SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Net-zero by 2050:

An exploration of decarbonisation pathways for heating and cooling in Ireland

Annex to Final Report of the National Heat Study – Model Description

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The National Comprehensive Assessment for Ireland was commissioned by a project team across the SEAI Research and Policy Insights Directorate and developed with the assistance of Element Energy and Ricardo Energy and Environment.

Disclaimer

Sustainable Energy Authority of Ireland

SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with the public, businesses, communities and the Government to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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Introduction

SEAI's National Energy Modelling Framework (NEMF) is a full national energy-economy model that assesses the impacts of packages of energy policies and measures (PaMs) on energy supply and demand. It combines several SEAI sectoral models with data from the Economic and Social Research Institute (ESRI)'s Ireland Environment, Energy and Economy (I3E) macroeconomic model to produce policy-rich outlooks for the whole energy system.

The archetype model within the NEMF contains data on 680 individual heat demand archetypes, representing a combination of physical and consumer attributes, which in turn provide a detailed description of demand in residential, services and industry sectors, as well as agricultural energy use. The NEMF can also be used to examine variation in technology readiness, technical suitability, cost data, and performance data to assess various scenarios (including potential decarbonisation paths) in Ireland.

Technology suitability and performance are mapped to each archetype and the model contains representations of bioenergy and hydrogen resources and fuel supply chains as well as an infrastructure module that calculates the costs of infrastructure deployment linked to technology uptake. The model uses this techno-economic data to generate payback and lifetime cost estimates for the various technology options available, accounting for policy incentives, taxes, and regulations. This payback and lifetime cost information is used with other data on consumer decision-making behaviour to simulate how much uptake may result in various scenarios and in response to policy measures and what impact a given set of policy measures can have on the energy system. Where technology deployment is based on centralised decisions, these are accounted for outside of the consumer decision-making framework: industrial Carbon Capture, Utilisation and Storage (CCUS) and district heating are dealt with in this way.

A high-level outline of NEMF is shown in

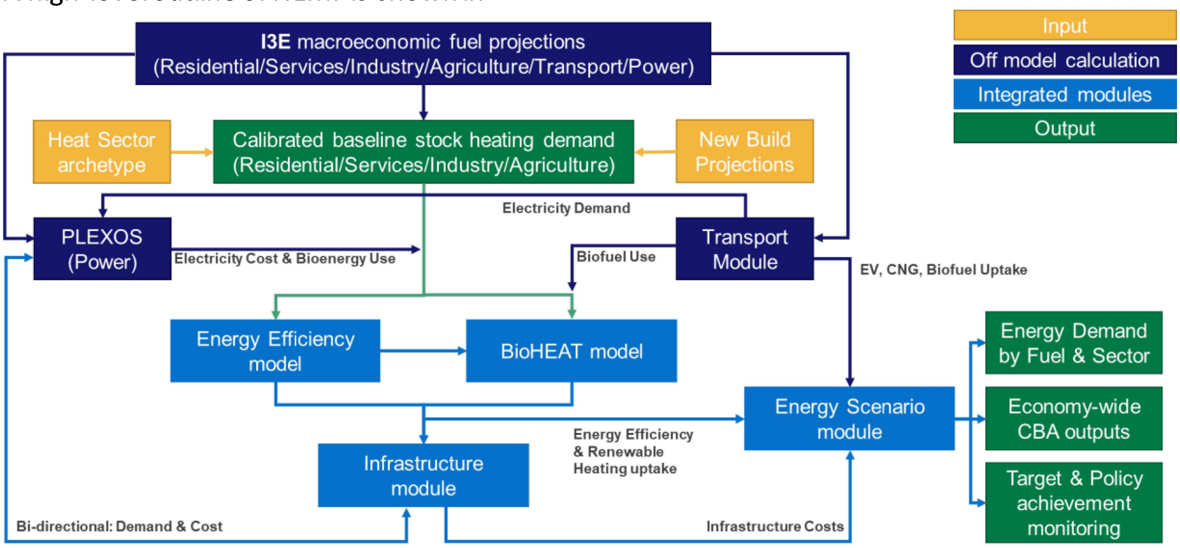

Figure 1.

