

Guidelines on good practice in cost-effective cost allocation and billing of individual consumption of heating, cooling and domestic hot water in multi-apartment and multi-purpose buildings

Support for the implementation of Articles 9-11 of *Directive 2012/27/EU on energy efficiency with respect to thermal energy supplied from collective systems*

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Disclaimer

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1 Introduction

The purpose of these guidelines is to support Member State authorities and building owners in correctly and effectively implementing certain provisions of Articles 9-11 of Directive 2012/27/EU on energy efficiency ("EED")¹ concerning the consumption of thermal energy for heating, cooling and hot water in multi-apartment and multi-purpose buildings.

The EED requires the introduction of **consumption-based cost allocation** and **sub-annual informative, consumption based billing** of heating, cooling and hot water in such multi-unit buildings, subject to certain conditions. The general idea is to ensure that users of such buildings have the right incentives and sufficient information to adopt energy-efficient practices. Inducing energy-efficient behaviour among building users should be seen as a complement rather than an alternative to actions aimed to improve energy efficiency at building level, such as improvements in the envelope or the central heating system.²

The guidelines in particular focus on how to apply consistent criteria, based on the best available evidence, for determining "technical feasibility" and "cost-effectiveness", should Member States wish to make use of exemptions to the Directive's general requirement to

- ensure that individual heat meters or heat cost allocators are installed in existing buildings (EED Art. 9(3) 2nd subparagraph) enabling consumption-based allocation of costs (EED Art. 9(3) last subparagraph), and
- ensure provision of consumption based billing and "frequent"/sub-annual billing information in respect of thermal energy for space heating, space cooling and hot tap water (EED Art. 10(1) & Annex VII).

The national authorities of the Member States have, to date, taken different regulatory approaches to transposing these EED requirements. The terms "viable", "open" and "exempted building class" are introduced here to describe the three main approaches. For example, EED Art. 9(3) requires that individual consumption measurement for heating is installed in existing multi-unit buildings, where technically feasible and cost-efficient³. Using this example, the three typical regulatory approaches are:

- Owners of existing multi-unit buildings are required to install individual consumption measurement for heating in the building, unconditionally. This approach is referred to here as declaring a large "**viable building class**".
- Owners of such buildings are required to install individual consumption measurement for heating in the building, but only where technically feasible and cost-efficient. This approach is referred to here as declaring a large "**open building class**". It implies that an assessment needs to be made for each building, not for the class as a whole.
- No regulation has been introduced, with the effect that no building owner is required to install individual consumption measurement for heating in the building. This approach is referred to here as declaring a large "**exempted building class**". An assessment must be made which is valid for the entire class.

With the EED setting out minimum requirements, Member States are free to include all the multi-apartment and multi-purpose buildings in the country, creating a viable building class of maximum size. In practice, exceptions are made, and these create exempted building classes. Examples from recent legislation include the exception of:

- zero energy buildings or buildings with a very low heating requirement;
- buildings used for particular purposes, such as old peoples' homes or student residential accommodation, hotels and hospitals;
- buildings part-occupied by the building owner;
- buildings comprising fewer than 5 apartments.

¹ <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN>

² For buildings subject to a "warm rent" system where energy costs are paid by owners and only implicitly or partially reflected in the rent paid by tenants, the introduction of consumption based cost-allocation may require alteration of the principles according to which rent levels are negotiated or set, in order not to have the unintended consequence of removing building owners' incentives to take action at building level. See also Section 8.

³ This reformulation of provisions of Art 9 (3) is for illustration only.

If exempted building classes are defined so that they include buildings in which individual consumption measurement for heating is technically feasible and cost-effective, cost-effective energy efficiency potential is lost, and this is potentially not in line with the EED. These guidelines seek to support optimal definition of exempted building classes.

Where the regulatory approach involves declaring an open building class, technical feasibility and cost efficiency needs to be assessed at the level of the individual building, rather than for a whole class of buildings. Such an assessment is not in all cases a trivial exercise, so the guidelines make recommendations on how Member States might seek to minimise the effort necessary to do so by owners (or other "obligated actors"). The recommendation made here is that obligated actors in an open building class should be provided with information and tools allowing assessment of their building which is both easy to perform and based on the best current evidence of savings and costs.

