Is an assessment framework for energy efficient buildings hiding in plain sight?

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Abstract

The focus of the Energy Performance of Buildings Directive (EPBD) was on standardising the assessment and energy efficiency rating of Europe's building stock. Energy assessments and energy performance certification (EPC) concentrated on the material properties of buildings, and used simple physical models to estimate energy consumption from these inputs. However, the EPBD has always allowed the use of empirical energy consumption to assess buildings.

This paper comprises an analysis of energy assessments in the six largest European countries, looking at the methods used to generate EPCs and how they vary across countries, regions and buildings. Differences are noticeable and can have considerable impact on what constitutes an energy efficient building within a standardised assessment framework. For example, Germany, Poland and France currently use absolute energy consumption as the basis for EPCs for some of their building stock. Each country applies different philosophies, categories and values to the assessment of the material and physical properties of its building stock.

The simultaneous use of empirical and modelled energy assessments for existing buildings can generate varying results with implications for energy policies that expect standardised assessments. This research quantifies the current extent and use of empirical and modelled assessments and further examines the use of estimated values within modelled assessments. Our research reveals the extent to which empirical data is currently being used across Europe and the variation in input data used for the physical modelling of energy consumption in buildings.

The use of empirical energy assessments can be consistent with the EPBD and formalising their use may be a way ahead for a more coherent low-energy building policy. Variations in the input values available for modelled energy assessments can diminish the authority of assessments for both building residents and policymakers. Identifying good and bad practice in energy assessment may help to develop better compliance structures for the future. This research makes clear the value of carrying out a pan-European analysis of energy assessment methods.

Introduction

The Energy Performance of Buildings Directive (EPBD)[1] was introduced by the European Union (EU) in 2004 and recast in both 2010 and 2018. The recast 2010 directive required countries within the EU to introduce minimum standards for the energy performance of newly constructed buildings and assessments of the existing building stock as tools for reducing the 40 % of final energy consumption that was associated with buildings. The EPBD aimed to introduce a "legal instrument … to lay down … concrete actions with a view to achieving the great unrealised potential for energy savings and reducing the large differences between Member States" results in this sector".

The EPBD established the use of Energy Performance Certificates (EPC) to provide information on the energy performance of both newly constructed and existing buildings. EPCs are required when a building is constructed, sold or rented. Since many member states had existing construction standards and assessment systems which calculated energy use in buildings, the EPBD did not mandate one method for establishing the energy use of a building but allowed for methods which were "differentiated at national and regional level". Annex 1 of the EPBD which described the framework for calculating energy performance stated that it could be determined on the basis of "calculated or actual annual energy … consumed".

This paper examines in detail the methods used to generate EPCs for existing residential buildings in the six largest EU member states. It analyses the legislation and regulations for each member state to establish how energy assessment methods could be applied to the building stock in 2014. Data from the European Building Stock Observatory[2] is used to quantify the portion of the member state's building stock that each energy assessment method could be applied to. Data on household energy use in each member state is also used to provide an indication of the relative energy use that each energy assessment method can affect. The energy assessment methods are sorted into categories which provide a transnational view of building energy assessments.

For existing buildings, construction details are often not available. An estimate of material properties for the building elements is required if calculation models are used to provide energy assessments. Each member state provides a database of input values for use in energy assessments. These input values are based on the typical construction details for building elements as interpreted by each member state. This paper examines the range of input values provided for thermal transmittance of exterior walls by each member state.

Energy Assessment Methods

VARIATION BY REGION

In January 2015 a report[3] to the Energy Directorate of the European Commission identified 35 different methodologies that were being used to calculate energy performance in buildings across the 28 European member states whilst in 2014 the Buildings Performance Institute Europe published a mapping of EPC implementation across Europe [4]. This paper examines and quantifies the methods used to generate EPCs for existing residential buildings in the six largest European member states in 2014. Methods are categorised to identify the effect that different methods may have on energy use and energy policy across the European Union.

