiting the way they source and produce energy. Albeit energy is fundamental for any commercial activity, its related emissions make up the lion's share of the carbon budget of most businesses. Investing in on-site or off-site renewable generation and energy efficiency projects, switching to renewable or low-carbon fuels, purchasing green electricity from the market, are among the viable options to improve the environmental sustainability of a company. However, the radical transformation of the energy system can be a challenging task for an enterprise. Many external factors, like the sustained increase of the costs of fossil fuels and electricity, the volatility of power and carbon price, as well as the unprecedented deployment of new technologies, call for the establishment of a robust planning methodology. In this perspective, it is essential to provide companies with the appropriate tools to develop their energy strategies. These tools should be able to conjugate a long-term vision [4] with the impellent necessities dictated by the recent energy crises.

Energy System Models (ESM) could provide the necessary analytical tools to manage complexity [5]. ESM have a long history in supporting decision-making at national and international level [6–8]. Though their focus remains on large-scale systems [9], their application to local energy planning has received growing attention over the last two decades [10,11]. The definition of local or Distributed Energy System (DES) encompasses a wide range of spatial scales: from a single building or factory, to an urban district, up to entire cities and regions [12]. Given their scope, DES models could be suited for the analysis of the facilities

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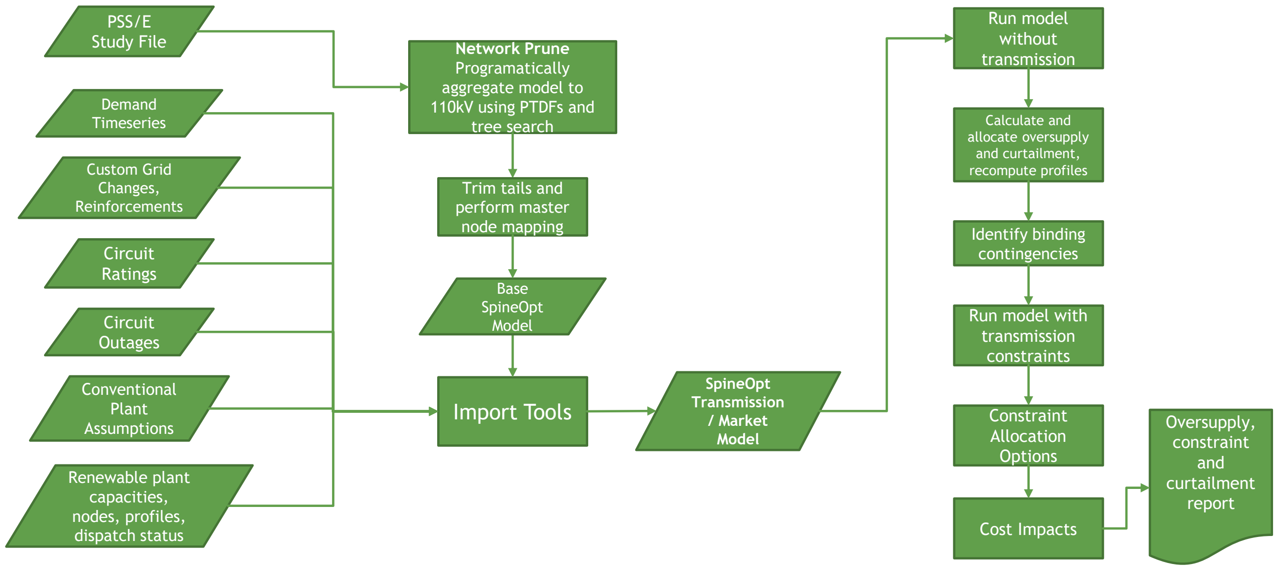
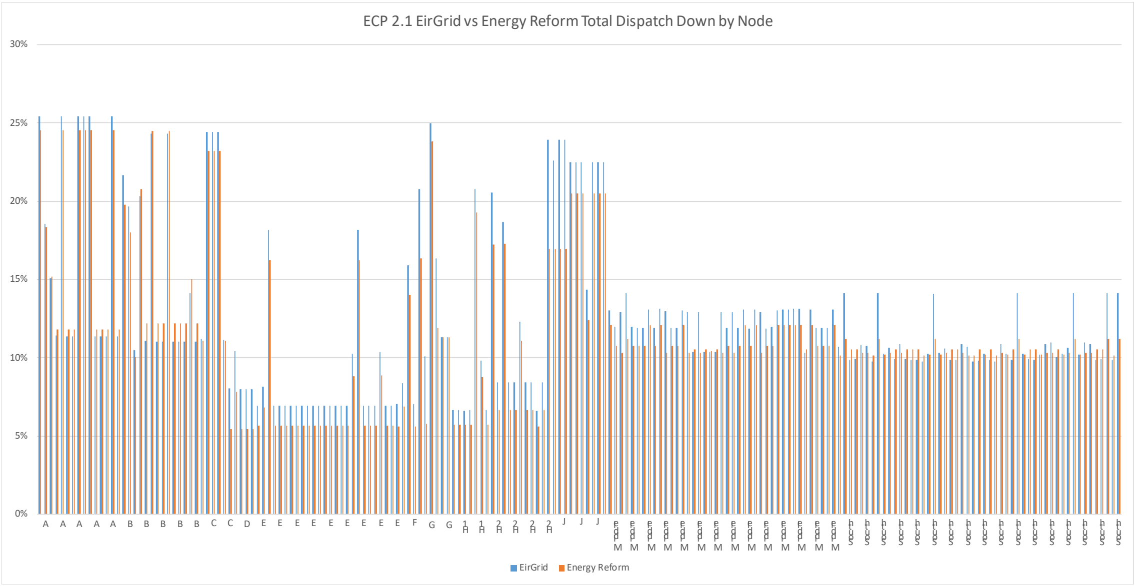
Spine H2-IRL