In drawing up these guidelines, the target has been to minimise the effort required and costs incurred by everyone involved, from government to landlords and tenants, while maximising the significant levels of saving which can be expected from these major uses of energy through implementation of the EED across Europe. Though implementation is clearly not possible without some administrative effort at national level, this may be reduced by coordinating action at EU level, or by delegating tasks to building owners or other sector actors, where this is more efficient. There is also the opportunity for economies of scale through cooperation between Member States, such as a pooled European evidence base for the energy-efficiency effects to be expected from implementation of EED requirements.

The guidelines presented in the following sections deal first with the specification of **building classes**, and with the assessment of the cost-effectiveness of action in respect of individual buildings ("**building assessment**"). The same approach is recommended both for testing/defining exempted building classes and for assessing individual buildings (as is required in open building classes). Guidance is given on the use of reference prices, the use of competitive prices discovered in the market, and the use of the current evidence base of research on energy saving. The guidelines also include recommendations for **cost allocation** and examples from regulatory practice.

On 30 November 2016, the European Commission presented a **proposal to change certain provisions of the EED**⁴, including certain aspects of Articles 9-11 and Annex VII. With respect to metering and billing of thermal energy in multi-apartment/purpose buildings, the focus of these guidelines, the proposed changes are few and of limited relevance to the present guidelines; in essence the changes, if adopted as proposed, would

- spell out that conditions of technical non-feasibility and non-cost effectiveness, in the context of Article 9(3), shall be clearly set out and published by each Member State.
- require that Member States shall introduce transparent rules on the allocation of the cost of heating.
- approximate the cost-effectiveness test for the provision of sub-annual consumption information in the case of thermal energy, currently in Art 10(1), with a simpler condition on whether or not remotely readable devices are installed, and replace the condition of "technical feasibility" for consumption based billing with the availability or not of measurement devices.
- require the transition to remotely readable heat meters and cost-allocators between 2020 and 2027, with the view to requiring ultimately to achieve monthly information to all sub-metered users.

These changes, if adopted as proposed, would not significantly affect the validity of the guidelines in this document. They would however imply that for buildings where no devices have yet been installed, the two service levels (consumption based cost allocation, and sub-annual consumption information service) would need to be assessed together as a whole as of 2020. In any case, it must be emphasised that the proposed changes will need to be adopted by the co-legislators to enter into effect.

⁴ <https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition>

2 Building classes

2.1 Introduction

The assessment of technical feasibility and cost-effectiveness may, in principle, be carried out for each individual building in a country. However, it will often be desirable to take a more aggregated approach, to minimise overall administrative effort. This section introduces regulatory approaches which declare entire classes (collections, types) of buildings as either viable or exempt from the provisions of EED Articles 9-11. For buildings not falling in either category, individual assessment will be required for each building, and the recommendation here is that this should be based on information easily available to building owners. The three types of building class are as follows:

- "**viable** building classes", in which all buildings are required to implement EED requirements for individual metering, cost-allocation and billing (referred to as "EED building measures");
- "**exempt** building classes", in which none are required to implement EED building measures;
- "**open** building classes", in which all are required to test the technical feasibility and cost-efficiency of EED building measures, and to implement these if the result is positive.

2.2 Viable building classes and exempted building classes

The recommended regulatory approach, to ensure full compliance of the national implementation, is to maximise the size of viable building classes and minimise the size of exempted building classes. For example, a national authority might require the introduction of consumption-based cost allocation for heating in all multi-apartment buildings, but wish to exempt low energy buildings, and therefore specify that buildings are exempt where the heating requirement for the building is below a certain level, perhaps 15 kWh per square metre and year. If, in this example, this were the only provision in the regulation of multi-apartment buildings, two building classes would have been declared:

- multi-apartment buildings with an annual heating requirement of less than 15 kWh per square metre would form an "exempted building class", and
- all other multi-apartment buildings would form a "viable building class".

The Member State concerned should be able to show, using the building assessment procedure described here, that for no building in the exempted building class would the EED building measure - the introduction of consumption-based cost allocation for heating - be cost-effective.⁵ In other words, there should always be reasonable assurance that no building in an exempted building class would pass the building assessment procedure described here, otherwise no action would be taken and cost effective savings lost. Because the EED provisions reflect minimum requirements laid down at EU level, there is no similar need, for the purpose of complying with the EED, to provide assurances that within viable building classes, all buildings without exception would pass building assessment. See **guidelines BC01 and BC03**.