The six largest member states (Germany, United Kingdom, France, Spain, Italy and Poland) have 353 million residents[5] or 70 % of the population of the European Union. These states have 174 million permanently occupied dwellings in total, which consumed the equivalent of 211 million tonnes of oil for household use in 2014. Household energy use per resident in 2014 varied across the six member states[6] as shown in Figure 1. All data on resident populations and energy use at the level of member states is taken from Eurostat which defines household energy use as the "electricity and heat every citizen consumes at home excluding energy used for transportation".

The six member states used 15 assessment methods to generate EPCs for existing residential buildings in 2014. Although there are some similarities, the regulations of each member state assigned the assessment methods to different sections of their building stock. If the assessment is being conducted to generate an EPC because the building is being sold or rented, the cost of the assessment is borne by the building owner. In cases where more than one assessment method can be applied to an individual building, evidence from Germany [7] suggests that building owners have a strong preference for the cheapest assessment method.

Data from the European Building Stock Observatory[2] has been used to quantify the portion of each member state's building stock to which each assessment method could be applied. In cases where more than one assessment method could be applied the cheapest method has been selected. The household energy use for each country as shown in Figure 1 has been allocated to these portions of the building stock to provide an indication of the energy use that was subject to each assessment method.

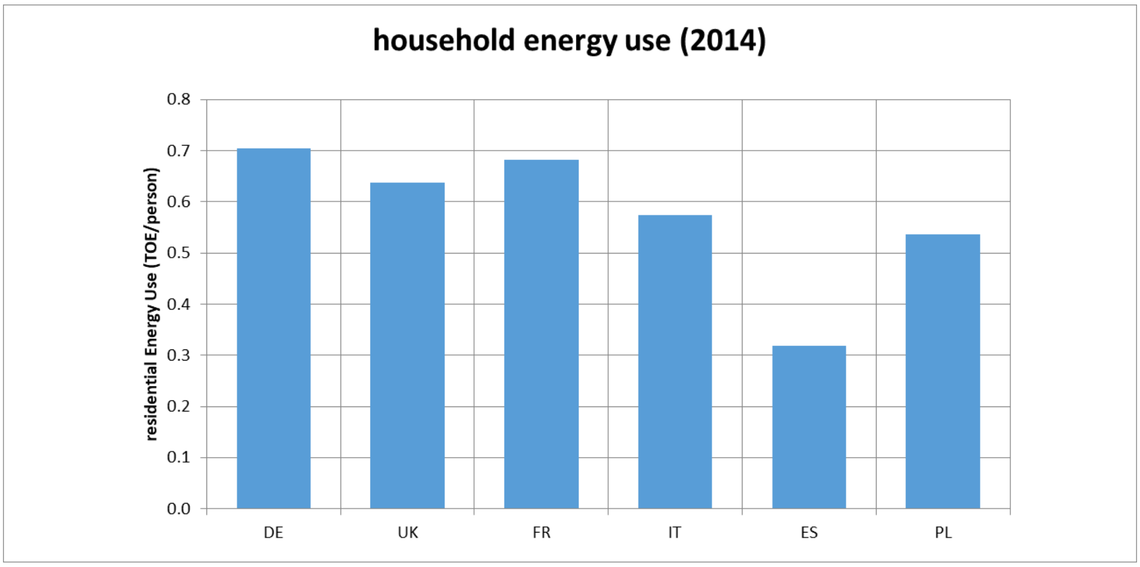

Figure1. Household Energy Consumption (2014).

Table 1. Energy Assessment Methods (Germany).

Assessment method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
DIN 18599	Buildings constructed after 2009	602,710	1,133,958
DIN 4108 (simplified)	Buildings for single households constructed before 1977	11,513, 277	19,277,286
Certification based on Consumption [*Verbrauchsausweis*]	Buildings constructed between 1977 and 2009	21,373,926	36,286,656
	Buildings for multiple households		

Table 2. Energy Assessment Methods (United Kingdom).