Example Spine Workflow





Programmatic creation of combined market and grid model and calculation of oversupply, curtailment and constraint

Validation against EirGrid ECP 2.1 Constraint Report results

Spine H2-IRL

Spine H2-IRL Project Overview

- Explore the potential role of Hydrogen in the Irish energy sector
- Identify viable Hydrogen development pathways for Ireland
- A focus on adequacy
  - Security of Supply
  - Resiliency
  - Flexibility
  - Network Infrastructure

Spine H2-IRL

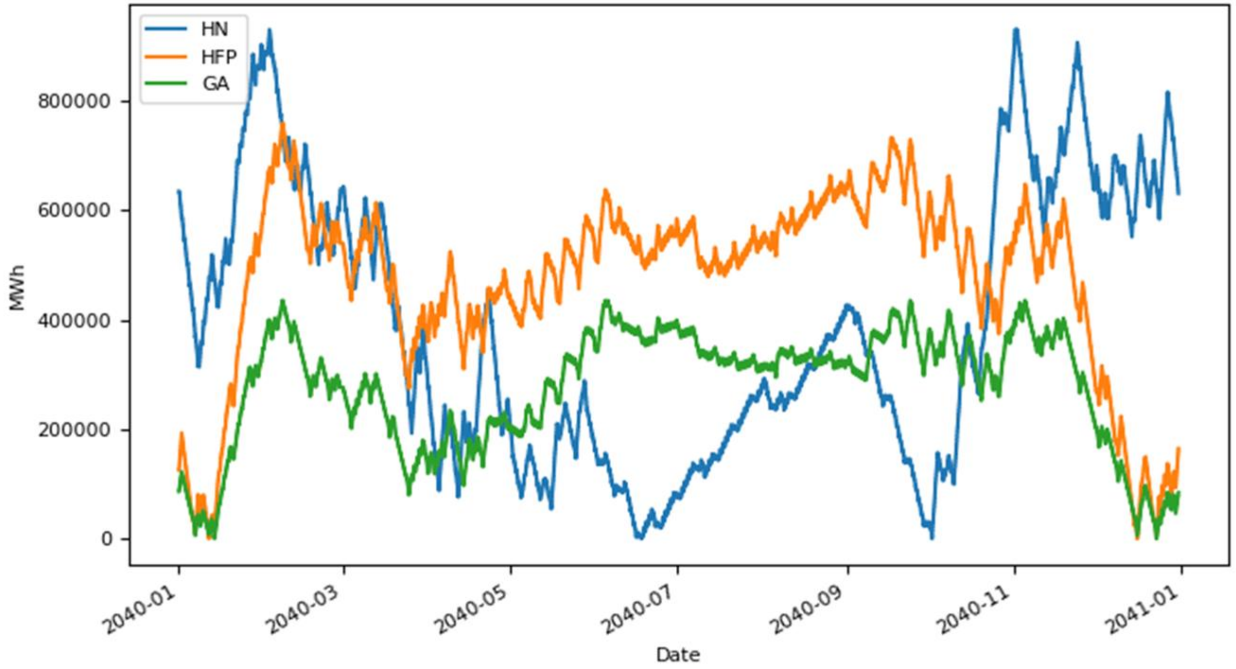
- Build on previous work with more targeted scenarios, informed by the National Hydrogen Strategy & stakeholder input
- Expand existing Spine models to ensure system flexibility requirements and network constraints are adequately considered as part of the long-term pathways model
- Develop new capabilities within Spine to enable comprehensive reliability assessments
- Open Models – available to Irish researchers, facilitating further innovation and work on the energy transition

Aims & Limitations

- Co-optimisation of hydrogen production, electricity generation, electricity and hydrogen networks, considering flexibility and security requirements
- Valuable insights into the scale of network development required (and cost of limited development)
- Considerable uncertainty surrounding costs, performance, infrastructure, extent of electrification
    - Comprehensive sensitivity analysis beyond the scope of the project
- Carefully selected scenarios, with expert stakeholder input and collaboration with HyLIGHT project
- Open Models published at the end of the project to facilitate further analysis

Background - Spine Case Study C3

- Explored pathways for Hydrogen investments in the Irish energy system
- Focus on long-term hydrogen storage (demonstrating capabilities of SpineOpt)
- Short-term operational details considered as part of the long-term investment problem
- Investments in hydrogen production, electricity generation, long-term storage all co-optimised



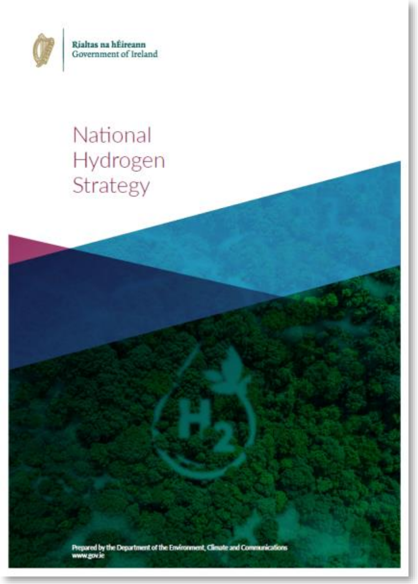
Co-optimisation of short term and seasonal use of H2 storage in Spine Case Study C3, possible using SpineOpt

Resulting peer reviewed publication:

O'Dwyer, C.; Dillon, J.; O'Donnell, T. Long-Term Hydrogen Storage—A Case Study Exploring Pathways and Investments. *Energies* **2022**, *15*, 869. https://doi.org/10.3390/en15030869

Spine H2-IRL – What’s new?

