CONCERTED ACTION
ENERGY PERFORMANCE
OF BUILDINGS

Primary Energy Factors and Members States Energy Regulations

Primary factors and the EPBD

Authors: **Roger Hitchin, Building Research Establishment (BRE), United Kingdom**

Kirsten Engelund Thomsen, Danish Building Research Institute, Aalborg University, Denmark

Kim B. Wittchen, Danish Building Research Institute, Aalborg University, Denmark

Introduction

Primary energy is a major metric within the Energy Performance of Buildings Directive (EPBD – Directive 2010/31/EU), but the methodology used to calculate its value is left up to each Member State (MS) to decide. Specifically, the EPBD requires that the energy performance of a building shall "*… include an energy performance indicator … based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on-site production*"[1].These performance indicators are used to set minimum requirements for new and renovated buildings and as the basis of informative Energy Performance Certificates (EPCs) that are required whenever a building is constructed, sold or let.

The reduction in the use of primary energy for the end-uses covered by the EPBD is an important policy goal, both through minimum performance requirements and for EPCs. From the perspective of building owners, managers and designers, primary energy is particularly important for meeting mandatory regulations for new and renovated buildings, but cost is likely to carry more weight than primary energy when assessing possible improvements to existing buildings.

Within the EPBD, the choice of values for primary energy factors (PEFs), which are used to calculate the primary energy content of energy delivered by different energy carriers, is at the discretion of MSs. From a physical perspective, some differences between PEF values in different MSs for the same energy sources are inevitable because of differences in local conditions, such as greater leakage from or compressor power for longer gas pipelines. In addition, different conventions are possible for the various steps of calculating PEF. For example, there are several different internationally-recognised conventions for the primary energy content of electricity from renewable or nuclear sources. These can differ by as much as a factor of three.

Inspection of the published PEF values and enquiries to MSs reveal that reported PEF values do indeed vary by more than the purely physical differences for the aforementioned reasons.

As a consequence, the reliability of primary energy savings (or consumption) in buildings aggregated from national totals is undermined. The consistency between cost-optimisation of national regulations and definitions of Nearly Zero Energy Buildings (NZEB) is also weakened.

The methodologies to determine PEFs are often not transparent (including those involved in implementing the EPBD). As a result, it is not possible to assess the nature or size of discrepancies in any detail.

[1] *EPBD DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast) – Annex I.*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 692447.

The European Standards Association CEN has recently started work to develop a template for reporting the conventions used, which will be accompanied by explanations of the advantages and disadvantages of each choice.

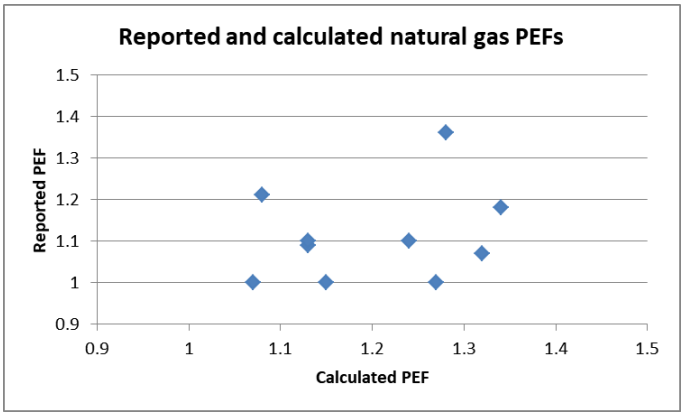

Figure 1. Comparison between reported and consistently calculated PEFs for natural gas.

Figure 1 shows, as an example, the PEF values for (pipeline) natural gas in ten MSs. The "*calculated*" values are based on an identical procedure and differ only in terms of physical characteristics. The "*reported*" values are actual national figures. There is a degree of correspondence but the correlation is very weak.

Basic definitions

Primary and Secondary Energy

The concept of primary energy attempts to provide a single metric for all forms of energy that are supplied to, or transmitted through, a defined delivery boundary. It is the metric used for building energy ratings and building minimum performance requirements in most EU countries. In this case, the delivery boundary is the "*assessment boundary*" – usually the building envelope, though precise definitions vary.

Primary energy is also used in other legislation, notably the Energy Efficiency Directive and Regulations deriving from the Energy Labelling and Energy-related Products Directives, though with little or no scope for national flexibility. Primary energy is reported in energy content terms such as GJ or kWh.

There are several internationally recognised definitions for primary (and secondary) energy. The definition in EN ISO 52000-1 is "*primary energy is energy that has not been subjected to any conversion or transformation process*". A more general definition is "*Primary energy sources are inputs into energy systems (or conversion processes) through which they are converted into energy carriers such as electricity, oil products, enthalpy (including heat), or mechanical work*". Other definitions restrict "t*ransformation*" to only include human-induced transformations, and differ as to whether or not energy used for extracting or cleaning fossil fuels is to be included.

There are usually several transformation stages within an energy supply chain. For example, oil products may be derived from crude oil, transported to a customer and then converted into heat. In effect, all energy carriers are secondary (or tertiary) forms of energy and secondary energy may be more than one stage removed from primary energy. One definition constrains primary energy to be "*the first energy form downstream in the production process for which multiple en*ergy *uses are practical*". With this definition imported energy could be considered to be primary energy at the national border, although there may be many transporation and processing stages before it arrives.

