Energy Poverty Observatory

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ABSTRACT

The concept of the Energy Poverty Observatory (EPO) aims to transcend traditional understandings of energy poverty by pioneering a federated database that will serve as a comprehensive and integrated repository, encompassing all pertinent factors impacting on energy poverty. The approach addresses previous limitations with respect to data availability and diversity. An integrated database approach aggregates diverse sources of information in near real time, encompassing surveys, interviews, historical databases, census data, sensors/IoT, and beyond. The database leverages from state-of-the-art machine learning (ML) algorithms which will be used to identify new correlations within these datasets, facilitating data-informed decision-making and policy formulation. By consolidating disparate data streams, including energy commodity fluctuations, renewable energy statistics, and socio-economic indicators, it will be possible to support holistic comprehension of the underlying risk factors and impacts of energy poverty. The efficacy of the platform will increase with time, as the ML algorithms refine their insights through the increase of historical data. Continuous integration of data will ensure the availability of timely and standardised information, bolstering the efficacy of decision-making tools and predictive simulations. The EPO is underpinned by robust theoretical framework and supported by delineated key performance indicators (KPIs) to promote reproducibility and long-term adoption by policymakers and other stakeholders alike. The EPO aspires to emerge as the reference tool for data-driven policy formulation and simulation exercises in the realm of energy poverty. By nurturing collaboration across academia, industry, policymakers, and other stakeholders, the EPO will affect enduring change in addressing energy poverty and its socio-economic implications.

Keywords: Energy poverty, energy cost, energy efficiency, transport poverty, health.

NONMENCLATURE

Acronyms and Abbreviations	
CAP	Climate Action Plan
EPAH	Energy Poverty Advisory Hub
GDP	Gross Domestic Product
IERC	International Energy Research Centre
IoT	Internet of Things
IREPO	Irish Energy Poverty Observatory
KPI	Key Performance Indicators
ML	Machine Learning
PV	Photovoltaic
SDG	Sustainable Development Goal
SEAI	Sustainable Energy Agency of Ireland
UCC	University College Cork
UNDP	United Nations Development Programme
WEC	World Energy Council

1. INTRODUCTION

In order to make progress towards the reduction and eradication of energy poverty it is critical to understand its scale, nature, and impact on different social strata.

Considerable work has been devoted to developing definitions and metrics for energy poverty. The "10% rule" suggests that if a household spends over 10% of its income on energy, it's considered energy poor in Ireland (Lawlor & Visser, 2022). However, indicators based on the income/expenditure paradigm are not as objective as believed, as they necessitate significant adjustments, often depending on decisions by data analysts, impacting energy poverty rates. Thus, the complexity of energy poverty should encompass the various facets of this

multifaceted phenomenon (Bouzarovski & Petrova, 2015), influenced by factors affecting energy service delivery, with notable implications for energy poverty and deprivation (Herrero, 2017; Sareen et al., 2020).

For example, the energy generation mix in Ireland, comprising a diverse array of resources, from renewable options (e.g., hydro, wind, solar PV) representing 12% of the primary energy requirement, to 87% from non-renewable sources (e.g., oil, natural gas, coal, peat), with a 1% net electricity import (SEAI, 2022). Conversely, the demand side (e.g., space and water heating, cooling and refrigeration, and cooking) presents varied demands, with profound socio-economic implications.

This underscores the need for comprehensive planning structures to address the complexities of energy poverty in conjunction with existing and new policies, including the transition to low-carbon sources. Initiatives and strategies related to policy and regulation (e.g., governance procedures supporting fuel and supplier transitions, and investment in energy efficiency) can be advantageous, as well as enhancing community groups and local government capacities for upgrades and efficiency (Drescher & Janzen, 2021).

To accomplish this, developing a sophisticated, multi-dimensional approach to energy poverty is crucial, incorporating factors like energy consumption, costs, supply chain, income, efficiency, and socio-economic and gender-related issues (Arsenopoulos et al., 2020; Robinson & Mattioli, 2020; Sánchez-Guevara Sánchez et al., 2020). Such approaches, proposed with varying assumptions and focusses, stress the need for in-depth socio-economic and demographic analyses on energy poverty factors (e.g., income level, employment status, age, and health), particularly a gender-specific approach and self-reported energy poverty (Drescher & Janzen, 2021). Behavioural analysis, integrating a behavioural economics perspective, can provide crucial insights into household energy-use decisions and their contribution to energy poverty (Caballero & Della Valle, 2021).

Moreover, the impact of energy poverty extends beyond finances to health, education, well-being, and behavioural consequences, demanding intervention strategies to overcome barriers faced by energy-vulnerable households (Pan et al., 2021). Studies (Apergis et al., 2022) underscore the negative effect of energy poverty on public health and education, highlighting the importance of policies improving energy access for better socio-economic outcomes.

Also, other studies on energy poverty and transport (Lowans et al., 2021) underline the complexity of analysing how energy poverty affects transport, suggesting technical solutions tailored to different demographics and sectors, and advocating for the adoption of official transport poverty indicators alongside energy poverty indicators as a broader impact on human development.