Assessment method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
Standard Assessment Procedure (SAP) 2012	Buildings constructed after 2009	466,163	820,100
Reduced Standard Assessment Procedure (RdSAP) 2009	Buildings constructed before 2009	27,447,836	40,184,900

Germany

Standards for energy use in buildings in Germany are mandated by the Energy Saving Ordinance[8] [*Energieeinsparverordnung*] (EnEV) which was updated in 2009 to include the use of EPCs. Germany has established a detailed and comprehensive calculation method DIN 18599 to calculate the energy performance of all building types. This method is used to assess the predicted energy use for all buildings constructed since 2009. The use of DIN 18599 to generate EPCs is optional for existing buildings and most owners of existing residential properties use a simplified version of DIN 4108 or, where applicable, calculation via actual consumption to generate EPCs. Actual consumption can be used for residential buildings constructed since 1977 and for multi-household buildings.

United Kingdom

In the United Kingdom the Energy Performance of Buildings (England & Wales) Regulations of 2012[9] and the Energy Performance of Buildings (Scotland) Regulations of 2008 consolidated previous building and energy legislation with the EPBD and confirmed the use of the Standard Assessment Procedure (SAP), to assess all residential buildings. A simplified version of this procedure, known as Reduced Data SAP (RdSAP), could be used for buildings constructed after 2009. Although SAP has been regularly updated since its formulation in 1995, the RdSAP inputs were established in 2009 and were still in place in 2014.

France

In 2005 the Thermal Regulations [*Réglementation Thermique*] [10] introduced a detailed assessment method for new buildings which was applied to all residential buildings constructed since 2006. For residential buildings constructed between 1948 and 2006 the Standard Calculation of Consumption for Dwellings [*Calculs des Consommations Conventionnelles dans les Logements*] (3CL) was specified. For buildings constructed before 1948 and for apartments using collective heating systems, 36 months of utility bills could be used to demonstrate the actual energy consumption of the building.

Italy

Within Italy some elements of the implementation of the EPBD are delegated to regional governments so the following information, while based on national guidelines, may not have been applied in all areas in 2014. A national decree in June 2009 [*Linee Guida Nazionali per la Certificazione Energetica*][11] established guidelines for energy certification. The national standard UNI/TS 11300 defines the standard calculation methods, using construction details, for all buildings constructed since 2009. For existing residential buildings the Diagnostic & Certification Software, DOCET [*Diagnosi e Certificazione Energetica degli Edifici Residenziali Esistenti*] can be used. For existing residential buildings with floor areas below 1,000 m^2 the simplified method [*Metodo Simplificado*] within DOCET can be used. The average floor area of a single-family dwelling in Italy is 110 m^2 so, in practice, the majority of existing residential buildings constructed before 2009 can be assessed using the simplified method within DOCET.

Spain

In 2006 the Technical Building Code [*Código Técnico de la Edificación*][12] (CTE) described the standards for new buildings and specified the assessment methods to be used for EPCs for new and existing buildings. The CTE specifies that new buildings use a detailed Combined Heating/Cooling Tool [*Herramienta Unificada Lider Calenar*] (HULC) distributed as free software via the CTE website. For existing buildings, three simplified tools are available from the CTE website: an Abbreviated Method for Residential Properties [*Certificacion Energetica Residencial Metodo Abrevido*] (CERMA) for residential buildings and CE3 and CE3X for any building type.

Table 3. Energy Assessment Methods (France).

Assessment method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
Thermal Regulations RT2005 [*Réglementation Thermique*]	Buildings constructed after 2006	2,898,527	3,908,556
Standard Calculation of Consumption for Dwellings 3CL [*Calculs des Consommations Conventionnelles dans les Logements*]	Buildings constructed between 1948 and 2006	19,272,381	24,754,188
Actual consumption [*méthode des factures*]	Buildings constructed before 1948	11,369,092	14,765,656
	Buildings with collective heating systems		

Table 4. Energy Assessment Methods (Italy).

Assessment method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
UNI/TS 11300	Buildings constructed after 2009	1,274,286	1,711,530
DOCET – simplified method [*Diagnosi e Certificazione Energetica degli Edifici Residenziali Esistenti – Metodo Simplificado*]	Buildings before 2009	24,838,134	32,519,070

Table 5. Energy Assessment Methods (Spain).

Assessment Method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
Heating Cooling Tool [*Herramienta Unificada Lider Calenar*] (HULC)	Residential Buildings Constructed since 2006	571,850	744,095
Abbreviated Method for Residential Properties [*Certificacion Energetica Residencial Metodo Abrevido*] (CERMA)	Residential Buildings Constructed before 2006	31,022,080	14,137,805

Table 6. Energy Assessment Methods (Poland).

Assessment Method	Applied to	Number of applicable dwellings in 2014	Estimated Household Energy Use in 2014 (toe)
ISO 13790	Buildings constructed since 2010	675,432	1,020,350
ISO 13790 (simplified)	Buildings constructed before 2010 with unmetered energy supply	10,732,432	15,713,390
Actual consumption	Buildings constructed before 2010 with metered energy supply	2,489,906	3,673,260

Poland

Poland has a distinctive profile for energy use and CO_2 generated by buildings. In 2014, the majority of dwellings (70 %) used coal as their primary source for space heating. Although the EPBD was adopted in Poland in 2010, as of 2013, the requirement to provide EPCs for all buildings that were sold or rented had not been fully implemented so there is limited information on the operation of EPC assessments for existing residential buildings in Poland in 2014. Existing buildings which have a metered energy supply and where 36 continuous months of utility bills are available can use actual energy consumption to generate EPCs. For other buildings Poland uses the international standard ISO 13790 as the basis for its national assessment procedure for both new and existing buildings. A simplified version of this is available for buildings constructed before 2010.

VARIATION BY CATEGORY

Standardisation of assessments was a key aim of the EPBD and there are many similarities between the fifteen assessment methods used in the six member states to generate EPCs. Assessments can be based on past performance or on predictive models. The models used for assessments can use construction details or approximations based on knowledge of the construction details that were likely to have been used in the building. Where approximations are used, the level of detail and the amount of in-situ measurement required can vary. Three categories were established to allow analysis of common assessment types across regional boundaries.

Standard Calculation

These methods use calculation models which balance the assumed energy required for heating, cooling and lighting under standard conditions using regionalised climate data with the energy losses through fabric and ventilation based on detailed construction data. When applied to buildings under construction this can be described as a *Design Rating*. The material and energy system properties used for this calculation method are standardised across Europe. The variation between the energy use calculated by these Standard Calculation methods and the actual energy use once the buildings are occupied has been described as the *Performance Gap* as discussed by Tronchin and Fabbri[13] in Italy and Tuohy and Murphy[14] in the UK. Standard Calculation Methods are mainly used for buildings constructed since 2010 when the EPBD was introduced.

Reduced-Input Calculation

These methods are adapted for existing buildings where accurate information on the building's geometry and construction details may be limited. These methods also use models, which balance the assumed energy required with energy losses. These methods can produce a rating independent of the buildings use, also known as an *Asset Rating*. All of these methods can use exact material properties if these are available. Where detailed construction data is not available for the building fabric, default values are provided. The default values available are based on the building's construction date, location and use. The range of values available varies between methods. Reduced-Input Calculations are also subject to a performance gap. The selection of inappropriate default values by assessors can also lead to errors in EPC ratings, which reduces the authority of the EPC information in the six member states.

Actual Consumption

These methods use billing data for occupied buildings. Weather and occupancy adjustment may also be used to compensate for individual building use. These methods generate an *Operational Rating*, defined as "a numeric indicator of the amount of energy consumed during the occupation of the building"[15]. The three countries that use this method (France, Germany and Poland) used 36 months of metered energy bills as the basis for this assessment method.

The application of each method within the six member states was quantified to allow analysis across national boundaries. The estimate of household energy use in each member state was also quantified to indicate the energy use, which each method could be used to assess.