2.3 Obligated actor

The legal entity given responsibility for taking action for a given building is referred to as the "obligated actor". The obligated actor is likely to be drawn from among landlords, building owners, building owner associations, building managers, district heating providers, energy suppliers, ESCO etc. See **guideline BC02**. Applying the principle of minimising additional cost, the organisation or individual chosen should ideally already have a contract with final customers of the building, whether for rent, energy delivery or other services.

⁵ A calculation showing that in a climate typical of Germany consumption-based cost allocation is not cost-effective in these low energy buildings, is given in Oschatz, B (2004) Heizkostenerfassung im Niedrigenergiehaus, published in BBSR Heft 118.

2.4 Ease of recognition of building classes

The purpose of declaring large building classes as viable or exempt is to make it clearly evident whether action needs to be taken or not, thus reducing the overall administrative burden and maximising energy saving opportunities. The building class description should therefore enable landlords, other obligated actors, and the courts to easily determine if any building is in the class or not in the class, and therefore subject to the obligation, or exempted from it. If a detailed examination of the building by experts is needed to determine if it is in a building class or not, that class fails its purpose. The example given above of an exempted building class "multi-apartment building with an annual heating requirement of less than 15 kWh per square metre" is only satisfactory if the annual heating requirement of a building is a quantity landlords can easily - and cheaply - determine. See **guideline BC05**.

2.5 Application of test cases for building class exemption

Some analytical reports supporting national transposition of the EED have made the case for exemption of a class of buildings based on calculations which relate to an average or typical building in the class. A calculation which shows that, say, the introduction of metering for space heating would not be viable in an average building of a certain type in a country does not preclude that, in at least some buildings in that class, metering for space heating would be viable. There might even be a sizable number of buildings in the class, perhaps in the most northern areas or mountain zones of the Member State, which would be able to implement heating measures viably. These should not be exempted.

Instead of exempting a class based on the average building, the criteria set out here for exempting an entire class of buildings set out from a "**test case**", namely the building in the class which is most likely to present a viable case for action. See **guideline BC01**.

For example, if a national authority declares as a class "all buildings in the region of Erehwon" exempt from an obligation to introduce consumption-based cost allocation for heating with heat meters or cost allocators, the **test case** should be a building in the coldest part of Erehwon. The chosen building should be as large and as poorly insulated, and with as inefficient a heating system and expensive fuel as any building known to be located there. Only if the assessment for metering for heating of that test case building returns a negative could the entire class be properly exempted. Exemption of the region might be reported to the European Commission along with a documented assessment of the test case and any evidence providing reasonable assurance that few or no building in the class - the region - would have a better chance of a positive viability assessment than the building used in the test case.

2.6 Guideline on building classes (BC01-BC05)

It is recommended that Member State authorities take action as follows:

- BC01 for each class of building for which there is reasonable evidence that no buildings in the class would pass building assessment for an EED building measure, to exempt all buildings in the class from the obligation to implement that measure⁶ (exempted building class).
- BC02 to define the legal entity to be the obligated actor for each building not in an exempted building class.
- BC03 for each class of building in which it is likely that only few buildings would fail a building assessment for an EED building measure, to make it mandatory for the measure to be implemented in all buildings in the class (viable building class).

⁶ An exempted building class must always be specific to an EED building measure, as described in section 5

- BC04 to allow an obligated actor to appeal against the inclusion of a building in a viable building class by showing that an individual building assessment fails, if by allowing appeal in this way the viable building class can be significantly increased in size without causing disproportionate costs for dealing with appeals.
- BC05 when declaring a class of building as viable or as exempt, to ensure this is done in such a way that any obligated actor, tenant or other building user can easily, reliably and at no, or minimal, expense determine if the building falls in the class or not.

2.7 Open building classes

After declaring classes of building exempt or viable, there may remain a residual set of buildings which are difficult to assess at an aggregate level but where a Member State still may prefer to allow for exemptions based on technical feasibility/cost-effectiveness. In this "open building class", the obligation to determine technical feasibility and cost effectiveness needs somehow to be delegated to and implemented by the landlord of the individual building, or other obligated actor. See **guideline BC06**.

In this case, it is recommended that the administrative burden faced by obligated actors should be addressed by providing an **online tool as a calculation aid**, along with access to necessary data applying to all buildings in the class, from physical constants to climate data and reference costs.