Despite the accelerating transition to clean energy (IEA, 2023) enabled by more ambitious energy and climate policies, new technologies, investments (USD 1.4 trillion in 2022, a 10% increase over 2021 and 70% of the growth in energy investments), and renewed concerns about energy security (e.g., Russia's invasion of Ukraine, COVID-19, commodities price fluctuation), fossil fuels still dominate the energy generation mix in most countries. Irrespective of these conflicting developments in the supply chain, it is clear that these factors are having and will continue to have short-term and long-term impacts on energy poverty.

The correlation between Gross Domestic Product (GDP) per capita, household fossil fuel consumption, and energy poverty has been previously identified (Halkos & Gkampoura, 2023) emphasizing the need for region-specific policies addressing sustainability, security, and affordability (energy trilemma).

While much research has focused on micro-level factors influencing energy poverty, macro-level root causes, particularly related to supply chain dependencies, have received less attention. Understanding these larger-scale influences can refine policies, adapting them to specific realities and ensuring more comprehensive planning (Recalde et al., 2019; Xiao et al., 2021), albeit acknowledging the challenges nations face in balancing energy security, welfare, and environmental protection - the "*energy trilemma*" proposed by the World Energy Council (WEC).

Energy poverty arises from potential complex interdependencies, where energy prices and policies can exacerbate it regardless of household income (Primc & Slabe-Erker, 2020) if not supported by data-driven approaches and comprehensive analyses. Understanding energy poverty is crucial to support multifaceted policy measures. An up-to-date, data-driven decision support tool like the one proposed in this project can aid in monitoring energy poverty, gaining insights, and supporting effective energy policies, offering statistical and machine learning analytical functionalities - including more accurate predictive models.

2. MAIN OBJECTIVES

Moving beyond the commonly defined factors behind energy poverty (Lawlor & Visser, 2022), dwelling characteristics, energy price, and consumption demands,

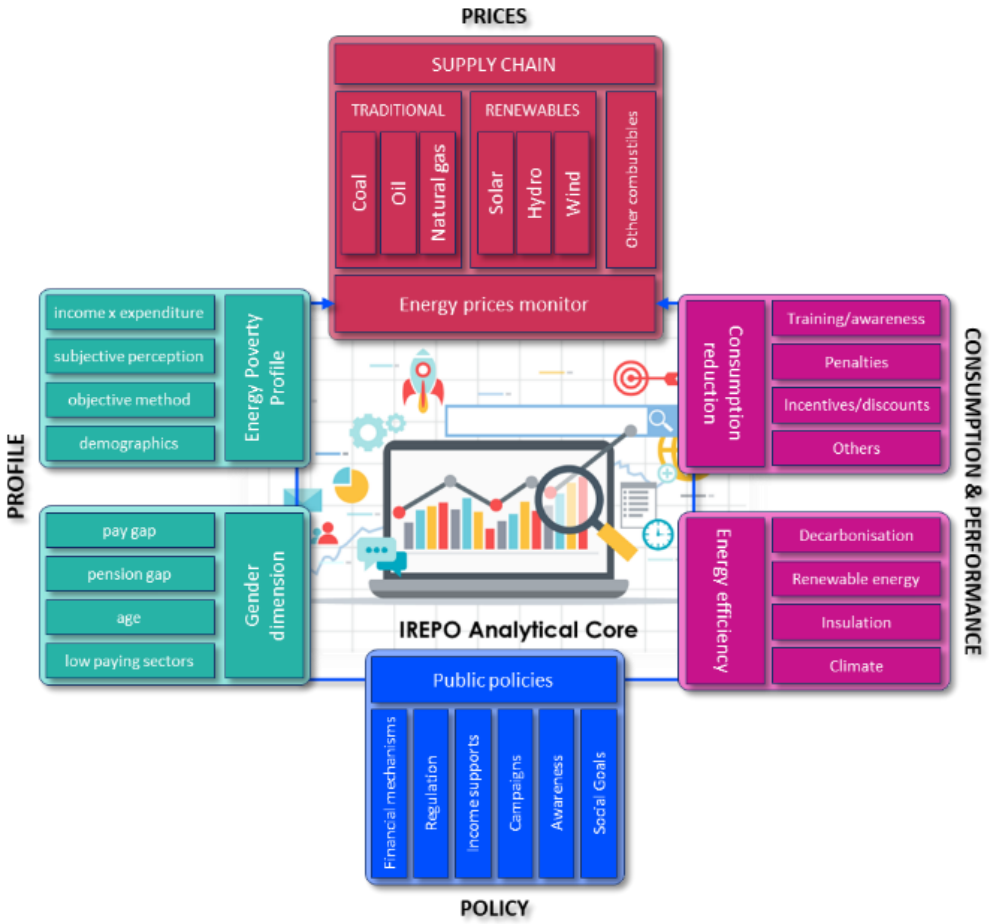

Figure 1 - Energy Poverty Observatory platform: high-level blocks.

this work will establish, demonstrate and evaluate a comprehensive, continuously integrated, and up-to-date federated database for Ireland. This database will consolidate all pertinent factors influencing energy poverty, overcoming typical data limitations (Lowans et al., 2021) in availability and timeliness. Advanced data integration will facilitate the development of a data-driven decision-making tool and policy support guide, with near-real-time integration of dependable data from various sources.