The categories of assessment methods are not evenly distributed across the six member states. There appears to be a tendency for actual consumption to be applied more in colder countries[16] such as Germany and Poland which have higher energy consumption. However, the small number of countries being investigated here does not allow for this to be described as a causal relationship

VARIATION BY INPUT VALUE

The largest category for assessment methods is Reduced-Input Calculation, which could be applied to 97,844,467 dwellings in the six member states in 2014. The households in these dwellings used an estimated 107,221,839 toe energy in 2014. This represents 70 % of all household energy use across the six member states. The Reduced-Input Calculation Methods are used to assess existing buildings where construction details may not be available. All the Reduced-Input Calculation Methods provide default values for the buildings material properties if actual details are not available. The form of default values provided for building elements such as windows or heating systems vary enormously across Europe and some building elements such as roofs are not present in all building types. However all six countries provided default values, where actual construction details are not available, for exterior walls in the form of U-values.

For this paper the building element of exterior walls and the value of thermal transmittance were selected to provide an indication of the range and distribution of values available. All the Reduced-Input Calculation Methods examined used the measure of U-values (W/m^2K) to establish the thermal transmittance of exterior walls. Each member state used the same thermal transmittance values for specific materials however the variation in construction methods across regions and eras meant that these thermal transmittance values are used in many different combinations. Default values are provided by each member state for selection by energy assessors working with individual buildings where construction details are not available. Assessors can use their knowledge of construction methods and a visual inspection of the building to select the appropriate default value from their country's database.

Each country's database of default U-values for exterior walls is arranged differently. The variation in the number of default values is striking: Germany [17] provides just 16

Table 7. Energy Assessment Methods by Category.

Calculation method	Country	Method type	number of dwellings	Indicative energy use (toe)
méthode des factures	France	Actual Consumption	35,232,924	54,725,572
Verbrauchsausweis	Germany			
actual consumption	Poland			
DIN 4108 (simplified)	Germany	Reduced-Input Calculation	97,844,467	107,221,839
RdSAP	United Kingdom			
3CL	France			
DOCET	Italy			
CERMA	Spain			
ISO 13790 (simplified)	Poland			
DIN 18599	Germany	Standard Calculation	6,488,968	9,338,589
SAP	United Kingdom			
RT2005	France			
UNI 11300	Italy			
HULC	Spain			
ISO 13790	Poland			