2.8 The timing of individual building assessments

For buildings in an open building class, it is recommended that building assessment, as described here, should use competitive costs⁷, and that some time limit be imposed on when the assessment is to be made. The time-frame should, where possible, be aligned to the deadlines set in the EED so as to avoid delaying the impact of the EED. See **guideline BC06**.

Assessment of an individual building should be repeated at reasonable intervals, because viability may emerge as system costs fall, energy prices rise or through building alterations that give final customers new freedom over temperature settings. The 4-5 years in guideline BC08 is arbitrary, but longer periods will delay response to market changes and reduce EED impact. Some such changes also affect the test cases which define exempted building classes, which is why repeated reviews of exempted building classes are also recommended.

2.9 Incentives for other energy efficiency measures

Alteration of a building may change building assessment results. In particular, if insulation is improved, the benefits from introducing individual metering of thermal energy uses will be reduced. Where improved insulation or other energy efficiency measure is planned, the assessment of cost-effectiveness should be allowed to reflect the situation after these plans are realised, i.e., should reflect the lower expected benefits from users' behavioural changes. Taking account of the resulting, improved building will help preserve incentives to carry out other energy efficiency measures in the building. If plans are not realised within a reasonable period, permission to reflect the situation after improvement should lapse, or improvement plans may be used in bad faith to avoid taking action. See **guideline BC09**.

2.10 Incentives for consumption information services

There is a risk that potential for cost-effective energy saving may be lost in buildings where consumption-based cost allocation (sub-metering) has already been introduced, but where information based on actual consumption is limited to data required to determine the billed amount, and only provided once a year. Users of these buildings would not receive the kind of rich and frequent information, the "consumption information service"⁸ - which would help them identify new energy efficient practices - and in particular they would not receive the

⁷ On the definition of competitive costs, please refer to section 4

⁸ On the definition of consumption-based cost allocation and consumption information services, please refer to section 5.

information listed in EED Annex VII, such as informative comparisons. Benefits from a more frequent and complete consumption information services alone will rarely be sufficient to justify replacement, with remotely read measurement devices supporting such information services, of locally read devices already delivering consumption-based cost allocation⁹. It is recommended that assessment of a building be required to be repeated whenever heat meters or heat cost allocators which are locally read are about to be replaced, or, in general, immediately prior to incurring any major cost to maintain operation of an EED building measure. See **guideline BC06**.

2.11 Guideline on building classes (BC06 - BC09)

It is recommended that Member State authorities (MS) take action as follows:

- BC06 for buildings not falling in exempted or viable building classes for all EED building measures ("**open building class**"), to require that *building assessment*¹⁰ be performed and that the EED building measure¹¹ which is expected to save most energy be implemented without delay, unless all¹² fail building assessment. Obligated actors who have not yet implemented all EED building measures should be required to carry out building assessment at most four years after the previous assessment and, in addition, immediately prior to incurring any major cost to maintain operation of an EED building measure.
- BC07 to adopt as regulatory approach the declaration of viable building classes (BC03), with appeal options (BC04) if required, leaving or declaring exempted building classes only if compliant with guideline BC01, otherwise declaring open building classes (BC06), providing support to obligated actors and effectively monitoring compliance.
- BC08 to repeat building assessment of test cases for exempted building classes, for example every 4-5 years,¹³ and at any occurrence of a significant change in prices or other factors affecting the cost-effectiveness of EED building measures in the test case building.
- BC09 for any planned alteration to a building in an open building class which will result in significant change to any parameter of building assessment, to require the obligated actor to use the changed parameters in a second building assessment. If the first building assessment is positive and the second negative, the obligated actor should be given a reasonable deadline to complete the alteration. The obligations arising from the first building assessment should remain in force for the event that the alteration does not take place by the deadline set.

⁹ It is reported that many consumers value remotely readable devices for avoiding the need for entering premises to read traditional devices. Along with other such additional benefits which are difficult to quantify, this advantage is not taken into account in building assessment

¹⁰ The *building assessment* referred to here is the process of assessment described in section 3.

¹¹ A single *EED building measure* may comprise more than one component, e.g. consumption-based cost allocation for both space heating and hot tap water. See section 5.2.

¹² *All EED building measures* means all combinations of the components defined by 3 uses of thermal energy and 2 levels of service. See section 5.2.