Through the extensive use of ML algorithms, this platform will identify patterns within datasets, automating the process to analyse relationships between features and learn patterns connecting them (Lowans et al., 2023). By combining diverse data sources, it will offer a comprehensive picture of energy poverty risk factors and impacts, embracing the multidimensionality of the problem (Arsenopoulos et al., 2020; Gouveia et al., 2019). Figure 1 depicts the high-level blocks of the **Irish Energy Poverty Observatory (IREPO)** in which this work was based on, and exemplifies how this approach is implemented.

It is important to note that the accuracy of this solution's functionalities will improve over time as its ML algorithms benefit from the growth of historical data. Continuous data integration will ensure timely data in near real-time and support powerful decision-making, simulations, and policy-supporting tools. Additionally, this platform will establish a development and implementation methodology KPIs, guiding analytical tool performance and ensuring reproducibility.

The combination of continuous and up-to-date data integration, monitoring of relevant energy poverty-related aspects, an advanced analytical core, robust expert methodology, and reproducibility will position this platform as a reference tool for decision-making, data-driven policy support, and simulations. By promoting collaboration across academia, industry, policymaking, and other sectors, it will extend its functionalities and services beyond the project's end, to keep addressing energy poverty and its social impact.

Regarding the relevance and impact of this project, it aligns with various topics outlined in the Climate Action Plan (CAP) 2023 (DECC, 2023), and the Impact 2030 (GoI, 2022): Ireland's Research and Innovation Strategy, the

Figure 2 - United Nations SDGs targeted contributions.

Energy Efficiency Obligation Scheme, and the United Nations Sustainable Development Goals (SDGs).

Specifically, the Energy Poverty Observatory will contribute to enhancing knowledge transfer, tracking KPIs, improving social welfare measures, supporting energy efficiency initiatives, and addressing various aspects of the SDGs - as per Figure 2 (GoI, 2023; UN, 2021) - thereby making significant strides toward combating energy poverty and its associated social and economic impacts.

3. CONSIDERATIONS

Energy poverty is a multi-dimensional issue, and addressing it requires careful consideration of its complex scenarios, spanning generation, demand, and impacts. Failure to do so may result in suboptimal outcomes.

In terms of academic impact, the Energy Poverty Observatory platform will serve as a valuable data source for energy research, encompassing its various interdependencies, such as social, economic, and educational factors. Collaboration among diverse partners with relevant expertise in the energy poverty landscape is integral to its development and long-term utilisation.

EPOs hold significant potential for collaboration with other platforms and initiatives at both national and international levels, owing to its replicability and compatibility with various projects. For instance, partnerships with initiatives like Horizon Europe's Energy Poverty Advisory Hub (EPAH, 2024a, 2024b; European Commission, 2024) and similar projects across Europe (and beyond) can foster knowledge exchange and synergy.

Moreover, it can offer insights into energy poverty for non-exchequer-funded research, including activities supported by private donations, foundation grants, or corporate partnerships. International agencies like the World Bank and the United Nations Development Programme (UNDP) may find the platform useful for demonstration projects showcasing effective energy poverty strategies.

Furthermore, NGOs, philanthropic foundations, and public-private partnerships engaged in research and development activities related to energy poverty could benefit from this platform's support, with its data-driven decision tools to guide investments in areas like solar panel production or retrofit industries, aligning efforts with identified needs.

The potential impacts of the Energy Poverty Observatory project extend to societal and policy domains, including improvements in quality of life, health, education, climate change mitigation, and social equity. By promoting collaboration and providing robust tools, it aims to enhance Ireland's scientific capacity and relevance in addressing the critical issue of energy poverty.

To do so, this project is expected to be fully operational with web tools available and continuous data integration established and validated. Also, collaborations with relevant data sources and experts are expected and the platform must be able to accommodate further data and expertise, facilitating information exchange and constructive collaboration from the outset.

4. CONCLUSION

This work will design, develop, and evaluate an EPO for Ireland, known as IREPO. This will lead to a replicable platform that catalyses research, development, and deployment (RD&D) efforts nationally (Ireland) and internationally. Through fostering collaboration, promoting long-term usage, and forging partnerships, this project aims to design an advanced, data-driven toolset to support decision-making and policymaking on energy poverty issues.

The primary objective of IREPO is to develop a dynamic tool continuously updated with data from reliable sources at local, regional, and international levels. This collaborative effort will yield a tool offering multi-dimensional, up-to-date data covering various aspects such as social, economic, behavioural, market trends, gender insights, and other factors relevant to energy poverty policies and actions.

This diverse dataset will empower stakeholders including public bodies, policymakers, academia, and private markets to make well-informed decisions in addressing energy poverty. Additionally, IREPO will employ ML-based algorithms to create simulation environments. These environments will enable users to analyse data from multi-dimensional repositories, extrapolate scenarios, address barriers to energy poverty, validate existing policies, simulate new policies, and promote the uptake of renewable energy.

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