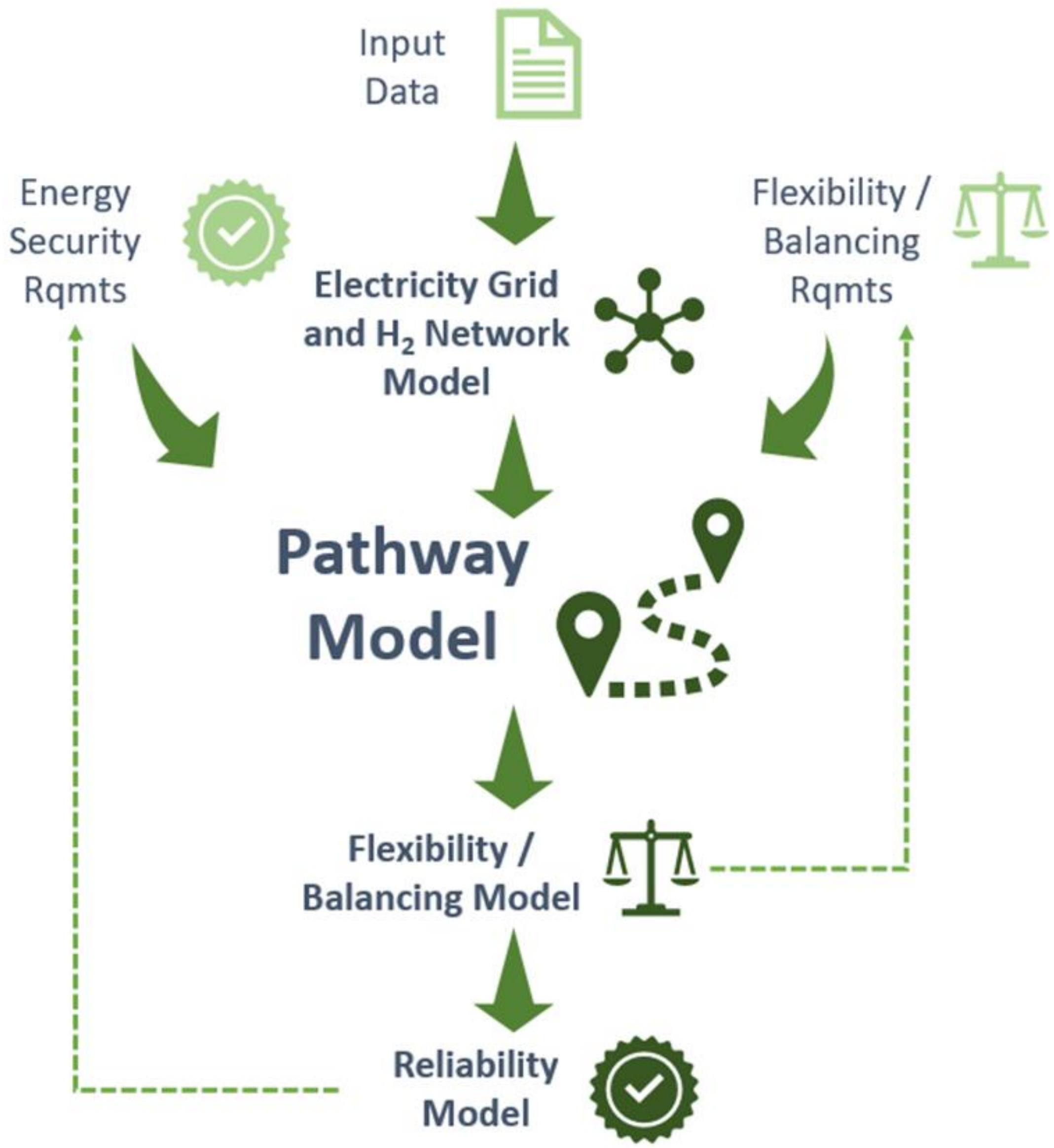
- Network Detail (Electricity & Hydrogen)
- Flexibility assessment
- Reliability assessment
- Updated hydrogen scenarios & assumptions



DCU Ollscoil Chathair Bhaile Átha Cliath Dublin City University

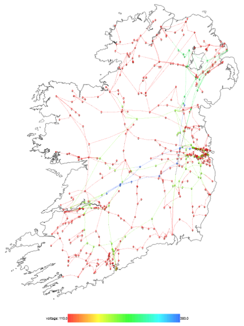
HyLIGHT

Spine H2-IRL Workflow



Electricity Grid and Network Model

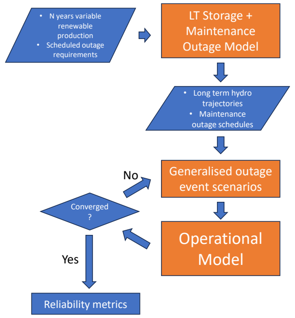
Power market modelling with full transmission representation including N-1 secure dispatch and commitment. Replicate oversupply, constraint and curtailment results in arbitrary future scenarios



