Principles of carbon counting for buildings in use

A discussion paper by Bill Bordass ***bilbordass@aol.com***

Summary

1 INTRODUCTION

This working paper has been prepared at the request of the second expert meeting on Carbon Counting on 7 February 2006, chaired by Colin Challen MP. It outlines some general principles which can be applied to counting the annual carbon dioxide emissions associated with the energy supplied to keep a building and everything in it running - the so-called ***operational energy.*** It does not deal with other building-related sources of emissions, e.g. from construction, consumables, alteration, repair and maintenance; and travel of people and goods.

2 THE KEY STEPS

The four key steps in counting the impact on the outside world are:

1 ***Define the boundary of the premises.*** Boundaries should be where they make practical sense in terms of where the energy can be counted (e.g. the area fed by the meters) and how the area is run (a tenancy, a building, a site; or even a district or a city). One may look at more than one boundary, e.g. for a university the campus, specific buildings, and individual departments; and for a rented building the whole building, and each tenancy.

2 ***Measure the flows of each energy supply across the defined boundary.*** Normally this will be annual totals by fuel, though details of load profiles could sometimes be included.

3 ***Define carbon dioxide factors for each energy supply,*** as discussed below.

4 ***Multiply each energy flow by the appropriate carbon dioxide factor,*** to get the annual total.

Depending on the UK's proposals (which have yet to be announced by ODPM) this counting procedure could potentially be the same as that used to report actual energy use of public buildings ("Operational Ratings") under the EU Energy Performance of Buildings Directive.

3 CARBON DIOXIDE FACTORS

The previous meetings have endorsed counting the mass of the carbon dioxide[1]. There also needs to be clarity about what exactly is being counted. Ideally this would include the Global Warming Potential (GWP, expressed in mass of CO_2 equivalent), of all emissions associated with the supply of the fuel both downstream of the boundary (e.g. burning gas on the premises) and upstream (e.g. extraction, processing and distribution), including the effects of releases of other greenhouse gases (e.g. methane emissions from coal mining and gas distribution). ***We are not sure that the factors currently published (e.g. by Defra) include all the upstream effects, and a review would be desirable.*** Sometimes it may also be important to assign the embodied energy and CO_2 of the upstream installations to each unit of fuel supplied[2], but this could be difficult. There are probably two main reasons for wanting to count these CO_2 emissions:

- ***Outside the boundary***, national CO_2 reduction policy will want to know what the total impact of the premises is, and perhaps to relate it to benchmarks, e.g. per unit floor area.
- ***Inside the boundary,*** other policies and actions affecting building design and operation will be concerned with how well the premises are running and the scope for improvement.

4 DETAILED PROBLEMS WHICH WILL NEED TO BE TACKLED

A number of potential difficulties arise in considering the details of carbon counting.:

1 ***Knowing how much energy has been supplied and its CO_2 emissions.*** It would help hugely and be far more efficient nationally if government required suppliers (e.g utilities and landlords) to provide annual statements, than for customers to prepare their own.

2 ***Wide variations in CO_2 factors for electricity.*** Electricity is the most valuable source of energy, as is normally recognised in a high CO_2 factor. But renewable supplies have a low factor. This could encourage people to switch to electricity for inappropriate purposes (e.g. resistance heating), displacing load onto fossil sources. Low CO_2 factors for "green" tariffs may also have to be disallowed unless users actually invest in new renewable capacity.

3 ***There is no unique set of factors.*** A building's CO_2 footprint will vary not just with its use and efficiency, but with the local energy economy. For different policy purposes (e.g. EU, National and local), different factors may be needed. One must therefore report the amounts of each type of energy used and be clear what CO_2 factors were applied.

4 ***District heating etc..*** Both standard and site-specific factors may be necessary.

5 ***Inside the boundary, differentiating between buildings with low energy demands and those with on-site renewable subsidies.*** The European Standards Organisation CEN defines BEU (building energy use), which quantifies the inputs from renewable supplies.

1 Sometimes only the mass of carbon atoms in the carbon dioxide molecule are counted, a factor of 12/44.
2 e.g. from the construction and decommissioning of a power station, particularly a nuclear one.

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1 Introduction

1.1 BACKGROUND
Heightened awareness of the need to reduce carbon dioxide emissions has led to interest in the principles of carbon counting. Clear conventions are required to support a diverse range of activities, e.g. personal and organisational footprinting, purchasing decisions, CSR reporting, building design, assessment and benchmarking; and to underpin proposed regulatory measures such as domestic tradeable quotas (DTQs) and building energy certification[3].

1.2 CURRENT STATUS
To help resolve the issues, Oxford Brookes University is holding a series of meetings, attended by various experts and Colin Challen MP - leader of the All-party Parliamentary Climate Change Group. The first meeting in October 2005 was very productive and appeared to be reaching a consensus. At the second meeting in February 2006, detailed considerations emerged which made the focus less clear. While the issues inevitably become complex as one gets into more detail, it was hoped that some simple and consistent underlying principles could be developed.

1.3 PURPOSE OF THIS PAPER
The Usable Buildings Trust was asked to contribute ideas on carbon counting for buildings, but some of the detail we provided may have added to the complication. This paper therefore sets down some general principles which might be applied to one aspect of counting: the annual[4] carbon dioxide emissions associated with the supply of ***energywares***[5] to keep a building and everything in it running (not including industrial process energy) - the so-called ***operational energy.*** It does not deal with other building-related sources of emissions, e.g. from construction, consumables, alteration, repair and maintenance, and travel of people and goods. The paper is primarily about the counting process, not about judging the result. However, it does touch upon how the exercise might be integrated with EU requirements for building energy certification.

2 Purposes and definitions

2.1 PURPOSES OF CARBON COUNTING FOR BUILDINGS
We see two main reasons for counting CO_2 emissions from the operational energy of buildings:

1. ***To assist national policy on carbon counting,*** in particular the effect of the use of energy in the premises on national CO_2 emissions. This we see as the main purpose of this paper.
2. ***To help improve building design, occupation and management,*** to define how well the premises are performing in use, and to help all those involved to reduce their impact.

The two requirements are closely connected but subtly different. For example, national carbon counting policy might be concerned only with defining the boundary of the premises and determining the magnitude of its footprint. However, at the building level, one might need to differentiate between, say, premises which are efficient and inefficient, heavily and lightly-used, and with and without on-site renewable energy supplies. This is discussed in Appendix B.

2.2 DEFINITIONS
Even the words in the phrase ***carbon counting for buildings*** require some definition.

- ***Carbon***. Some people count the mass of carbon dioxide emitted, some only the mass of carbon atoms in it. The meetings have endorsed using the mass of the carbon dioxide[6].
- ***Counting***. For a fuel, are we counting the "bare" carbon dioxide emissions from the related fossil fuel combustion, or the total global warming potential (GWP) including upstream emissions and other greenhouse gases, e.g. methane emissions from coal mines and gas leaks. expressed as an equivalent mass of carbon dioxide? More clarity is required here. Ideally the factors applied to the consumption of any energyware should take full account of all its upstream and downstream effects. Alternatively, one could decide to work in bare CO_2 and include ***multiplication factors*** to account for augmenting effects[7].
- ***Buildings***. The idea of a single, self-contained building has limitations. People often occupy parts of buildings (e.g. a flat), or groups of buildings (e.g a site). To remind people that we are not just thinking of self-contained buildings, the word "premises" is used here.

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3 Under the EC's Energy Performance of Buildings Directive (EPBD), which must be fully implemented by January 2009.
4 While annual is assumed here, the principles could be applied to any time interval.
5 The CEN term ***energyware*** is useful if inelegant. The term covers all forms of energy that take the form of tradeable commodities: fuels (e.g. gas and oil) and energy carriers (e.g electricity, compressed air, hot and chilled water),
6 The use of CO_2 is also supported by ODPM in the 2006 Building Regulations Part L. published on 15 March 2006.
7 As happens for aircraft emissions, where the forcing factors are high: the current IPCC factor is 2.7 and it may rise.

3 Determining how the premises affect national CO_2 emissions

3.1 THE KEY STEPS

The three key steps in counting the impact on the outside world are:

1 ***Define the boundary of the premises.*** Any boundary could be used (a tenancy, a building, a group of buildings, a site, a city even), whatever best suits the counting taking place.

2 ***Record the flows of each energyware across the defined boundary.*** Normally this will be annual totals. If required, more detailed patterns of consumption (e.g. half-hourly electrical profiles) could be taken into account, see Section A6. The flows may include exports (e.g. of district heating, or wind-generated electricity). For each energyware, imports and exports could be combined into a net figure, or measured separately[8].

3 ***Define carbon dioxide factors for each energyware.*** See Section 3 4. and Appendix A.

Each energyware crossing the boundary can then be multiplied by the appropriate factor and the annual totals calculated. Outside the boundary, national CO_2 reduction counting policy will want to know what this total is. Inside the boundary, other policies and actions affecting building design, operation and management will want to know what can be done to reduce it.

3.2 STEP 1. PLACING THE BOUNDARY

The energywares crossing the premises boundary are a measure of the burden (or for exports the benefit) that the premises place on the outside world - a good place for national policy to bite. We suggest putting boundaries where they make practical sense (e.g. at a premise boundary and metering and/or fuel delivery point), not at a precisely defined geometrical position, e.g. a building boundary - which sounds simple and straightforward but isn't always. There could be good reasons to want to count at more than one boundary - for example a university could count the campus as a whole, specific buildings or groups, and individual departments; and in a tenanted building one might wish to look at both the building as a whole, and at each tenancy.

3.3 STEP 2. RECORDING THE ENERGYWARES PASSING ACROSS THE BOUNDARY

How can the amounts of energywares and the associated CO_2 emissions be quantified easily?

- ***For utilities*** (e.g. gas, electricity, and district heating), the information should be readily available, but often it isn't - e.g. owing to obscure bills, estimated readings, and records being kept off site and in money not energy. Nationally, it would be far more efficient for utilities to provide the data (which already exists), than for each customer to have to collect their own. We therefore recommend that the government requires utilities to provide ***Energy Statements*** showing the energy supplied to a premise over a 12-month period[9], together with the associated CO_2 emissions. In principle this could be made a standard OFGEM requirement[10], together with rules for collecting good and accurate metering data. As a reminder, annual consumption and emissions could also be summarised on every bill.
- ***For other fuels*** where there are regular deliveries (e.g. of oil, LPG and coal), a similar approach could be applied to that for utilities. For occasional deliveries or collections, it could be more difficult: this is probably less important, though it would be a loophole.
- ***For landlord's services*** in a tenanted building, as part of the annual service charge accounts the landlord could produce an annual ***Landlord's Statement*** of the energywares they supplied to and/or used on behalf of each tenant. UBT is currently considering the feasibility of this with the British Property Federation, with good results so far. To get the whole picture, the tenant could then combine this statement with their utility statements.

The alternative would be to require organisations to keep their own records, but these are only likely to be reliable for the better-managed ones. For energy suppliers to incorporate the energy (and CO_2) accounts in their billing systems would be much more robust and efficient - yet more so if the information was available electronically. Much of this already happens within the gas and electricity meter reading and billing systems in the UK, with the data provided to DTI.

3.4 STEP 3. ASSIGNING CO_2 FACTORS TO EACH ENERGYWARE

To calculate the total CO_2 emissions, the annual supply of each energyware needs to be multiplied by the appropriate CO_2 factors. For simplicity, and to map onto national policy drivers, we suggest there is a default set of national (or certainly regional) standard factors for each energyware. Where the national defaults are not appropriate, then alternative local factors may need to be applied ***as well,*** subject to appropriate approval procedures. Appendix A gives more detail on how factors might be chosen; and the difficulties that may arise. Since different factors may legitimately suit different purposes, a carbon counting report will need to show the annual consumption of each separate energyware, and to be crystal clear the set of factors used in reporting the CO_2 footprint, and why - using clear conventions for specific purposes.

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8 Large storage onsite may be a problem, e.g. oil storage which lasts months or years, and seasonal heat storage systems.

9 Within say the bracket 330-400 days between "true" (not estimated) meter readings and corrected to 365 days. Better billing information of this kind is also required under Article 13 of the EC's Energy Services Directive (2003).

10 The February 2006 meeting was told that a system like the one suggested already operates in the Netherlands.

4 Carbon counting and building energy certification under the EU Directive

4.1 THE ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE

Under the the EU's Energy Performance of Buildings Directive[11], buildings need energy certificates, which may include a CO_2 emissions indicator. To meet this requirement, in its consultation document of July 2004, ODPM proposed[12] two types of rating, both probably based on CO_2 emissions:

- ***Asset ratings (ARs)*** based on calculated requirements for heating, hot water, ventilation, cooling and lighting. ARs assess theoretical performance on a standardised basis and are designed to improve market awareness of likely energy performance at the point of completion, sale or rental. ARs take account of what is actually built: if calculated before work is complete (e.g. for client awareness and for building regulations compliance) they are called ***Design Ratings.*** This paper is concerned with actual outcomes, but these practical considerations might influence how the theoretical calculations are done and reported.
- ***Operational Ratings (ORs)*** for buildings in use. These are based on actual energy requirements for all end uses and are primarily aimed at getting owners, occupiers, users and managers to understand and improve their building's performance. ORs will first be calculated and displayed on public buildings over 1000 m^2 and frequently visited by the public, but their use could well expand to a wider range of building types and sizes.

4.2 THE OPERATIONAL RATING

With the right definitions in place, the OR may well be the preferred method of carbon counting, if the principles can be coordinated with those being applied by ODPM. Unfortunately, ODPM has published no further detail on ORs since its consultation document of July 2004, and informal discussions have thrown little light on its intentions. Meanwhile, the European Standards Organisation CEN has been working on a set of standards to help underpin the EPBD, including prEN 15217 on methods of expressing energy performance. A draft went out to public consultation via BSI in the second quarter of 2005 and is now undergoing revisions.

4.3 CEN's CURRENT PROPOSALS

What CEN will finally decide is also not known, but the December 2005 revision of prEN 15217 being debated by its Technical Committee includes the following procedures and definitions:

- ***Measured energy rating.*** This replaces the British term ***Operational Rating,*** which proved difficult to translate into some other languages. It is defined as ***the weighted sum of all energywares used by the building in one year, as measured by meters or other means.***
- ***Weightings*** can be by primary energy, CO_2 emissions, energy cost or policy-weighted. In the UK, the weighting is likely to be by CO_2, so an OR would be in tonnes of CO_2/year.
- An ***energy performance index*** (EPI)[13] is calculated by dividing the ***measured energy rating*** by the ***total conditioned (floor) area***[14] .
- The EPI needs to be compared with ***reference values.*** CEN proposes that the reference scale is calibrated against the stock median for the building type as a typical level; with national building regulations level for good practice. Correction for external climate may be applied.
- The ratio of the EPI to a scale based on the ***reference values*** allows the building to be graded into an ***energy class.*** The appendix of prEN 15217 shows options for grading both by the numerical value of the EPI; or on an A to G scale, as for domestic appliances.

Note that the prEN is formulated in terms of ***buildings*** while we prefer to think of ***premises.*** However, the prEN talks about a ***system boundary*** where the flows of energywares are measured and the ***measured energy rating*** (the OR) is determined. So if the ***system boundary*** is taken as the ***premises boundary,*** the procedures appear to be equivalent.

4.4 EXPORTED ENERGYWARES

The prEN allows for energywares to be either net figures; or for imports and exports to be counted separately[15]. Note that exports may not only be from on-site generation, they might also be supplies to energy uses, say a car park or an outbuilding outside the premises boundary. However, if the energy flows to the car park were not metered, then it might be better to include it within the chosen premises boundary.

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11 Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, Official Journal of the European Communities, L1/65-71 (4 January 2003).

12 ***Proposals for amending Part L of the Building Regulations and Implementing the Energy Performance of Buildings Directive,*** Office of the Deputy Prime Minister (July 2004).

13 If CO_2 units are used for weighting,then the EPI might more accurately by called a CO_2 emissions index (CEI).

14 This is similar to the UK's "treated floor area" which excludes areas like plant rooms, roof spaces, loading bays and unheated stores from the floor area used in the denominator of the index.

15 Separate counting may be necessary where the CO_2 factors applied to imports and exports are different, e.g. if there is a policy driver to encourage on-site renewable electricity generation. However, this approach is potentially dangerous, as it could promote investment in renewable supplies over that in energy conservation, which is normally a more robust and cost-effective way of reducing carbon dioxide emissions.

APPENDIX A: Carbon dioxide factors and different types of energyware

A1 INTRODUCTION

The choice of CO_2 factors for different energywares is not always straightforward. Factors may even have to differ with the purpose of the counting exercise. One therefore needs the option to apply different factors to each energyware, sometimes simultaneously (e.g. perhaps EU, national and local factors). Different energywares also have different types of uncertainty, as outlined below for four classes of energyware: fossil fuels, biomass, electricity, and other energy carriers.

A2 FOSSIL FUELS

Fossil fuels (e.g. natural gas, oils and solid fuels) have fairly well-defined CO_2 factors, though these are likely to increase over the years as extraction becomes more difficult and with UK gas imports. Although the uplifts to get total Global Warming Potential (GWP), can be uncertain, they tend to be a relatively small fraction (e.g. of the order of 10%). Since fossil fuels are also global (or at least continental) markets, it may make sense to apply universal factors to them.

A3 BIOMASS

Biomass tends to be thought of as zero-carbon, but is it? Burning any carbon-containing fuel - biomass or not - puts CO_2 into the atmosphere. While fossil fuels release new (i.e. previously sequestered) carbon, with biomass there is a chance that you are recycling carbon which not long ago was in the atmosphere - particularly for short-rotation energy crops. However, some of these incur substantial upstream emissions - directly and indirectly - to grow, process and transport. For example, life cycle analyses of some (but not all) vegetable oil producers have revealed that the fossil fuel used in cultivation, fertilisers etc., processing and transport can be similar to that from burning the mineral oil they replace. Even wood pellets supplied in the UK may have come from the other side of the world; while the home-grown product may have been sourced in Scotland and dried in Northern Ireland. These overheads must not be ignored.

A4 ELECTRICITY

A4.1 Electricity is the most valuable of the energy carriers - a low-entropy product, capable of doing the maximum amount of useful work. However, this high value is not consistently reflected in CO_2 factors, which are highly variable, from well over 1 kg CO_2/kWh for coal-fired power stations in some parts of the world, to near zero claimed for hydroelectricity, wind and nuclear[16]. This creates difficulties in making fair comparisons between buildings: for example, is the low-carbon building efficient, or does it just have a lower-carbon electricity supply? A narrow focus on "green" supplies may also have the perverse effect of people squandering valuable low-carbon electricity on low-value uses (e.g. electric resistance space heating), whilst displacing their new loads onto the less efficient high-carbon generators! ***Note that national level emissions are counted at the power station; but for buildings they need to be counted at the premises boundary.***

A4.2 A particular difficulty in the UK is that "green" electricity has little cost premium - unlike in Germany and Australia where the price is very high. While it is good that consumers can demonstrate a preference for non-fossil electricity, it is not fair that they can ring-fence part of a national resource that has been paid for largely by others (e.g, the non-fossil fuel obligation); and certainly not fair for their buildings to be credited as low-carbon as a result. For this reason, Sweden is understood to have scrapped green tariffs. To benefit, you have to invest!

A5 OTHER ENERGY CARRIERS

Apart from electricity, the most common energy carrier is water, heated or chilled; and sometimes steam. The UK has less district heating and cooling than many other northern countries, but its use is growing. Water and steam is also distributed within individual buildings and small groups; and normally metered (if it is) at the points of entry to the premises served. The appropriate carbon dioxide factors to be applied will vary with the primary producer of the heat (e.g. fossil fuel, biomass, waste burning, or combined heat and power (CHP)) and the efficiency of the production and distribution system. There may be a case for using standard factors as well.

A6 VARIATION OF CO_2 FACTORS WITH TIME

CO_2 factors for electricity in particular can vary greatly with time (e.g. time of day, day of week, and season of year) as supply and demand fluctuates; as is reflected in STOD (seasonal time of day) electricity tariffs. Where there is robust time series information on both demand and CO_2 factors, CEIs could be determined from these patterns and not just the annual averages. Factors will also change as time passes for all sorts of reasons. It will probably be more practical to agree standard factors and to review them, say, every three or five years, than to allow them to drift.

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16 Again depending how the overheads are understood and counted. Resent research indicates significant methane emissions from some hydroelectric works and even perhaps from growing biomass. The CO_2 produced in the preparation, reprocessing and waste management of nuclear fuels is also significant.

APPENDIX B: What happens inside the premises boundary?

B1 Questions about buildings and their energy and carbon efficiency occur at a number of levels:

1. ***Has the building the potential to be energy efficient?*** This is addressed by the building regulations, and by the calculated ***Asset Rating*** under the EPBD. See paragraph 4.1.
2. ***How is the building being used and operated?*** Whatever the theoretical potential, the actual outcomes are what finally matter: how much carbon dioxide is the building responsible for? There are two main influences on this: the ***intensity of use -*** (e.g. how many people; what are they doing and what equipment are they using; and what are the operating hours?) and the ***efficiency of operation*** (e.g. are people diligent, is the equipment efficient and well-controlled; and is energy management effective?). A strategic approach to energy assessment and benchmarking of nondomestic buildings was developed by UBT in 2005[17], with the support of Constructing Excellence and the Sustainability Forum.
3. ***What is the contribution of on-site active renewable energy resources*** (e.g. solar panels, wind, hydroelectricity, and even biomass grown on site)? Even though they may have the same Operational Rating (OR) - there is an important difference between an efficient building and a less efficient one with a renewable subsidy; and at the moment too many new buildings which boast renewable supplies are far from energy efficient. In addition, it is difficult to recommend relevant energy-saving measures unless one knows how much of each type of energy a building uses. These issues have been raised at CEN and discussed at recent meetings of the EPLabel project[18]. Separate identification of on-site renewables is now proposed, as summarised in Figure 1, where BEU[19] (the ***Building Energy Use)*** identifies all types of energy going into the building, including active renewables[20]. The differentiation between BEU and OR is included in the draft CEN standard prEN 15203.
4. ***Combined heat and power (CHP) systems.*** Similar thinking as for active renewables might be applied to CHP. After much discussion, EPLabel decided not to do this, as the same sort of argument could be applied to almost any building service and because - in the absence of exports - the carbon counted at both the OR and BEU boundaries would be identical.

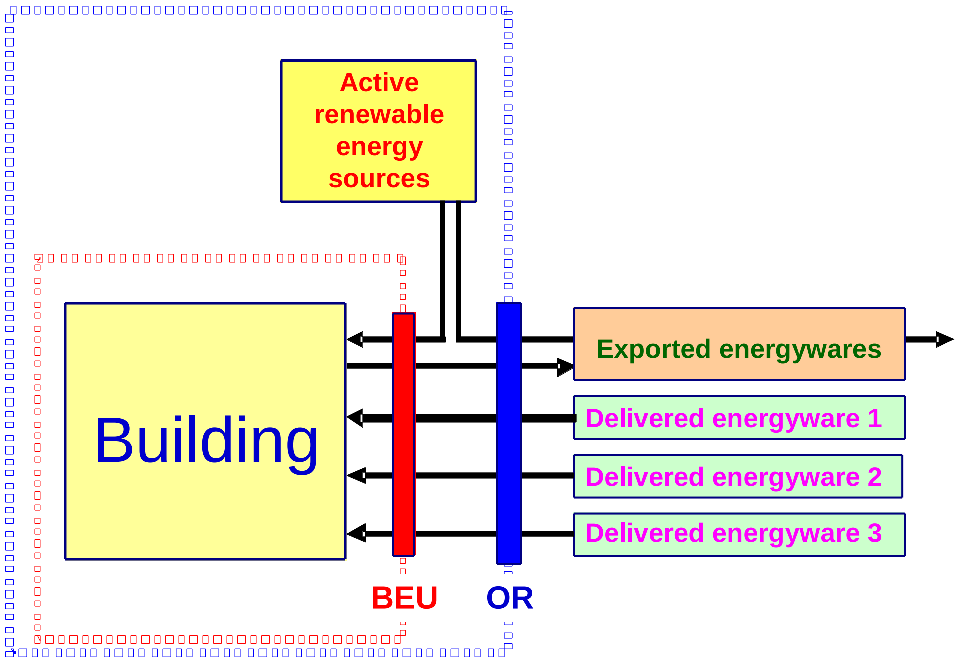

FIGURE 1. Diagram from the EPLabel project, showing the premises boundary for Operational Ratings (dotted in blue) and Building Energy Use (BEU, dotted in red). The red and blue vertical bars indicate the boundaries across which the flows of energywares are measured.

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17 The Usable Buildings Trust, ***Onto the Radar: How energy performance certification and benchmarking might work for nondomestic buildings in operation, using actual energy consumption*** (June 2005). Downloadable from www.usablebuildings.co.uk

18 EPLabel is a research project under EU's SAVE programme, which is building a common platform to help support Operational Ratings across the EU. It is led by the UK partner, and funded by ODPM in the UK. See www.eplabel.org

19 CEN definition: the net weighted delivered energy that would be used if the renewable energy systems were not present.

20 Passive renewables (e.g. direct solar gains) are not included, as the energy is not converted on site into a form that could potentially be exported as an energyware.