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The statistical relevance and effect of assuming pessimistic default overall thermal transmittance coefficients on dwelling energy performance certification quality in Ireland

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ABSTRACT

In the EU, Energy Performance Certificates (EPCs) are issued for dwellings whenever they are constructed, sold or leased. Where requiring data would be prohibitively costly, nationally applicable default-values for the thermal transmittance coefficients of the building envelope are employed. Use of such worst case default U-values ensure that a poor dwelling does not attain a better energy rating than is merited. In the absence of empirical data in Ireland thermal-default U-values, as in many other EU member states, are determined by the type and date of construction and then prevailing building codes. Using 463,582 dwellings representing 32% of the total Irish dwelling stock, this work assesses the relevance of current default U-values. Significant levels of retrofits have been found to lead to the default U-values used now being higher that is typical in reality, thus decreasing the accuracy, and hence credibility, of an EPC. Lack of certification accuracy also inhibits investment in energy efficiency.

1. Introduction

Building energy classification allows inter-comparison of building energy use [1,2]. The EU Directive on Energy Performance of Buildings (EPBD) [Directive 2002/91/EC] mandates comparable energy performance classifications, in the form of Energy Performance Certificates (EPCs), be issued for buildings constructed, sold or leased across the European Union [3,4]. Different approaches to calculating the energy classification of dwellings have been adopted across EU Member States [2,5]. In Ireland and in the UK the energy classification of a building compares energy consumption and CO_2 emissions theoretically calculated for an actual building, with a standardised benchmark building of the same typology and floor area as shown in Eqs. (1) and (2) below [6];

$$\frac{\text{Primary Energy Use}_{\text{actual}}}{\text{Primary Energy Use}_{\text{benchmark}}} = \text{Energy Performance Coefficient}\left[\frac{KWh}{m^2.annum}\right] \quad (1)$$

$$\frac{CO_2\ \text{Emissions}_{\text{actual}}}{CO_2\ \text{Emissions}_{\text{benchmark}}} = CO_2\ \text{EmissionsIndicator}\left[\frac{kgCO_2}{m^2.annum}\right] \quad (2)$$

An EPC:

- Presents the calculated energy performance coefficient of the building on a scale of A (which should have the lowest fuel bills) to G [2].
- Uses the same scale to define the impact a home has on the environment through greenhouse gas emissions.

In Ireland [7] and in the UK [8] publically-available EPC methodologies are used to calculate the energy classification of dwellings. EPC methodologies at the national level need to have;

- credibility and accuracy so that buildings with better labels should use less energy [2,9],
- applicability to a wide variety of buildings balancing some loss of accuracy with remaining representative [5],
- clarity so that users should be able to understand (a) the overall result and (b) the effect of choices (input) on the calculation result [5,9],
- reproducibility so that for a specific building the underlying method used leads to the same result; irrespective of subjective or arbitrary choices and independent of the user [2,5],
- transparency and encourage improvement to ensure the energy label of a given building is relevant and useful [2,5,9],
- cost-effectivenes

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– obtaining the building data needed for an energy performance certificate must not be too labour intensive to avoid significantly adding to the cost of the label particularly compared to the impact of the certificate on the energy performance [5].
– complexity and user skills – avoiding poorly user-interfaced complex simulation programmes that require a high training level for the programme user [10].

The results outputted by EPC methodologies can only offer an estimation of the actual building energy consumption since input data is often based on default operating conditions for *inter alia* external temperatures, internal loads, system efficiencies, prices and occupancy patterns [2,9,11–16]. There can thus be a major gap between the theoretical prediction and actual energy consumed in homes when occupied by real people [2,11,17]. In general, and as shown in Fig. 1 theoretical predicted energy consumption tends to be [11];

– Overestimated for average and less energy-efficient dwellings. This is explained partly by the 'prebound effect' [14] wherein occupants consume 30% less heating energy on average than the theoretical predicted rating, and
– underestimated when observing new or retrofitted dwellings. This is explained partly by the 'rebound effect' [18] wherein thermally retrofitted dwellings enable higher internal comfort temperatures more affordable leading to increased energy consumption rather than reduced energy bills [11,19–22].