¹³ A requirement to repeat assessments of individual buildings is integral part of the suggested specification of building assessment.

3 Building assessment

3.1 Introduction and overview

This section sets out a methodology that can be used to assess whether an EED building measure (i.e. cost-allocation/sub-metering or frequent consumption based billing/billing information¹⁴) is **technically feasible and economically viable for a given building**. The method of calculation is aligned to standard practice, using net present value to adjust for differences over time. A positive result - cost effectiveness, economic viability - is given where the net present value of one-off and annual costs is no higher than the net present value of annual benefits.

To avoid complexity, only benefits and costs flowing directly from action on the building are considered. It is assumed that some wider impacts, on the environment and on markets, will be factored into local energy prices. Additional direct savings benefits are expected from improved automation, from building audits and other measures. Indirect benefits, also not taken into account, include the potentially massive cost of allowing unnecessary heating and cooling to accelerate climate change. Risk of additional costs such as mould formation through inadequate ventilation or infrequently used hot water allowing legionella to develop are seen as a topic for improved building management rather than as a necessary consequence of the EED measures on metering.

Where the procedure recommended here for the assessment of a building yields a positive result, the implication is that the measure is cost-effective for the building, and therefore action should be taken in respect of that building to comply with the EED. The positive result does not necessarily mean that the measure will be cost-effective for all stakeholders - owners, landlords, tenants etc. - so that economic incentives may need re-allocation (see Section 8).

3.2 Technical feasibility

The installation of heat meters or heat cost allocators is not possible in some buildings without carrying out minor or major building alterations, from relocating a single radiator up to replacing the entire heating system. Though minor alterations in a building comprising many dwellings might remain within the viability limits of EED building measures, replacement of a heating system including its distribution network in the building will normally be at prohibitive cost when compared to the energy cost savings in prospect. In this case the EED building measure in question might be regarded as being **not technically feasible** (more accurately: too technically complicated to be cost-effective). This will often apply in cases of a necessary change of in-house pipe-work¹⁵.

There are a number of cases where the introduction of EED building measures is not technically feasible in this sense.

In the case of heat cost allocators, it would not be considered technically feasible in buildings where heating operates without a radiator or other heat exchanger surface on which the device can be mounted, where design surface temperatures of radiators or other heat exchangers exceed the device working range, or where the thermal output of the radiator or other heat exchanger cannot be reliably determined because, for instance, there are movable vents to control heat flows or other variable obstructions to the flow of air over the heat exchangers or fans are used to accelerate heat flow.

Most heat meters cannot be deployed if the heating is provided other than by hot water in pipes. Their deployment in hot air systems or steam systems is not considered technically feasible. Furthermore heat meters require a certain length of straight pipe in an appropriate location for mounting, and may be restricted in the angle they are mounted at.

¹⁴ In the assessment of cost-effectiveness, these levels of service are formalised as "consumption-based cost allocation" and "consumption information services". Please refer to section 5.4.

¹⁵ Compare recital 29 to the EED and paragraph 23 of EUROPEAN COMMISSION "Guidance note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Articles 9 - 11: Metering; billing information; cost of access to metering and billing information", SWD(2013) 448 final, Brussels, 6.11.2013: <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=SWD:2013:0448:FIN>

For heat meters and heat cost allocators together, technical feasibility of consumption-based cost-allocation for heating requires that the heating energy is distributed in the building by means of hot water (rather than air or steam). On this basis, **buildings using hot air or steam to transport heating energy can be declared an exempted building class for space heating.**

There are some further special cases for which heat meters and heat cost allocators cannot be expected to deliver a reliable measurement of heat flow - such as where heat exchangers are built into the ceiling of one unit and also heat the floor of the unit above, or into building walls with similar effect. No reliable system is available to subdivide the heat flow into a flow upward and downward, so buildings with heating systems of this kind can be declared an exempted building class.

Technical feasibility is specific to a particular technical approach to measurement, and to the devices associated with that approach, in particular heat meters and heat cost allocators. Given this dependency, technological development can have an impact on feasibility. Buildings in which, today, neither heat cost allocators nor heat meters are technically feasible may, in future, be able to introduce effective consumption-based cost allocation using new devices, e.g. devices to measure thermal energy flows in air. Such devices might also be covered by EED Article 9 (3), if not as "individual consumption meters" then as "individual heat cost allocators" (as their purpose would be the allocation of heating costs).