Combined grid and market model

Reliability Model

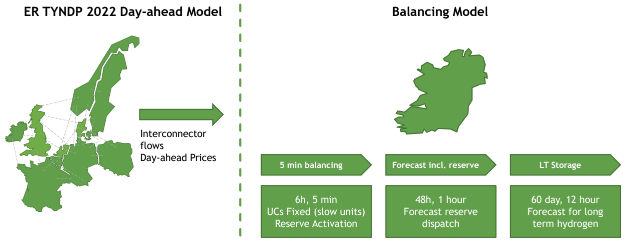
Development of models and tools to study energy system reliability. E.g. capacity outage probability table approach and Monte-Carlo-based methods



New Resource Adequacy Framework

Flexibility / Balancing Model

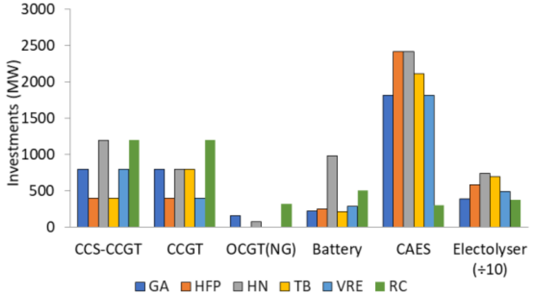
Modelling of day-ahead, intraday and balancing markets across Europe for revenue forecasting across multiple markets and value estimation for financing and grant support



Modelling of day-ahead, intraday and balancing market

Pathway Model

Modelling of the evolution of the energy system to achieve high-level targets such as decarbonisation and renewable transition.



