INTRODUCTION

The world has witnessed a major population shift to urban areas over the past few decades. At present, approximately half of the world’s population (54%) resides in urban areas compared to a mere 30% in 1950, and the number is projected to rise up to 66% by 2050. With higher levels of technology and services than rural areas, urban areas account for about two-thirds of the world’s total energy consumption, which relates to approximately 70% of global greenhouse gas emissions. Around 39% and 36% of the CO2 emissions are associated with buildings in the United States and Europe.

Buildings play a significant role in urban demand and supply of energy. In the building sector at urban scale, there is considerable potential to achieve significant reductions in energy consumption and emissions. These reductions are possible through retrofitting existing buildings into more efficient and sustain-able buildings. Building retrofitting poses a huge challenge for owners and city planner because they usually lack the expertise and resources to identify and evaluate cost-effective energy retrofit strategies. One of the viable solutions is to improve the energy efficiency in buildings with limited information, which can be accomplished by using energy modelling.

RESEARCH QUESTION

• What type of buildings have the greatest potential for energy savings with cost-effective retrofit solution?
• How the building performance can be improved using GIS-based energy modeling?

KEY ISSUES IN URBAN ENERGY MODELING

![Key Issues in Urban Energy Modeling Diagram]

CONCLUSIONS

The aforementioned methodology could provide the urban platform to help city planner, city energy managers, building owners, utilities, energy consultants, and building owners to evaluate district and city-scale energy efficiency issues and opportunities in buildings. The modeling results will help where and what type of buildings have the greatest potential for energy savings throughout the city. The intelligent recommendation system helps the city planners to identify what are the energy efficient with cost saving retrofits measures for the buildings. For spatial analysis and planning of city or districts building stocks will use CityGML data model which provides high levels of details with effective visualization in 3D format. The CityGML will also help exchange data between the building energy model and other urban environmental analysis models.

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INTRODUCTION
To achieve housing retrofit targets, traditional house-by-house approaches must scale. Neighbourhood retrofit also facilitates community participation. This work aims to quantitatively characterise the heat energy demand of similar homes in a post-retrofit neighbourhood.

METHODOLOGY
A modern semi-detached house is modelled as thermal (RC) network. The passive thermal network is calibrated against an equivalent EnergyPlus model. The Modelica model, employing library AIXLib, generates time series heat energy demand to achieve occupant comfort. Its output separates space heating and domestic hot water (DHW). Simulations repeat for a range of house occupancy profiles, with varying heating schedules and occupant quantities.

RESULTS
With the hourly Dublin weather, the Modelica simulation of internal temperature responds faster than the equivalent EnergyPlus simulation. Nevertheless, an annual time series MAE (mean absolute error) of the passive fabric is relatively small. The slower thermal dynamics of EnergyPlus reduce annual heat demand when simulating the same house.

CONCLUSIONS
Occupant profiles of a post-retrofit semi-detached house increase annual heat energy demand by 77%, and the coincidence of daily peak demand persists across occupant profiles. Percentages of domestic hot water demand start from 20% or 24% and plateau at 39% or 45% depending on space heating schedule. A statistical distribution of energy demand by a neighbourhood is not perfectly Normal, skewed to larger energy demands.

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A generalization approach for reduced order modelling of commercial buildings
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INTRODUCTION
Buildings, as an end use instance, are often considered as isolated entities in the current energy system, which is mainly due to their varying nature of operation. Moreover, the models associated with buildings vary with the building function and there are certain stochastic factors, for instance, occupancy levels, that accompany each model. Detailed building models have been popular in performing energy predictions during the past few decades, although, these require extensive monitoring and are not often the cost-effective solution. Hence, simpler modelling approaches that relate the building’s physical properties to its operating environment are required.

Grey box modelling combines the advantages of data-driven and physical modelling approaches. Therefore, these models are accurate and computationally efficient. The design approach of grey-box models is often application specific, for instance, the design approach for grey box modelling of commercial buildings differs on a case by case basis. Furthermore, the scalability of these models is limited by the network order, which defines the level of complexity incorporated in the model. Reduced order grey box approaches counter these limitations by achieving a trade off between the network order and desired accuracy.