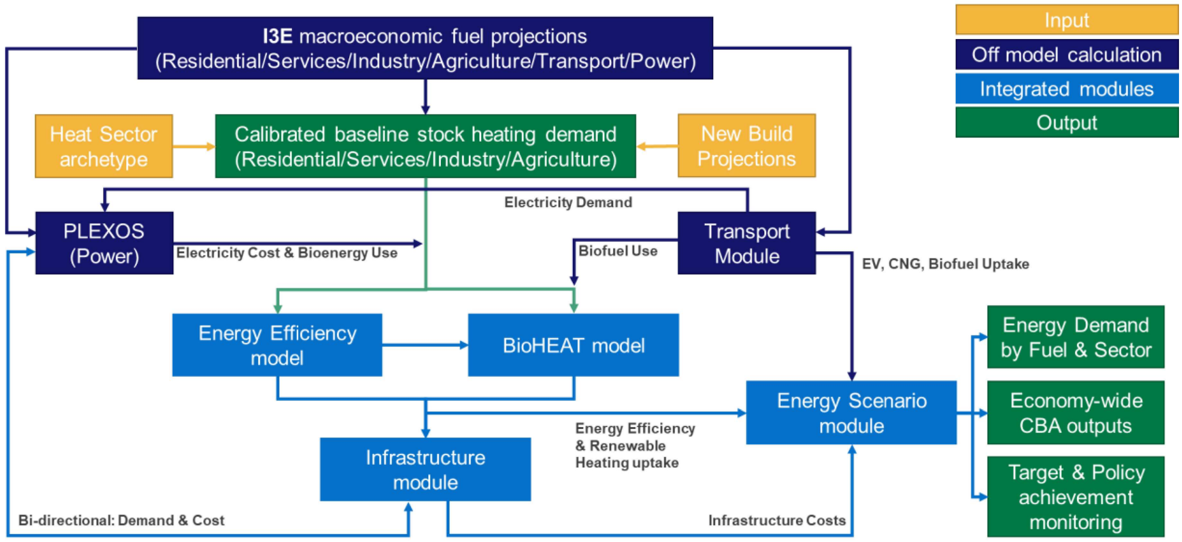

Figure 1:NEMF schematic

Macro-Economic Projections

Baseline energy demand, shaped by macro-economic trends such as prices for fossil fuels and carbon, is provide by computable general equilibrium modelling provided by the ESRI's I3E model. The sectoral (residential, commercial, public, industry, agriculture) energy demand estimated by engineering stock models are calibrated against the results of the macro-economic modelling of these sectors of the economy. This provides the energy demand before future PaMs are implemented. Further detail on the I3E modelling framework can be found in [1].

BioHEAT

The BioHEAT module is populated with best-available data on Irish building and heat sector stock, with 680 archetypes representing 2 million buildings. Each year, the turnover of the heating stock is defined by a decision-making frequency (15-year life assumed by default). All suitable heating technologies and energy efficiency packages are compared on a payback-period basis using capital expenditure (CAPEX), operational expenditure (OPEX), fuel costs, technology efficiency/performance data and sector specific willingness-to-pay curves. *Figure 2* illustrates the five different willingness-to-pay curves used in the uptake modelling, one for each sector, apart from residential, where there is a distinction between tenure types. These curves are based on consumer surveys of consumer preferences in the residential, commercial, public and industrial sectors [2], [3]. Further detail on the BioHEAT module can be found in [4].

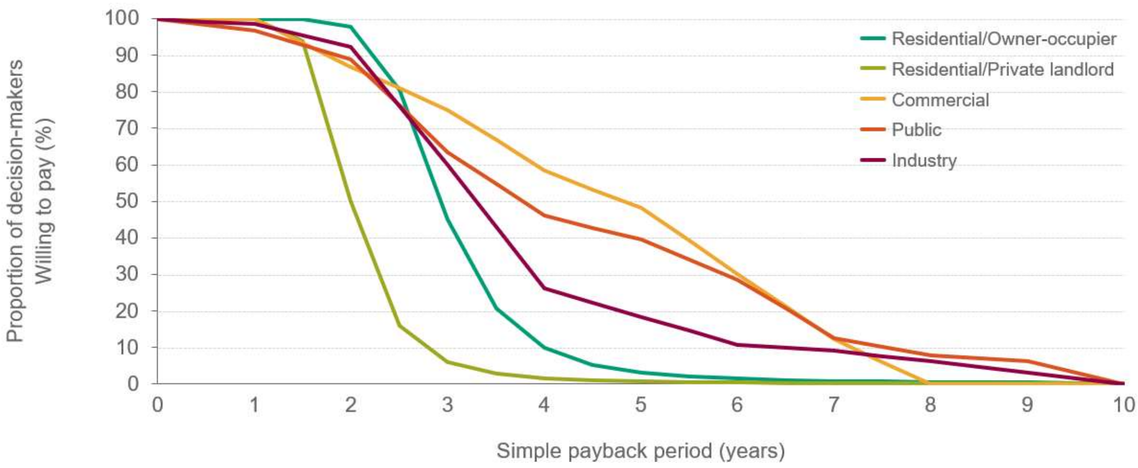

Figure 2: Willingness-to-pay curves

Energy Efficiency

Further uptake of energy efficiency packages is considered separately, given the higher decision-making frequency of shallow, medium and deep energy efficiency packages across archetypes. An estimate for the post-package 'rebound effect' exhibited in empirical data, i.e., an increase in energy consumption due to an increase in internal temperature is included to mitigate over-estimating energy efficiency savings.