Definitions always cover combustible fossil fuels, but are usually silent as to other energy sources. For combustible fuels, primary energy is taken as the total energy that can be obtained by combustion – the calorific value. There is less agreement on how to define it for other energy sources and carriers, notably for electricity produced from nuclear and renewable sources. By convention, "*embodied energy*" – the energy used to construct the equipment used to extract or "*transform*" energy carriers – is not included, although it can be significant when compared to the amount of energy produced for some renewable technologies.

The definitions allow PEFs to be based on "*Gross or Net Calorific Value*" and to differentiate between distant, nearby and on-site sources. In addition, imported and re-delivered energy may have different factors. The proposed revisions to the EPBD clarify that, within the Directive, "*Primary energy factors shall discount the share of renewable energy in energy carriers so that calculations equally treat:*

- *(a) the energy from the renewable source that is generated on-site (behind the individual meter, i.e., not counted as supplied);*
- *(b) the energy from renewable energy sources supplied through the energy carrier*".

For economists, "*primary energy*" allows the energy content of different energy sources to be aggregated and used to compile national energy balances that relate delivered energy to resource use. Its value for other energy policy purposes is limited since it does not distinguish between the different energy sources except in terms of thermal content. In particular, it does not reflect differences of environmental impact, supply security or price – all of which are important aspects of energy policy. As a result, MSs sometimes declare PEF values that depart from a strict physical calculation. For similar reasons, EN ISO 52000-1 distinguishes between "*renewable*" and "*non-renewable*" primary energy (while permitting values that do not have a strictly physical basis).

Primary Energy Factors

PEF is calculated as the inverse ratio between the amount of delivered energy (in say GJ) and the primary energy required to provide it. Thus, 1 GJ of natural gas delivered to a building may have a PEF of, for example, 1.1.

PEFs may legitimately differ between (or within) MSs since the primary sources may differ and the amount of energy required for transportation or processing may vary as well. They may also legitimately differ over time, since the sources and transformation processes may change.

Several aspects of the calculation of PEFs present difficulties, either in data reliability or fundamental methodology. As a result, different conventions can be adopted which result in different estimates of the PEF value.

Summary of PEFs used by MSs

Principal values

It was expected that a set of PEF values could be constructed from national cost-optimisation reports, but these reports generally only report a limited number of PEFs – and sometimes none at all. Values have therefore also been taken from the 2012 Concerted Action report and other published sources. Nevertheless, there remain gaps and the values may not always be strictly comparable.

MSs differ in the level of disaggregation of energy carriers reported, and whether they report only a total value or also renewable (or non-renewable) PEFs.

Table 1 shows the interval of values of total PEF for the categories most frequently reported.

Countries	Mains gas	LPG	Oil - general	Diesel or heating oil	Fuel oil	Coal - general	Biomass - general	Wood - general	Wood pellets	Grid Electri-city	District heating - general
EU countries in average	1.00-1.26	1.00-1.20	1.00-1.23	1.00-1.14	1.00-1.20	1.00-1.46	0.01-1.10	0.01-1.20	0.01-1.26	1.5-3.45	0.15-1.50
CEN (non-renewable) defaults	1.1	1.1	1.1	1.1	1.1	1.1	0.2	0.2	0.2	2.3	1.3

Table 1. Values of PEF for the categories most frequently reported.

Some of the values in Table 1 are impossible in a strictly physical sense (fossil fuel PEF must be greater than 1), others probably reflect differences between the uses of "*non-renewable*" or "*total*" (renewable plus non-renewable) primary energy, while some of the variations undoubtedly reflect physically-derived national differences.

Conclusion and needs

The calculation of PEFs is not a simple process; the values depend on a rather large number of conventions for which there are alternative choices. The procedures adopted by each MS for EPBD purposes are far from transparent and, as a result, it is not possible to distinguish reliably between inherent differences and those that result from the use of different procedures. They also differ from the values used in other directives.

This is important because:

- primary energy consumption as reported through the EPBD is not directly comparable between MSs;
- national cost-optimisation and definition of NZEBs based on primary energy may not be consistent between MSs;
- rankings for recommended energy savings actions based on primary energy savings may not be consistent between MSs;
- several actions could be taken to improve transparency and encourage greater consistency, such as by providing greater clarity of national methodologies, which is being addressed by CEN in the form of a

reporting template. A draft standard template and supporting explanatory report are expected to be put in the public domain during 2018.

- The consequences of using different conventions must be understood, and thus the CEN is developing information on the impact of different choices.

In the longer term, the objective should be the development of an agreed set of workable conventions coupled with advice on their applicability.

The calculation of PEFs can clearly become complex and problematic. For EPBD purposes, a reasonable, practical objective would be to identify conventions for PEFs that are reasonably straightforward to calculate and apply, and which do not result in seriously misled energy supply decisions. This would sometimes require compromises to be made between theoretically ideal procedures and practical applications. It is important to identify the situations in which simpler methods may produce misleading results so that the risks are evident and more complex approaches can be considered.

References

- DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast) - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF
- ISO 52000-1:2017, Energy performance of buildings -- Overarching EPB assessment -- Part 1: General framework and procedures. International Organisation for Standardisation
- OECD/IEA/Eurostat Energy Statistics Manual 2005 https://www.iea.org/publications/freepublications/publication/energy-statistics-manual.html accessed September 2017
- Lightfoot H D, "What Engineers and Scientists should know about scales for measuring primary energy", 2nd Climate Change Technology Conference, Hamilton, Canada, 2009
- EED DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC