

# Energy ratings based on measured energy consumption: A practical approach for implementation of EPBD and identification of high-energy use buildings.

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## ABSTRACT

Article 7 of the EU Energy Performance of Buildings Directive requires Member States to implement energy certification for buildings, and particularly for large public buildings, requires an energy certificate to be displayed in public. This paper outlines a simplified procedure for the certification of existing public buildings based on measured energy consumption, which is applicable even in countries where information on the building stock is not currently available. Energy consumption data collected for a number of buildings is used to develop energy benchmarks for typical and good practice energy performance. The rating procedure is based on a comparison between the energy consumption of each building and the derived benchmarks; a process that is illustrated in a sample of 88 Irish primary schools. The paper concludes with a discussion on the next steps to a more detailed measured rating procedure.

## 1 INTRODUCTION

EU Member States are in the process of implementing the Energy Performance of Buildings Directive (EPBD) (European Council 2002) which was transposed to national legislations in January 2006, a requirement of which is to provide buildings with energy certificates when constructed, rented, or sold.

Member States have or are in the process of developing tools for the certification of buildings. Devising certification tools that are robust and repeatable and at the same time easily applicable and cost-effective is a difficult task. This is particularly the case for non-domestic buildings, which comprise a full range of types, sizes and usages. A detailed knowledge of the energy performance of the building stock is often a prerequisite for the development of appropriate tools. While some countries have a good tradition of calculating energy performance, conducting energy audits and processing energy performance data, other Member States are facing the situation of having to develop tools without previous knowledge of their building stock.

This paper presents a certification methodology that is easily applicable and with only outline knowledge of the building stock energy performance required. The methodology is based on the actual measured performance of buildings and is here applied to schools. Measured rating based on actual energy use is appropriate for public buildings as the EPBD requires them to place certificates in a prominent place clearly visible to the public and generally experience fewer sale or rent transactions than other non-domestic buildings.

## 2 BENCHMARKING ENERGY PERFORMANCE OF PRIMARY SCHOOL BUILDINGS

From the range of public non-domestic building types this research targeted primary schools. Primary schools represent a reasonably homogeneous group with similar building size and construction types and

also present similar occupancy profiles and types of usages. This makes them a suitable study group for the testing of a simplified certification approach based on measured energy usage.

Energy performance benchmarks for primary schools in Ireland did not exist at the time of this research. The data required to establish energy benchmarks was based on the size of the buildings and the annual energy use by each energy carrier. The required data was collected for primary schools by means of questionnaires. The most effective model of questionnaire proved to be one-page in length and with simple data entries that offered the respondents the possibility of inputting the annual energy use data in whatever measure they had available (energy costs, liters of oil, etc.). The questionnaire also allowed the number of pupils to be stated as an additional indication of the size of the building where the area was not known. Post-processing of the information was required to help complete the information and included assumptions to convert energy costs into energy usage and converting the number of pupils into a corresponding internal floor area based on average figures of pupils per square meter (available for approximately 50% of the schools). This normalization facilitated the derivation of benchmarks in terms of kWh/m<sup>2</sup>.

For the purpose of this research, 88 Irish schools for which electricity and fossil fuel indicators were collected is considered as a representative sample of the Irish primary school building stock. Figure 1 shows the data for the 88 schools on a cumulative distribution.