For more information on energy efficiency modelling, see the *Low Carbon Heating and Cooling Technologies* report in this National Heat Study.

Power

The Electricity (power) module, which employs the PLEXOS unit commitment and economic dispatch tool [5] and Xpress solver [6], simulates the scheduling of resources (generation, storage, interconnection, and demand side management) to meet electricity demand at an hourly resolution.

The model is based on data provided by regulatory authorities [7] and the European Network of Transmission System Operators [8], with extensions made to include transmission system operator security constraints [9] and new technologies.

The electricity modelling determines what growth in renewables is required to meet targets for renewable energy shares in electricity (RES-E) and decarbonisation as electrification and other areas such as data centres drive increased electricity demand. The CAPEX, OPEX and fuel costs of the power sector are used for calculation of the electricity retail price.

Transport

The transport module assesses the impact of relevant policy and measures on the underlining macro-economic transport demand outputted from the I3E model. The module estimates the fossil fuel displacement achieved by policy measures relating to electric vehicle uptake, public transport improvements, demand management measures, vehicle efficiency and increased biofuel blending amongst others. This displacement is then deducted from the baseline transport energy demand to give the final projected energy demand as well as the renewable energy share in transport (RES-T).

The uptake of transport policy measures is target driven and the module does not model consumer choice in this sector. The module also outputs the electricity demand, biofuel usage and hydrogen demand to the Power, BioHEAT and Hydrogen modules respectively so this can be accounted for in overall electricity, bioenergy and hydrogen demand.

Infrastructure

The Infrastructure module covers the costs of energy networks including electricity, gas/hydrogen and district heating infrastructure.

Electricity

The electricity demand profiles for the Electricity (power) module are constructed by including the electrification that has occurred along with energy efficiency uptake and assumptions for data centre growth.

This demand growth along with other key assumptions are utilised to estimate the cost of electricity network expansion, as outlined in the *Electricity Infrastructure* report of this National Heat Study.

Hydrogen

The hydrogen module considers biomass gasification and renewable energy-driven electrolyser options, i.e., only 'green' hydrogen production is considered.

Hydrogen demand is compared to the constraints (biomass availability, renewable generation capacity limits) on green hydrogen production and the production options are selected in order of least-cost. A weighted average production cost is used as the hydrogen cost for competitive uptake in the following year.

Network costs for the transmission and distribution of hydrogen are based on parameterised costs of distribution network conversion and transmission network repurposing and connection.

See the *Low Carbon Gases for Heat* report of this National Heat Study for further information.

District Heating

District heating (DH) uptake for each small area is treated independently. The district heating cost for each small area is found for biomass boilers, biomass combined heat and power (CHP), air-source heat pumps and ground-source heat pumps (GSHP). The lowest cost of these options in each small area is selected if it is lower than the average counterfactual cost in that area, with district heating uptake limited to a fraction of the total suitable heating demand.

In the BioHEAT module the fraction of the stock of each archetype that takes up DH is removed from the competitive uptake calculations.

CCUS and BECCS

Apart from the application of techno-economic suitability criteria for each site, the level of CCUS and BECCS growth per scenario are scenario-storyline-based input assumptions. The sites chosen to apply CCUS in each scenario are removed from the stock used within the main BioHEAT module, i.e., they are treated separately.

All industrial/power sites above an emissions threshold (>20ktCO_2/y, based on 2019 Emissions Trading System data) are taken forward for further analysis on the potential for CCUS/BECCS suitability. The cost of carbon capture at each site is calculated and added to the cost of CO_2 transport and storage (site, dependent on scale of emissions and site distance from shoreline terminals).

For industrial sites, levelised costs greater than €180/tCO_2 are excluded, with the other sites potentially being considered for CCUS/BECCS in the various scenarios.

Cost Benefit Analysis

The cost benefit analysis (CBA) module computes the net present values per sector for a given scenario from two approaches:

- economic analysis, i.e., from a societal perspective, including socio-economic and environmental factors,
- financial analysis, i.e., from an investor's point of view.

The economic analysis uses a social discount rate, shadow prices of carbon (traded and non-traded), and damage costs of non-greenhouse gas pollutants, sourced from the *Public Spending Code* [10]. The financial analysis employs discount rates from [11].

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