Objective(s)
• Devise a generalisation approach to develop reduced order grey box models for commercial buildings based on pre defined metrics.
• Deploy the models to evaluate flexibility, scalability and inter operability of isolated buildings.

METHODOLOGY
RC network modelling approach employs: RC networks to represent the heat transfer mechanisms, conduction and convection through internal and external walls, wall openings and roofs. Besides conduction and convection, solar radiation adds to the heat transfer through windows and other openings. Also, heat gains result from the heat emitted by the occupants and the equipment as shown in Fig. 1.

RESULTS
Buildings connected to the district heating network on college campus are used as the methodology case study. The buildings are analysed based on the algorithm presented in Fig. 2.

• Building taken into consideration: Library to illustrate the importance of combining net floor area with peak power in the analysis (Fig. 4).
• Building considered for the analysis: Science North, which is a laboratory building. Maximum peak power demand: 6871 kW, suggests a complex RC network (Fig. 4).
• Building considered: Tierney building, which consists of administrative offices. Flat power demand curve suggests simpler network (Fig. 4).

CONCLUSIONS
The presented methodology aims to achieve generalization through peak power characterization. There are other building metrics that play a role in network order identification, which need to be added to the current methodology. This generalization approach would reduce the complexities involved in identifying the order of RC networks. Furthermore, this approach could be utilised to generate scalable models for commercial buildings.

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INTRODUCTION

- Flexibility: Ability of a power system to respond to changes in energy demand / supply
- Volume of renewable energy used for producing power will experience growth in following decades
- Increasing variability and uncertainty — increasing requirement for obtaining flexibility

Objectives

Create a model:
- Unit commitment / Transmission / Heating load functions for different power grids, nodes and units
- Satisfy future power system flexibility needs according to various forecasts / future scenarios
- Low cost (cost-efficient) and implementable solution
- Balance between model efficiency and complexity

Minimise: Total cost (objective function)

st. Constraints:
- Ramp up / down
- Start up / shut down
- Demand
- Reserve
- Transmission
- Heat
- Wind/solar/water flows (weather/climate)
- Storage
- …

METHODOLOGY

Mathematically:
- Mixed Integer Programming / Non-linear Programming
- Uncertainty modelling / Sensitivity Analysis
- Chance-constrained Programming
- Stochastic Programming / Scenario planning

An adaptable energy system model:

The Backbone Model (written in Gams) will address various questions:
- How much will increasing the volume of installed renewable energy affect system flexibility needs?
- How can flexibility impacts be best captured within a unit commitment / investment model?
- Can the gas network, heat network and waste water treatment system (as examples) provide additional flexibility for the power system?

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The potential to harness demand-side flexibilities from large-scale wastewater treatment plants in an integrated energy system

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The Economic and Social Research Institute 1, University College Dublin 2

BACKGROUND

Flexible operation of wastewater treatment plants can provide a tool to introduce more demand-side flexibility to the energy system.

• In developed countries, 42% of water-related electricity consumption is used for wastewater treatment.
• Globally, wastewater treatment consumes about 200 TWh of energy.

Electricity consumption in the water sector by process and region in 2014; Source: IEA (2016).

RESEARCH QUESTION

Effects of flexibility?

Current incentives?

Potential corrections?

Identification and quantification of flexibility potential as prerequisite

METHODOLOGY

BACKBONE: generic energy system optimization tool written in GAMS.

• Adaptable
• Short-term forecasts and longer-term statistical uncertainties
• Data driven

APPROACH

Continuous cooperation within ESIPP

Input from Engineering
Step 1
Evaluation of flexibility potential
Flexible Wastewater Treatment Plant Operation
Integration into electricity system
Extension of the energy system model

Unit Modelling
• Consideration of biological, biochemical and chemical processes

System Modelling
• Focus on energy and water flows

CONTRIBUTION

Deeper understanding of the wastewater aspect of the energy-water nexus

• Integration in wider energy models
• Cooperation within ESIPP

Insights
Input
Implications

For Policy makers
For wastewater treatment plant operators

OUTLOOK

• Further work on Backbone
• Data for Ireland
• Wastewater treatment plant operation profiles according to different flexibility options
• Quantification of system benefits
• Potential extensions of the model

• Modelling the water grid to extend storage possibilities
• On-site biogas production
• Policy interventions