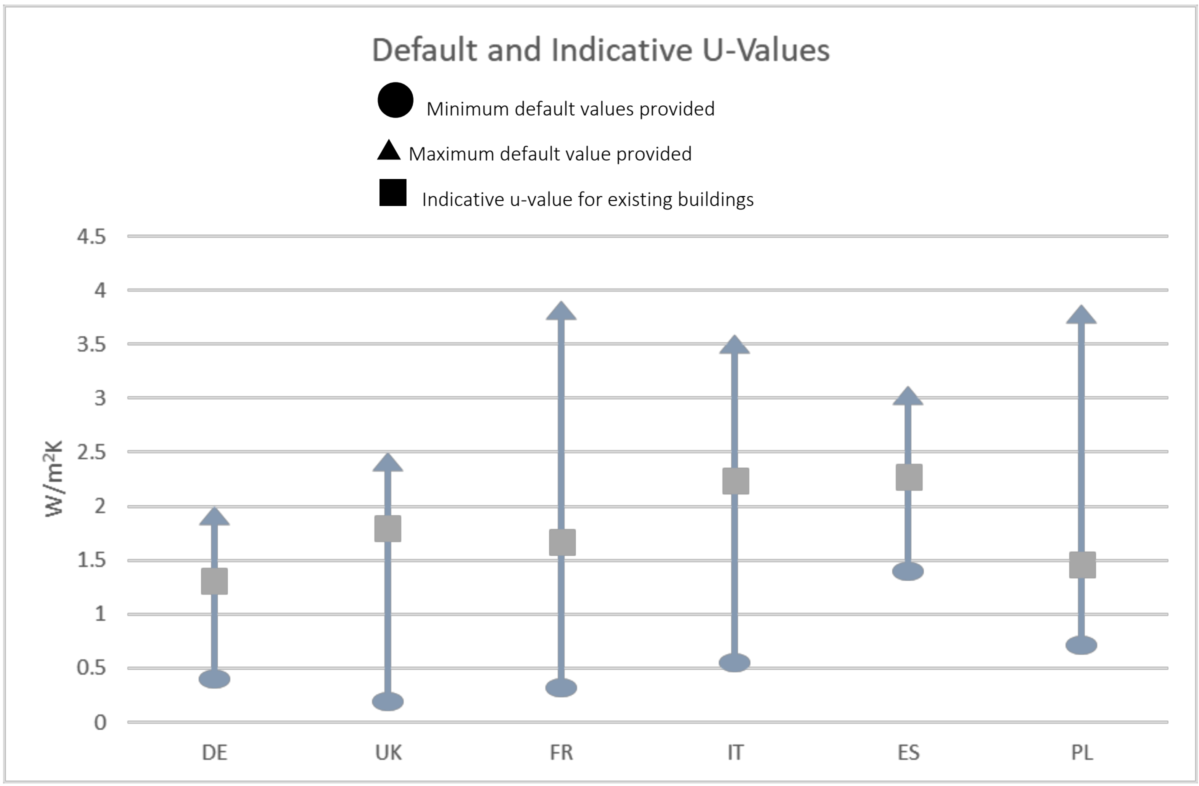

Figure 2. Exterior Wall U-value Options by Country.

default values to choose from (two different wall types over eight separate construction periods) whilst the United Kingdom [18] has 495 default values to choose from (fifteen different wall types over eleven construction periods and three regions). Figure 2 gives an indication of the range of default U-values (W/m²K) that are provided in each member state [17-22] for selection by assessors in Reduced-Input Calculation Methods where construction or actual details are not available.

Although exterior walls are only one element of the building envelope they make a significant contribution to the heat loss calculations contained within the models used for the Reduced-Input Calculation Methods. The European Building Stock Observatory [2] provides an indicative U-value for existing residential buildings across Europe. These U-values are derived from a basic average of the U-values of a building's elements and the source data varies from country to country. The figures are indicative only but they provide a basic picture of the existing residential building stock in each country which can be compared in Figure 2 to the range of default U-values available in Reduced-Input Calculation Methods.

Figure 2 demonstrates that the range of default values provided to assessors for existing residential buildings when construction details are not available varies across the six largest European countries. The range of default values does not always correspond to the actual properties of existing buildings as indicated in the European Building Stock Observatory. For example, Poland provides a range of values which are higher than those indicated for actual buildings whilst the United Kingdom provides a range of values which are lower than those indicated for actual buildings.

Since input values can be selected by assessors rather than derived from actual construction details, the selection of inappropriate values is an issue for Reduced-Input Calculation Methods. Inappropriate values are used when an assessor selects default values that do not correspond to the actual building. This issue has been noted by residents in all of the six countries. Comments from the consumer magazine *60 Millions de Consommateurs* "Too many guesses, too many mistakes … Our study of EPCs across the country shows that the work of assessors is still very uneven" [23] and the daily newspaper *Die Welt* "… it is luck or the mood of the assessor that determines [a building's] EPC rating" [24] are typical.

Conclusions

- 70 % of the residential energy use in the six largest member states of the EU can be assessed using estimated values for the material properties of the building. Is this an appropriate basis for energy policy?
- The selection of inappropriate values for individual assessments has reduced the authority of EPCs with residents across all six-member states examined.
- There is significant variation in the number and range of default values provided by individual member states for selection by energy assessors. This variation may have a significant impact on the energy ratings generated for homes in these member states.
- The option of using actual consumption for energy assessments is used by three of the six largest member states and can currently be applied to 25 % of homes across the six member states. Is this an option to develop a standardised framework for assessing energy use in all existing homes?

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