Eqs. (1) and (2) show that the benchmarking process is a comparative analysis [2] that also informs an associated advisory report recommending feasible energy efficiency measures from both technical and economical perspectives [2,9,15]. The underlying premise being that a householder decisions are predicated on financial savings. Informing the household about cost-effective energy-saving measures is anticipated therefore to result in marked behavioural change to reduce their energy costs [23,24]. However even when the majority of recommendations are economically advantageous, consumers are not generally persuaded to act rationally to adopt these measures [23–25]. A barrier perceived by homeowners is inaccuracy wherein the financial savings in reality smaller that the label estimates [17]. To overcome this barrier energy consumption associated with improving an EPC label after a specific energy saving intervention in a particular dwelling should reflect closely the actual decrease in energy consumption [3,11]. The effectiveness of the rating therefore depends on the proper selection of default data [2,13]. Where accurately obtaining all of the required building envelope data would be excessively labour-intensive and/or invasive, national default values are sometimes employed. Default values are normally pessimistic so as to [5];

• avoid offering a better than merited energy rating,
• allow the homeowner to know the energy advantage of carrying out retrofits,
• encourage the homeowner to maintain records of energy upgrades that inform EPCs, and
• encourage assessors to seek out information to improve the energy rating.

An illustrative case of two identical buildings is examined in Table 1 [5]. Where for one building the data item is not observable on site or via documentary evidence so a default is used, while for the other building the actual data available was used.

Information on the thermal characteristics of older dwellings is often more difficult to obtain than for recently constructed dwellings. If an improvement in the energy performance certification is the basis for renovation, use of pessimistic default values may lead to higher improvement expectations in the EPC rating [5,11]. Arkestijn and van Dijk [5] raised the policy-related question of whether it is fair to give a worse energy rating simply because less information is available. Furthermore, if the lack of information associated with the building is to be penalised – how tough should the penalty be? In other words how pessimistic should the default value be?

A thermal transmittance coefficient or U-value of a building element is the rate of heat transfer (in watts) through one square meter of the building element divided by the difference in temperature across the element structure expressed in W/m^2 K. The U-value is used to inform the heat energy consumption characteristic of a dwelling. The optimum choice of a default U-value characteristics should be based on empirical evidence. In the absence of such empirical data and as shown in Table 2, Irish thermal default U-values (similar to many other EU member states) were determined from [26,27];

• building element type,
• the date of construction for pre-thermal regulation dwellings (pre-1978).
• prevailing draft or finalised building codes by period of construction for post-thermal regulation dwellings (1978–2006) – allowing a grace period of generally two to three years after a proposed change in draft or finalised regulations for a dwelling to be completed [27].

Ireland [28,29] along with Italy [30], Spain [31] and Austria [32] use methodologies to calculate residential stock energy consumption using default U-values applied to equally default dwelling typologies classified by period of construction. The objectives of this work are to use the recently published Irish national empirical energy performance certification database [33] and SPSS® software, to:

• Assess the relationship of current default U-values relative to the empirical statistical distribution.
• Make recommendations for updated default U-value's relative to the empirical statistical distribution.
• Discuss the potential impact of default U-Value selection on the validity of,
• Energy performance certification,
• Use of default U-values as key inputs to national building energy consumption models.
• Highlight the potential contribution of their use to prebound effect in existing dwellings

2. Case study—the housing stock of Ireland

2.1. Context

As can be seen in Fig. 2, rural detached, oil-heated dwellings, Ireland's predominant house typology, comprises 18% of the total dwelling stock. This dwelling typology makes a good case study dwelling as;

• it qualifies as a reference dwelling under the European Commission delegated regulation no. 244/2012 [34],
• shown in Fig. 3, whilst Ireland has the highest proportion of single family dwellings in Europe [35] it is not extraordinary in this regard. Countries such as The UK, Greece, Norway and The Netherlands have similar profiles.
• 34% of the EU 28 population lived in detached houses in 2013 [36].