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**INTRODUCTION**

- Importance of the correct evaluation of renewable energy projects and the financial uncertainty related to these projects
- Real options approach for renewable energy investments:
  - Irreversibility of investment
  - Flexibility in decision making process
  - Uncertain environment
  - Key parameter: volatility
- The estimation of the volatility parameter has not received the attention it should in past research
- Sources of uncertainty considered:
  - Electricity prices
  - Solar Renewable Energy Credit (SREC) prices, used as proxy for policy uncertainty
  - Technology costs (cost of solar PVs)

**OBJECTIVES**

- Model the financial volatility related to utility-scale solar PVs in the United States as an input for real options
- Being one of the first papers to attempt modelling volatility for solar energy by considering this unique set of sources of uncertainty
- Being one of the first papers to model policy uncertainty using GARCH models

**METHODOLOGY**

- Model each different source of uncertainty using univariate generalized autoregressive conditional heteroskedastic (GARCH) econometric models over a period of study of 10 years
- Model comparison:
  - Bayesian Information Criteria
  - Diagnostic tests: Ljung-Box Portmanteau test, Barlett white noise test, Engle's ARCH Lagrange Multiplier test
  - Forecast comparison: mean squared error, mean absolute error, mean absolute percentage error

**RESULTS**

The standard GARCH(1,1) model is of the following form:

\[ h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \]

The conditional variance, \( h_t \), is a deterministic function of the model parameters and past data and follows an ARMA(p,q) process.

For technology costs data, standard ARMA(p,q)-GARCH(1,1) models are unable to model the characteristics of the data. Instead, an integrated GARCH model (IGARCH)-ARMA(0,1) is used. An IGARCH is characterized by the presence of a unit root in the autoregressive dynamic of squared residuals: \( \alpha + \beta = 1 \). The IGARCH(1,1) model is therefore of the following form:

\[ h_t = \omega + \alpha \varepsilon_{t-1}^2 + (1 - \alpha) h_{t-1} \]

The unconditional or long run variance can be computed as \( \sigma^2 = \frac{\omega}{1 - \alpha - \beta} \).

**CONCLUSIONS**

For electricity prices and SREC prices, standard GARCH(1,1) models are able to accurately model most relevant characteristics of the data. For technology costs an integrated GARCH (IGARCH) model was used. However, further work is expected in developing more accurate models, especially for technology costs.

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COORDINATING ENERGY POLICY AND ENVIRONMENTAL GOALS ACROSS ELECTRICITY MARKETS: A DEMAND SIDE PERSPECTIVE. 
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**INTRODUCTION**

![Energy Policy and Climate Policy](image)

Energy Policy → Climate Policy → Electricity Markets

EU 2030 CLIMATE AND ENERGY FRAMEWORK (EC, 2014).

- Are these objectives competing?
- How should electricity retail pricing change to accelerate the process of decarbonization?

**OBJECTIVES**

- Bridge the economic problem of consumers of energy services with the technological features of energy systems and climate objectives.
- Derive a generalizable approach to design electricity retail pricing schemes that are consistent with the pursuit of a specific environmental goal.

**METHODOLOGY**

**PARTIAL EQUILIBRIUM MODEL:**


- **INNOVATION:**
  - Inclusion of retail pricing schemes
  - Refined temporal representation.

**BALMOREL:**

Simulation of the environmental impact of each scenario by means of an energy system model.

- **INNOVATION:**
  - Calibration with Irish data
  - Definition of the demand side equations.

**PROBLEM DEFINITION**

We evaluate the implications on GHG emissions of different forms of activation of the price elasticity of electricity demand.

We compare the environmental efficiency of prioritizing flexibility as opposed to energy conservation on the demand side of the power sector.

- **SYSTEM PERSPECTIVE**
- **MODULAR DECOMPOSITION OF ELECTRICITY MARKETS**

**CONCLUSIONS**

By coupling a bottom-up approach with the economics of retail pricing, we define the overall environmental impact of demand side instruments and we suggest policy recommendations to align retail pricing of electricity with climate change priorities.

**REFERENCES**


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INTRODUCTION

Decentralized Energy Systems (DES) are broadly defined as systems in which energy is generated close to the place where it is used (Wolsink, 2012). DES are usually associated with higher level of public engagement with energy systems. Decentralization encompasses energy systems at different scales and involves technologies, institutions, policy and behaviours that differ from a centralized mode of operation (Watson & Devine-Wright, 2011). Overall aim of this research is to understand end-users’ role in DES and which factor influence their engagement.

STAKEHOLDERS’ PERSPECTIVES ON END USERS’ ROLE IN DECENTRALIZED ENERGY SYSTEMS

The first subtask is to identify stakeholders’ perspectives on the role of end-users in DES. After different perspectives are identified they will be analyzed and contrasted in the light of different worldviews. (Kilbourne et al., 1997).

Methodology

- Interviews [stakeholders from industry, civil society, academia]
- Defining Q set [collection of all the possible statements concerning DES]
- Q sort [ranking of statements]
- Q factor analysis [data reduction which identifies dimensions underlying different perspectives]

(WHY) DOES OWNERSHIP TRANSLATE INTO POLICY ACCEPTABILITY AND END-USER ENGAGEMENT?

Previous research has shown that public engagement with DES is linked with ownership (Warren & McFadyen, 2010). The aim of this study is to explore if different ownership models are associated with different levels of end-users engagement and why this may be the case. One reason may be because formal ownership leads to a sense of psychological ownership, which may, subsequently, lead to increased levels of engagement.

Methodology – scenario & field based experiments

- Formal ownership over DES
- Psychological ownership over DES
- Acceptability of DES & end-user engagement

REFERENCES


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Incentives for Energy Efficiency in the Residential Rental Market

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INTRODUCTION
The landlord – tenant problem in relation to energy efficiency can be characterised as a principal agent problem, resulting from information asymmetries and split incentives. Split incentives in the owner-occupant relationship in relation to energy consumption take the following form:

<table>
<thead>
<tr>
<th>Type</th>
<th>Occupant owns dwelling</th>
<th>Occupant rents dwelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) No split incentives</td>
<td>(2) Efficiency problem</td>
<td></td>
</tr>
<tr>
<td>(3) Both</td>
<td>(3) Usage problem</td>
<td></td>
</tr>
</tbody>
</table>

BER’s and their international counterparts have been brought about to correct for the asymmetric information problem. In the absence of information asymmetries, does the principal agent problem persist?

Objective(s)
The objective of this study will be to answer the following two research questions:

1. Is rental accommodation less energy efficient than owner-occupied accommodation, having corrected for the information asymmetry between landlords and tenants? (i.e. is there evidence of the split incentives problem, and if so, what is the magnitude of the problem?)

2. Is there a rental price premium associated with more energy efficient rental accommodation?

METHODOLOGY

1. Research Question 1:
   To answer the first research question, we use a combination of coarsened exact matching (CEM) and parametric regression. This allows us to estimate the causal effect of renting on efficiency as follows:

\[ ATT = E[Y | D = 1] - E[Y | D = 0] \]

We recreate the missing counterfactual of the level of efficiency of a rental property, had it not been rental (\( E[Y | D = 1] \)) by matching on a set of observable characteristics. In the case of binary and categorical variables we apply exact matching. In the case of continuous variables, we coarsen the data into distinct bands and apply exact matching.

Using both matching (as a pre-processing technique) and parametric regression on the matched sample reduces model dependence. In addition, as a robustness test we also apply propensity score matching and Mahalanobis distance matching.

2. Research Question 2:
   To answer our second research question, we will use a combination of CEM and hedonic regression with year-by-location and seasonal fixed effects. The dataset which will be used to address this question comes from the Residential Tenancies Board (RTB) and contains all active tenancies in the Republic of Ireland.

DATA: RQ1

The data used to answer RQ1 comes from the Building Energy Ratings (BER) database, which contains every BER ever issued in the Republic of Ireland.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER (kWh/m²)</td>
<td>157.32</td>
<td>120.16</td>
</tr>
<tr>
<td>Age</td>
<td>35.25</td>
<td>15.01</td>
</tr>
<tr>
<td>Size</td>
<td>120.16</td>
<td>99.03</td>
</tr>
<tr>
<td>Dep. Variable: ln(BER)</td>
<td>25.25</td>
<td>16.01</td>
</tr>
<tr>
<td>CEM1: Group age by 10 years, size by 20m² year intervals prior. Size by 10m²</td>
<td>251.42</td>
<td>162.25</td>
</tr>
<tr>
<td>CEM2: Group age by building regulation to 1990, 10 year intervals prior. Size by 10m²</td>
<td>120.16</td>
<td>99.03</td>
</tr>
<tr>
<td>CEM3: Group age by 2 years, size by 5m²</td>
<td>25.25</td>
<td>16.01</td>
</tr>
</tbody>
</table>

All procedures produce weights of the form: \( \frac{\text{H}_{10*}}{\text{H}_{20*}} \)

RESULTS: RQ1

Coarsening choice is at the discretion of the researcher:

CEM1: Group age by 10 years, size by 20m²

CEM2: Group age by building regulation to 1990, 10 year intervals prior. Size by 10m²

CEM3: Group age by 2 years, size by 5m²

A naïve comparison of means suggests no significant difference in efficiency between rental and non-rental accommodation. However, we may not be comparing like with like, since rental properties tend to be smaller, newer and more urban.

CONCLUSIONS

Rental properties in the Republic of Ireland are less energy efficient than their owner occupied counterparts even when the information asymmetry between landlords and tenants has been removed. This is consistent with the split incentives problem, however the magnitude of the problem does not appear to be very high: rental properties are on average 1-6% less efficient on a national level. When we split the sample into Dublin vs. the rest of Ireland, we find that the split incentives problem is two to three times larger in magnitude in the capital when compared to the rest of the state. Next steps: answer RQ2 "Is there a rental price premium associated with more efficient rental properties?" using RTB database.

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Introduction

Successful large scale integration of variable renewable energy sources requires an improved understanding of their spatiotemporal variability. Here we assess the impact of large scale sea level pressure (SLP) patterns (Figure 1) such as the North Atlantic Oscillation (NAO), the East Atlantic (EA) and the Scandinavian pattern (SCAND) on solar energy resources in Ireland.

Data & Methodology

1. Pyranometer observations of short-wave radiation and the Met Éireann’s new MERA Climate Reanalysis gridded dataset were used to produce winter (DJF) aggregated means of global SW radiation. This is an high resolution dataset. The results were compared with a previously used, lower resolution reanalysis dataset, the MERRA2 (not related to MERA, although the similarity of name).

2. NOAA’s Climate Prediction Center teleconnection indices (NAO, EA, SCAND) for the time period (1982-2015) for which there is greatest temporal overlap between the observations and reanalysis data were used to assess correlations with the global SW radiation time-series.

Results

- A significant relationship between winter SW radiation and the NAO index is confirmed across the UK (as in [1]) and Ireland.
- Correlations based on the sparse pyranometer data (Table 1) resemble those based on both MERA and MERRA2 datasets (Figure 3).
- Similar results were found for the effect of the SCAND pattern on SW radiation in Ireland and to a lesser extent in the UK (Figure 2c).
- Despite its proximity, the EA pattern does not significantly contribute to winter SW radiation variability in the region (Figure 2b).

Conclusions

- In the UK the correlation between winter SW radiation and the NAO index exhibits a strong zonal gradient. A similar zonal correlation gradient was found for Ireland, with highly negative correlations along the Alantic seabord (Figures 3 and 4), and weak to no correlations in southeast Ireland (Table 1).

Future work

- Explore these relationships further and their physical causality using:
  - Both high and (relatively) low resolution gridded datasets;
  - Sunshine Hours (SH) recorder data, which are much more abundant and widely available in the region, appear to be a good proxy for SW radiation and will be explored further in this project.

Table 1: Correlations between pattern indices and SW radiation average for different stations groups. R values x 100; bold (*) indicates significant correlation at p<0.01 (p<0.05).

<table>
<thead>
<tr>
<th>Ireland</th>
<th>NAO</th>
<th>EA</th>
<th>SCAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Atlantic&quot; stations</td>
<td>-73</td>
<td>-16</td>
<td>49</td>
</tr>
<tr>
<td>&quot;Middle&quot; stations</td>
<td>-52</td>
<td>9</td>
<td>32*</td>
</tr>
</tbody>
</table>

References


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