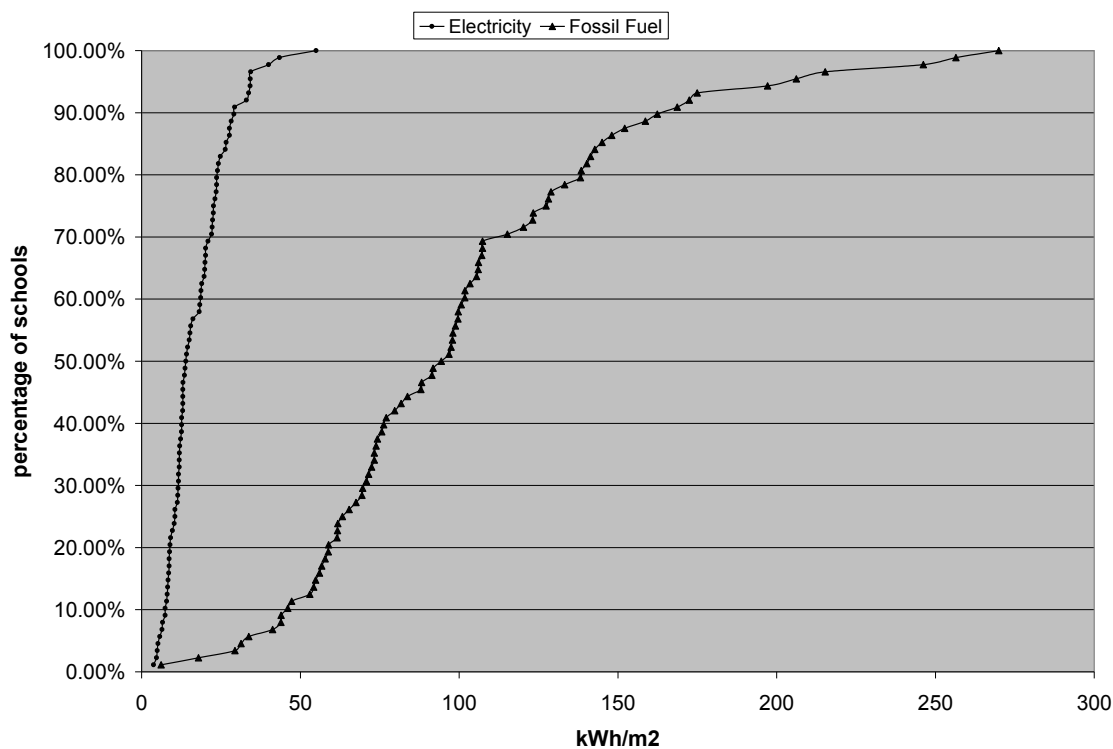


Figure 1. Cumulative distribution of electricity and fossil fuel energy use in Irish Primary School

Based on this distribution, the following definition of benchmarks was applied for the primary school building stock in the Republic of Ireland.

- Typical practice: The performance achieved by 50% of the building sample, which is the median of the distribution.
- Good Practice: The performance achieved by the best 25% of the schools from the building sample, which is the lower quartile of our distribution.

The results from this exercise can then be compared with other existing international benchmarks with similar climate and construction characteristics (Jones at al. 2000, The Carbon Trust 2005).

Table 1. Energy performance benchmarks for annual energy use at primary schools (kWh/m<sup>2</sup>)

Region	Electricity		Fossil Fuel	
	Typical	Good Practice	Typical	Good Practice
UK	34	25	157	110
Northern Ireland	18	12	119	91
Republic of Ireland*	14	10	96	65

\* Developed from our building sample of 88 primary schools

From this comparison it can be observed that the developed benchmarks in the Republic of Ireland are considerably lower than the equivalent in Northern Ireland and in the UK. Possible explanations for those differences, which justify further research, might be variations in occupancy hours and holidays, quality of the construction and systems, the indoor environmental conditions, and differences on the climates.

### 3 'BUILDING ENERGY EFFICIENCY' AND 'MEASURED EMISSIONS' RATINGS

The draft European standard prEN15217: 2005: Energy performance of buildings- Assessment of energy use and definition of energy ratings (CEN 2005) establishes a grading method for building energy performance, sub-divided into seven grades as described in Table 2.

Table 2. Grades classification according to prEN 15217:2005

Class A	$EP < 0.5 R_r$
Class B	$0.5 R_r \leq EP \leq R_r$
Class C	$R_r \leq EP \leq 0.5(R_r + R_s)$
Class D	$0.5(R_r + R_s) \leq EP \leq R_s$
Class E	$R_s \leq EP \leq 1.25R_s$
Class F	$1.25R_s \leq EP \leq 1.5R_s$
Class G	$1.5R_s \leq EP$

EP is the energy performance of the building to be graded. The reference values  $R_r$  and  $R_s$  are defined at national or regional level. For this grading exercise, the following were used:

- $R_r$  corresponds to a 'Good Practice' benchmark.
- $R_s$  corresponds to a 'Typical Practice' benchmark.

With this classification and associated reference values, the rating of the primary school buildings energy performance is now possible. For this exercise two different types of ratings have been defined: the Building Energy Efficiency Rating and the Measured Emissions Rating

#### 3.1 Building Energy Efficiency Rating

This rating is based on the separate electricity and fossil fuel energy use and their combined weighted overall energy use. A weighting factor of 2.5 has been applied to the electricity supply, based on the relative thermodynamic efficiency of energy delivered to the buildings, as a simplified approach to represent common practice on energy conversion. Table 3 shows an example of energy efficiency grades for a selection of schools analysed.

The four schools at the top of the table present an overall building energy efficiency grade B, which suggests that the schools are relatively energy efficient and perform better than 'Good Practice' or, more precisely, that they are within 25% of most energy efficient schools. The two samples in the middle, with an overall grading of C, perform in between 'Good Practice' and 'Typical Practice'. The three sample schools at the bottom, with an overall building energy efficiency grade of E, perform worse than the 'Typical Practice'.

Table 3. Energy Efficiency Ratings for sample Irish Primary Schools

School ID	Energy Use (kWh/m <sup>2</sup> )		Energy Efficiency Grade		
	Electricity	Fossil Fuel	Electrical	Thermal	Overall Building
PR_17	8.4	54.2	B	B	B
PR_21	4.7	73.3	A	C	B
PR_30	10.3	33.8	B	B	B
PR_88	29.1	6.1	G	A	B
PR_38	18.9	61.8	E	B	C
PR_39	13.5	73.3	D	C	C
PR_12	8.8	140.2	B	E	E
PR_40	34.2	54.8	G	B	E
PR_45	14.5	128.9	E	E	E

We can also observe that thermal and electrical efficiency differs in cases from the overall building efficiency. For example, school PR\_40, with a relatively low total delivered energy consumption, has an overall grade E as it exhibits poor electrical efficiency (Grade G), which is weighted at 2.5 in the overall grade. This approach would allow us to quickly identify schools with poor overall efficiencies and suggest the issues to be considered in each particular school with a view to improving overall energy efficiency. (e.g. lighting controls where there is a bad electrical efficiency grade).

### 3.2 Measured Emissions Rating

This rating assesses the overall emissions from a particular building and is particularly useful for comparison with building regulations or other policies relevant to an assessment of the building's contribution to national CO<sub>2</sub> emissions.

For the calculation of the grades, carbon dioxide emission factors have been applied to the different fuels used by a particular building. For this exercise, emission factors of 0.198 kg CO<sub>2</sub> per kWh for natural gas, 0.264 kg CO<sub>2</sub> per kWh for oil and 0.651 kg CO<sub>2</sub> per kWh for electricity have been applied and are based on national figures (Sustainable Energy Ireland 2005).

For the conversion of the 'Typical Practice' and 'Good Practice' energy performance benchmarks into emissions benchmarks weighting factors must be defined. In this example, we use the same conversion factor for electricity from the national figures and the conversion factor of natural gas for fossil fuel. Because of this approach, schools that use any other fossil fuel than gas are likely to get a worse rating, as they will be compared with benchmarks calculated using the weighting factor of natural gas. This decision has been taken as an approach to demonstrate how ratings can encourage the use of cleaner fuels (e.g. gas instead of oil) as well as more efficient technologies.

Table 4 shows an example of two schools for which the measured emission grades have been calculated.

Table 4. Measured Emissions Ratings for two sample Irish Primary Schools

School ID	Energy Use (kWh/m <sup>2</sup> )		Emissions (kg CO <sub>2</sub> /m <sup>2</sup> )		Measured Emissions Grade
	Electricity	Fossil Fuel	Electricity	Fossil Fuel	
PR_38	18.9	61.8	12.3	16.3	E
PR_39	13.5	73.3	8.8	14.5	C

School PR\_38 used oil for space and water heating and PR\_39 used natural gas. This factor, together with the higher relative use of electricity by PR\_38, results in this school exhibiting greater emissions and being two grades above PR\_39 for the measured emissions rating, despite having similar delivered energy use and the same overall building energy efficiency grades as was shown in Table 3.

## 4 APPLICATION OF THE RATINGS TO THE PRIMARY SCHOOL BUILDING STOCK

The two rating methods presented have been applied to the building stock sample represented by the 88 schools. Figure 2 shows the distribution of grades. For the energy efficiency ratings, 50% of the schools will

have a grade between A and D, and 50% of the schools a grading between E and F as the limit between grades D and E as defined in pr15217:2005 (CEN 2005) is the median of the building stock.