Role of Hydrogen-based technologies in the future Irish system

Spine Models

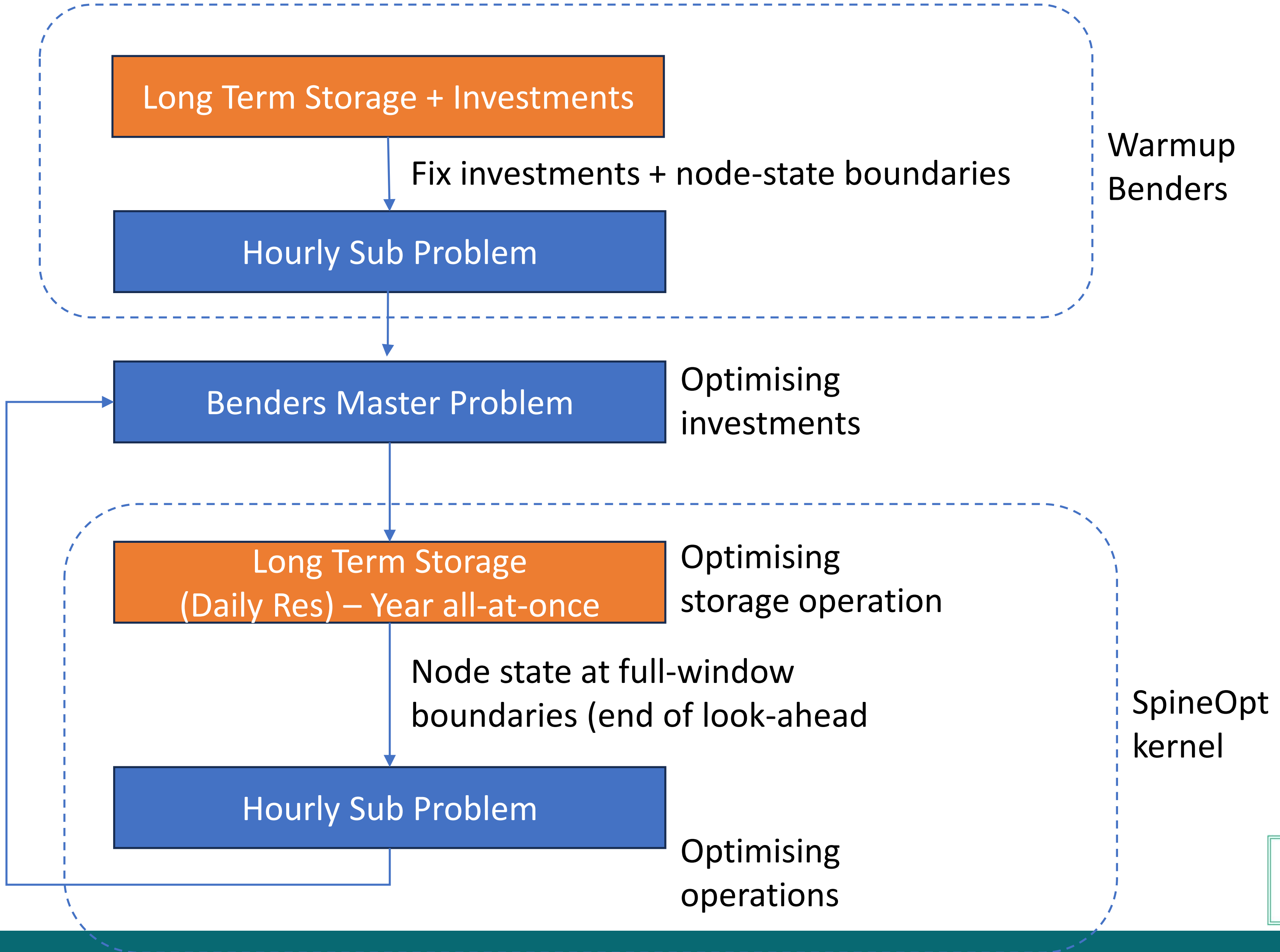
Spine H2-IRL

Pathway Model

SpineOpt model optimised for investments and long term storage

SpineOpt model optimised for operational detail

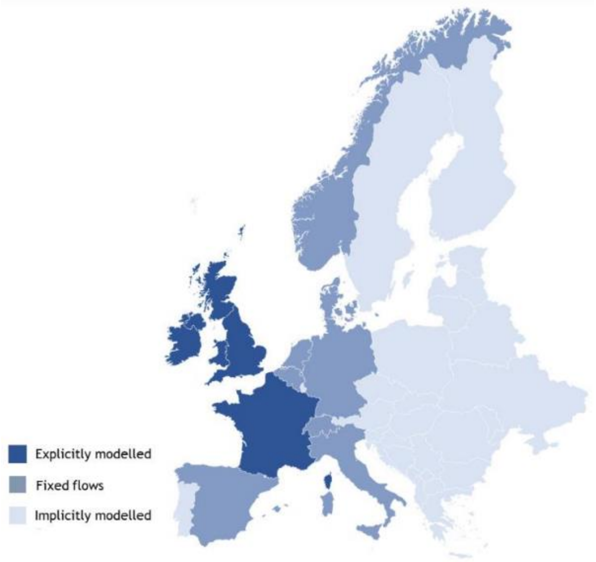
Use Benders decomposition to refine investments using impact on operational costs from operational model

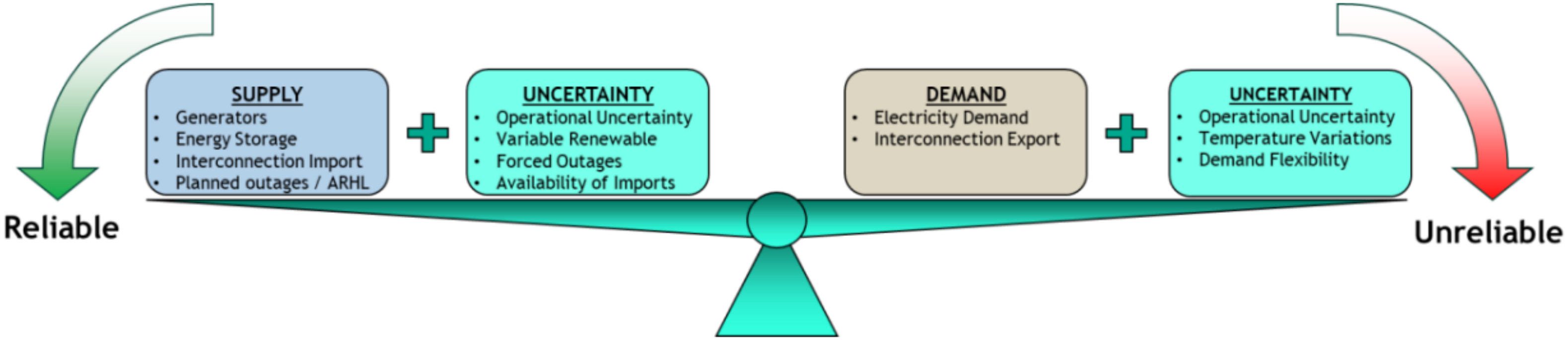


Spine H2-IRL

Reliability Assessment

- Energy Reform have an existing relabialbe model based on the Capacity Outage Probability Table approach
- Intention in SpineH2IRL is to develop a monte-carlo based approach for reliability assessment compliant with NRAA in SpineH2Irl and Mopo
- This will link with ER's European system model





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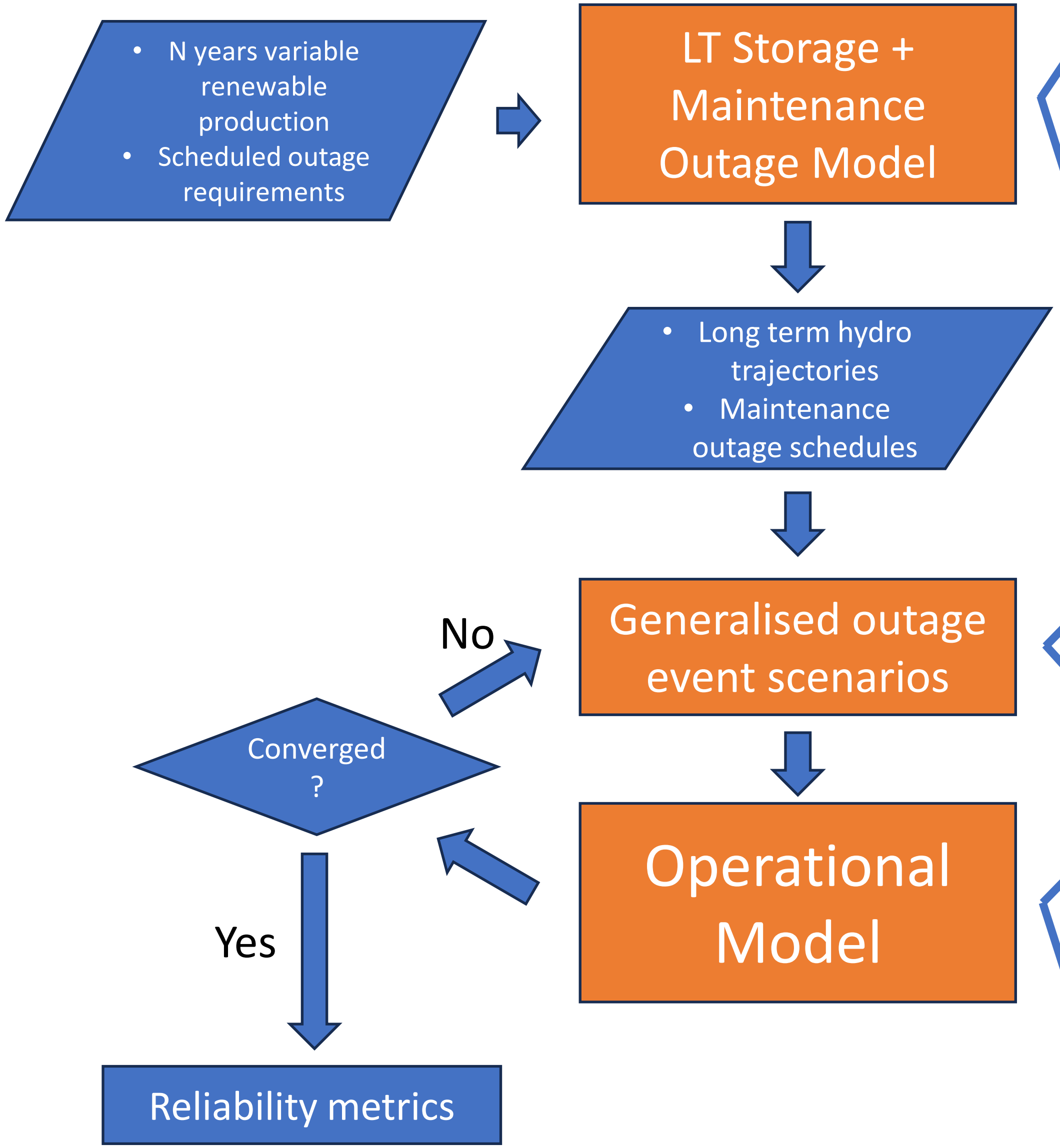
Reliability Model Design



- SpineOpt model configured to optimise long duration storage
- Leverages model update-in-place functionality
- Uses newly developed outage scheduling functionality and capacity constraints

- Enables generalised approach to reliability assement in the future system

- SpineOpt operational model optimised for fast solve
- Leverages model update-in-place functionality
- Leverages efficient rolling model functionality

Key Points

mopo

Developed in collaboration with the Mopo Horizon Europe Project

- New approach needed to study the future system with additional sectors and long-term storage such as H_2
- Leverages SpineOpt's flexibility to enable a generalised resource adequacy assessment
- Leverages SpineOpt's model update and rolling functionalities to efficiently evaluate many outage event scenarios
- Leverages SpineOpt's flexibility so the same model is used in different configurations

Scenario Consultation

Business as Usual	No Net Zero target. Fossil fuel generation remains online. No further transmission expansion or hydrogen pipelines.
Electricity Network	Net Zero target for electricity. Electricity transmission expansion introduced.
Hydrogen Network	Net Zero target for electricity. Hydrogen pipeline expansion introduced, along with large-scale underground hydrogen storage
Full Network	Net Zero target for electricity. Electricity transmission and hydrogen pipeline expansion both facilitated, along with large-scale underground hydrogen storage
Technology Breakthrough	As Full Network, with a further assumption that costs for hydrogen investments have fallen to lower bounds of future estimates
Alternative Net Zero	Net Zero target remains in place, without large scale hydrogen. LDES plays an important role. Limited use of fossil fuels is also permitted, balanced with BECCS

Scenario Report issued in March for consultation across a wide group of industry stakeholders

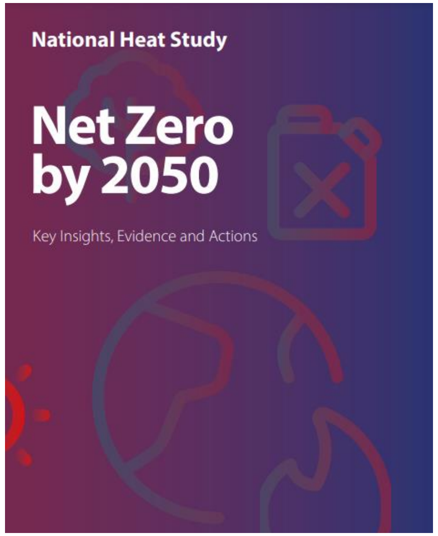
Spine H2-IRL

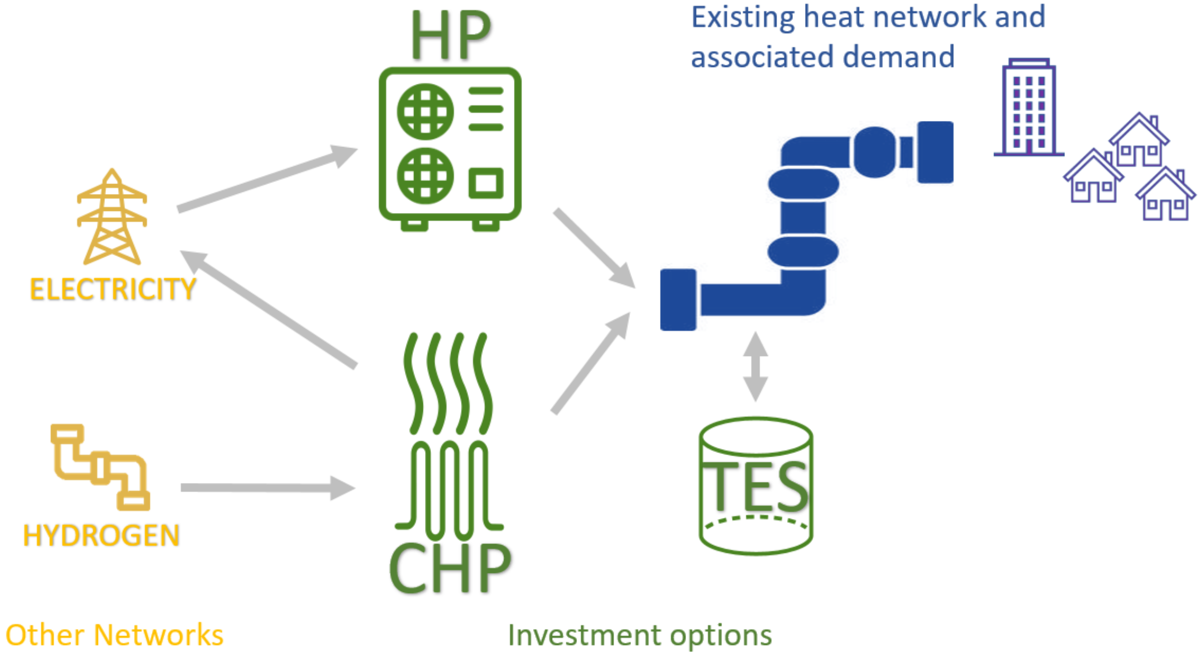
Spine H2-IRL Scenarios

	Fossil Fuel Generation	Electricity Network Expansion	Hydrogen Network Expansion	Hydrogen Demand	Hydrogen Storage	Hydrogen Investment Costs	Net Zero
Business as Usual	✓	✗	✗	●○○		€€€	✗
Electricity Network	✗	✓	✗	●○○		€€€	✓
Hydrogen Network	✗	✗	✓	●●●		€€€	✓
Full Network	✗	✓	✓	●●●		€€€	✓
Technology Breakthrough	✗	✓	✓	●●●		€€	✓
Alternative Net Zero	?	✓	✗	●○○		€€€	✓

District Heating

- Potential source of flexibility combined with TES
- Could provide valuable balancing opportunities – particularly for the Alternative Net Zero scenario
- Potentially fuelled by hydrogen
- Propose to assume a level of heat demand to be supplied by DH
- Assume network exists – common to all scenarios
- Allow investments in TES and different alternatives for heat generation
  - heat pumps
  - CHP





Spine H2-IRL Investment Options

												Heat Network Options		
	Gas CCGT / OCGT	H2 CCGT / OCGT	BECCS	Wind / Solar Gen	Batt (4-8h)	LDES (25-100h)	Elec Net-work	H2 Net-work	Electro lysers	H2 Tank	H2 Under-ground	TES	Large Scale HP	CHP
Business as Usual	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✗	✓	✓	✗
Electricity Network	✗	✓	✗	✓	✓	✗	✓	✗	✓	✓	✗	✓	✓	✗
Hydrogen Network	✗	✓	✗	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓
Full Network	✗	✓	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
Technology Breakthrough	✗	✓	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
Alternative Net Zero	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✗	✓	✓	✗

Base Portfolio – Before Investments

	Capacity Ireland (MW)	Capacity All-Island (MW)
Pumped Hydro Storage	292	292
Waste	79	94
Run-of-River Hydro	216	216
Onshore Wind	9000	11750
Offshore Wind	2000	2500
Offshore Wind (non-grid)	2000	2500
Solar	7000	7800
DSU	750	1000
DC Interconnectors	2450	3650

Assumptions – Fuel prices, Demand

	Ireland	Northern Ireland
Carbon Price (€/tonne)	147	
Gas Price (€/GJ)	5.7	
Operational Limit for Inertia (MWs)	20,000	
Demand TER* (TWh)	80	22
Demand Peak* (GW)	10	3.5

* Demand figures exclude electrolyser demand

Sources include TES, GCS, ENTSO-E TYNDP 2024

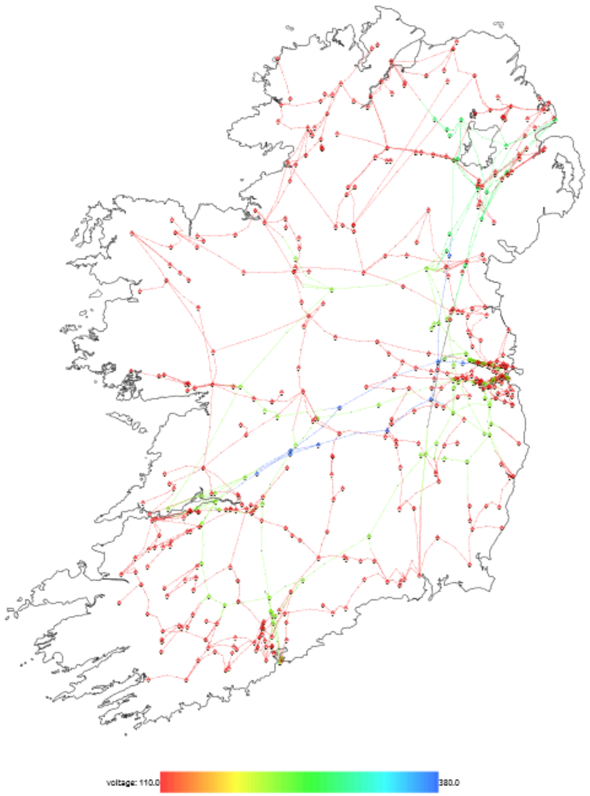
Spine H2-IRL

Core Hydrogen Assumptions

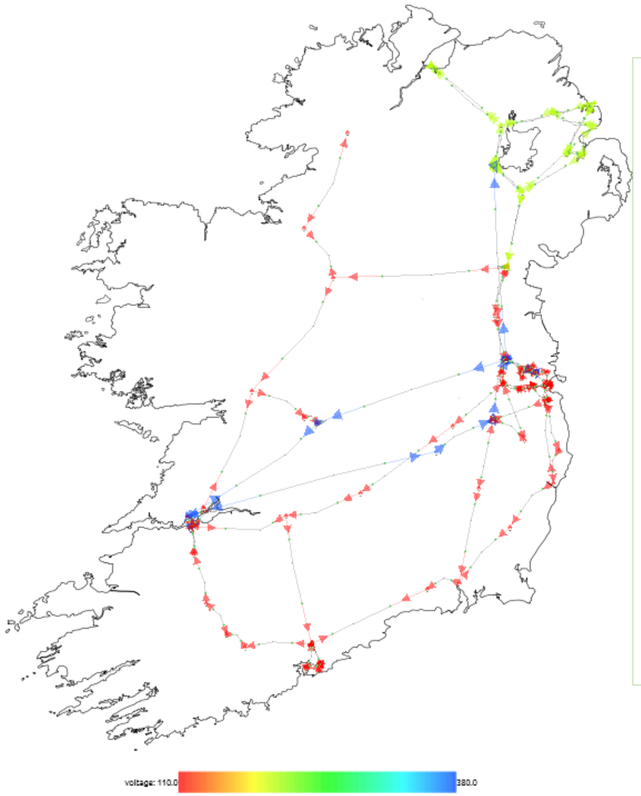
- Hydrogen hubs – locations and demand (2 levels, excluding power gen) informed by HyLIGHT
- Hydrogen storage, electrolysers and electricity generators all investment decisions
- Large-scale underground storage considered as investment option in scenarios with hydrogen network
- For scenarios with hydrogen network expansion, pipelines can be invested in, connecting clusters.
- Generally, assume new pipelines / repurposed for TB scenario
- For initial analysis, no import / export

Electricity & Hydrogen Network

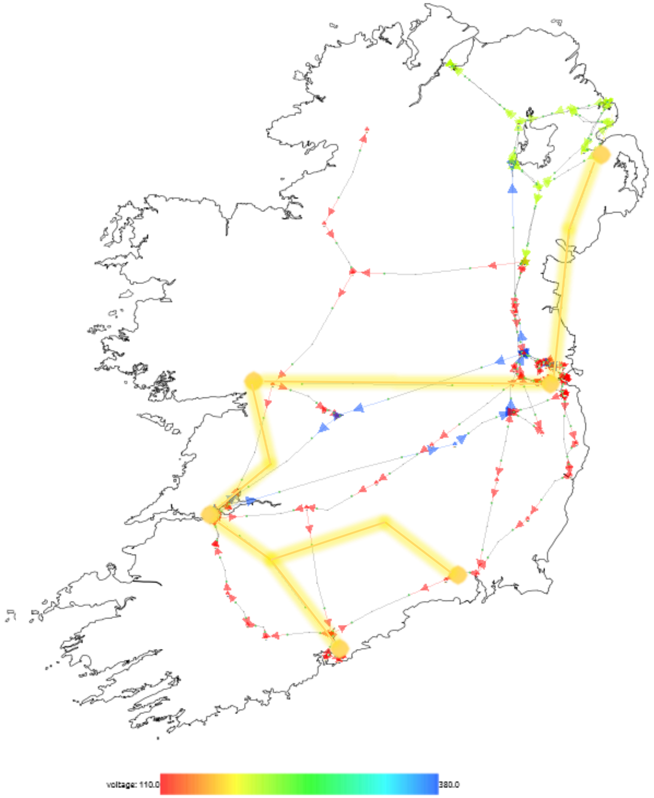
- Starting point is Energy Reform's detailed combined electricity grid and market model
- Detailed electricity and gas network physics are considered
- Leverages Spine's network reduction functionality to reduce computational burden



220 kV +



H_2 Network



Spine H2-IRL

Feedback

- Feedback on Scenarios
- Hydrogen assumptions
- Power system assumptions
- Input data
- General methodology
- Network approach
- Reliability assessment

Thank you

THIS PRESENTATION HAS BEEN SUPPORTED WITH FINANCIAL CONTRIBUTION FROM SUSTAINABLE ENERGY AUTHORITY OF IRELAND UNDER THE SEAI RESEARCH, DEVELOPMENT & DEMONSTRATION FUNDING PROGRAMME 2022, GRANT NUMBER 22/RDD/812