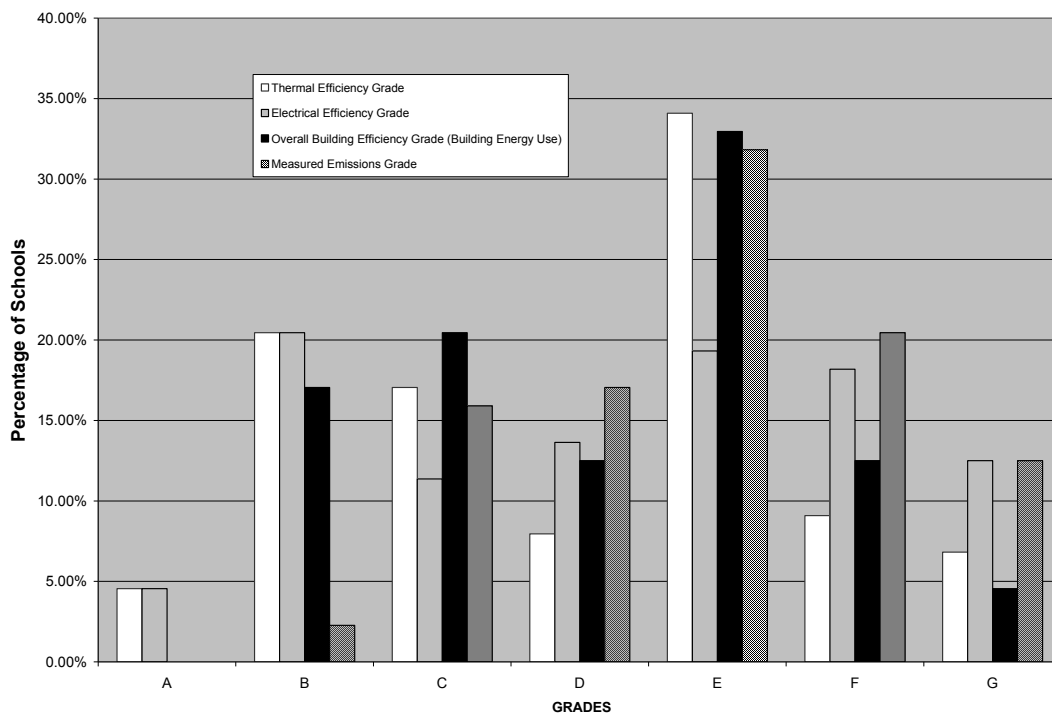


Figure 2. Distribution of Grades for the sample of 88 schools.

For the measured emissions grade, we can observe in the figure the influence of the approach of promoting cleaner fuels by using the weighting factor of natural gas for the fossil fuel benchmark. The measured emission grade is substantially worse than the overall building energy efficiency grade; only 35% having a grade between A and D and the other 65% of the schools in the building stock having the poorer rate of E, F or G. This result is due to the fact that, at present, most of the schools from the building stock use oil as their main heating source, which has more associated emissions than natural gas and generally is used in less efficient boilers.

## 5 FURTHER DEVELOPMENTS OF MEASURED RATINGS.

The simple methodology presented in this paper supports the identification of high energy users and high polluting buildings in a quick and cost effective way. It is expected that buildings which are awarded a poor rating or with a lower rating than expected might undertake a more detailed analysis. For further analysis, the methodology can be fine-tuned and expanded to account for possible particularities of a building. The EPLABEL project ([www.eplabel.org](http://www.eplabel.org) – use standard referencing notation and put this in the reference section) has developed a tool for certification including elements that facilitate this further analysis. The first refinement is to allow the identification of special energy uses within the buildings (such as car park lighting, server rooms, etc), which could have distorted the rating because these end uses are not included in the benchmarks. This quantification of a special energy use would help to further refine the comparison between a specific building and the benchmarks for its building type. Figure 3 illustrates part of the measured energy being identified as a special energy use that is deducted before a comparison is made with the benchmarks.

A further step also explored by the EPLABEL project is rating based on a comparison of a building's performance with customized benchmarks which are related to the specific activity and occupancy hours of the building in particular.

Figure 4 shows an example of the use of customized benchmarks for an office building. The measured energy use by the actual building, split between the fossil fuel and electricity is compared with typical and good practice benchmarks for a building of the same type, occupation and activities as the actual building.

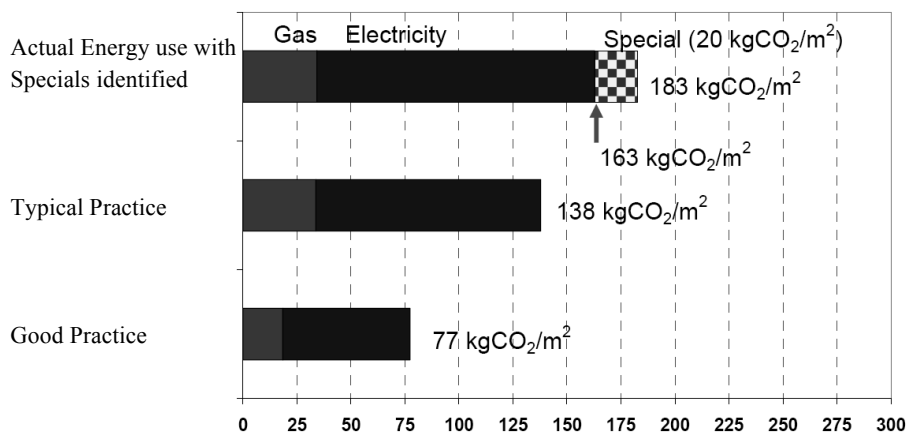


Figure 3. Allowing for identification of energy uses before comparison with benchmarks.

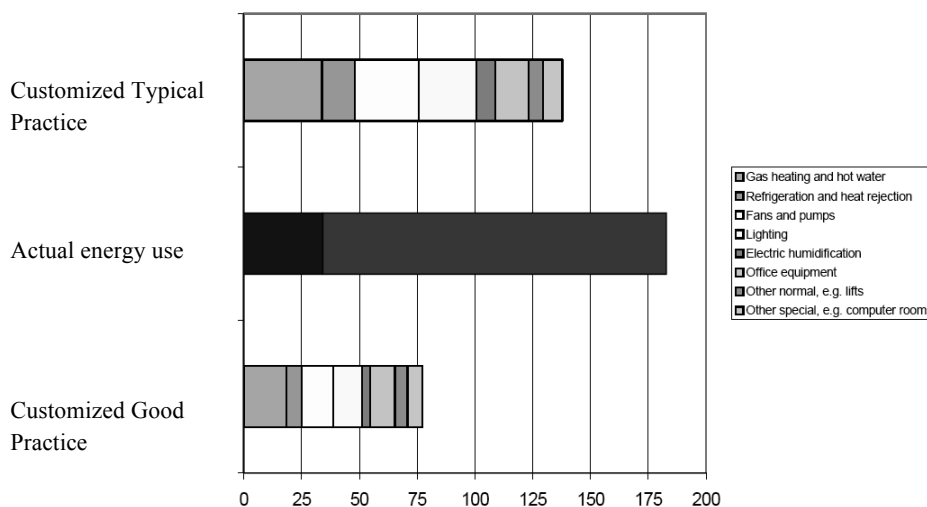


Figure 4. Comparison with customized benchmarks for activities and occupancy hours of the specific building, segregated in different systems.

In the situation where sub-metering is installed, it is possible to compare a measured individual energy end use with its respective benchmark, enabling different efficiency ratings to be applied to each energy end-use (heating, cooling, fans, lighting, etc).

It is also possible to extend this approach to component benchmarks, often expressed in W/m<sup>2</sup> of installed capacity (e.g. for heating, cooling, fans, pumps, lighting and office equipment), and/or as efficiency indicators, for example W/(litre per second) for mechanical ventilation systems and W/m<sup>2</sup> per 100 lux for lighting.

Customised benchmarks have two further uses:

- Simply by knowing the specific activities and intensity of occupation of a building one can generate the customised benchmark. Because it is tailored to a specific building, it can be used to estimate the relative scale of each energy end-use without any expert input: this is potentially powerful as it allows non-technical people to get more information.
- In a further step, the relative size of each energy end use in the benchmark can be applied to the measured energy use of the actual building, affording a first estimate of the actual energy end use breakdown. This breakdown can be refined by any further knowledge about the building, for example if there is sub-metering available or a robust estimate for one or more energy end uses as the lighting can be made.

Once the analysis has reached the stage of examining the actual energy end use breakdown, the assessor has moved towards identifying potential energy saving measures for the different end-uses. This approach would be particularly robust when sub-metering has been implemented in one or more of the major energy uses in a particular building.

## 6 DISCUSSION AND CONCLUSIONS

The advantages or disadvantages of measured versus calculated ratings, which have been extensively discussed in various European Forums, CEN committees and publications (Visier 2006) are not discussed in this paper. Instead, a practical methodology to produce energy ratings for use in existing public buildings based on measured energy consumption has been presented.

This simplified methodology aims to serve as a first step towards certification which is cost-effective, offers a quick implementation and would allow the identification of the worst performing buildings, which can then be encouraged to implement measures for improvement of the energy performance.

A sample representing the Irish building stock of primary schools is used as a practical example on how this measured rating could be implemented with very little resources. The method allows the identification of both buildings with high-energy use and buildings with high associated CO<sub>2</sub> emissions, by using the ‘energy efficiency’ and ‘measured emissions’ ratings. Each building can be provided with suggested priorities for improvement measures, either suggesting an improvement in thermal or electrical efficiency, the use of a fuel source with lower associated emissions (as natural gas or indeed renewable energy resources) or improving both factors.

Further refinement and fine-tuning of this measured rating approach has also been discussed, proposing customized benchmarking, which together with energy sub-metering could ultimately lead to a better understanding of the energy performance of the building stock and to identification of energy saving measures.

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