3.3 Level of control

Energy saving through the provisions of EED Articles 9 - 11 is expected to emerge from changes in behaviour of building residents or other users. If no behavioural change is possible in a building, because building users have been given no control, then no savings will be made. For example **where dwellings are provided with mechanical ventilation and windows cannot be opened, and/or room temperatures are set uniformly and centrally, residents cannot act to save energy through reduced ventilation or temperature.** In other cases control is apparently given but cannot be exercised, or is ineffective, as for example where a hotel guest has too short a time to control heating effectively or a bedridden person cannot access controls. Furthermore, where control is taken out of users hands through automation, similar considerations apply, whether or not the automation chosen is effective in delivering optimal performance.

In general, before or at the time an EED building measure is introduced, final customers in the building must have had or be given a certain minimum level of control over temperature and/or ventilation in order for behavioural changes to be open to them which have the potential for making savings. If this standard of control is not present, the introduction of consumption-based cost allocation or consumption information services will generate lower savings.

Lack of the usual level of control occurs in a number of settings, and impairs the cost-effectiveness of EED building measures - or renders them not technically feasible:

- Hotels and similar accommodation where most units are occupied for one or two days and where any temperature control by a resident affects the heat stored in the room, consequently influencing the amount of heating a successor requires;
- Homes, hospitals or other such buildings in which residents are effectively unable to change temperature settings or ventilation to meet their preferred comfort and cost level;
- Buildings in which units are not adequately be closed off to ventilation flows to and from common areas;
- Buildings with heat exchangers which heat more than one unit, e.g. where an under floor heating device also delivers significant heat through the ceiling of the premises below;
- Central temperature control in buildings where residents are not given access to controls and there are no (thermostatic) valves on radiators; TRVs can however be installed when sub-metering is introduced
- Buildings with exclusive mechanical ventilation where residents cannot ventilate by allowing outside air in, e.g. through opening a window and where ventilation is via ducts provided with heat exchange with outgoing air.

The **building assessment procedure recommended here provides adjustments for any lack of control**, both when applied to individual buildings and in the definition of exempted building classes. **Examples of relevant cases that justify modifications to the general assessment approach are given in the table of "assessment modification criteria" (Annex, section 11.1).**

The provision of controls to building users which are easier to use than simple radiator valves enable use of thermal energy to be optimally aligned with preferences with less effort. The amount of further savings more sophisticated controls can be expected to deliver is being investigated¹⁶, and it is not expected to be difficult to integrate the results into the approach recommended here.

3.4 Benefit calculation

The annual benefits flowing from each EED building measure are detailed as the sum of benefits of its components, each of which is a type of thermal energy use (space heating, space cooling, hot tap water) and a level of provision (consumption based cost allocation, consumption information services).

For heating and cooling, the benefits applied in building assessment are calculated by considering separately two dimensions of behavioural effect: via changes in use of ventilation equipment, windows etc. (VE); and via changes in temperature or flow-rate settings (TE). Applying existing evidence concerning average behavioural responses in these respects (see section 6), the calculation requires data related to the building, its location and the local market. With appropriate provision of common data in an online calculation aid, the information to be entered by the landlord or other obligated actor is minimal and available in energy performance certificates.

The calculation requires the number of **degree days**, the number of heating or cooling ("**production**") **days** and the **price of the various fuels used** to deliver thermal energy. These data can be provided centrally and the obligated actor need merely select these based on building location and fuel type. Other values, such as the heat capacity of air and water, and values from the evidence base - the ventilation effect and temperature effect of the building measure concerned in changes of air per hour and Kelvin - are invariant, requiring no input.

The data required for a building includes the efficiency of the system delivering thermal energy (based on simple categories), and the thermal loss rate of the building e.g. in Watts per Kelvin. The latter value may be calculated using the heat transfer coefficient for the building. Not least in view of the provisions of the EPBD on energy certificates, the heat transfer coefficient (U) will often be known for a building. U in $W/m^2 \cdot K$ is the rate at which a square metre of building element - window, wall, door etc - conducts heat. In such cases the surface area of the building envelope is also needed before it is possible to calculate TL, the thermal loss rate of the building as a whole.

3.5 Assessment modification criteria

Whereas the EED allows for exemptions on grounds of technical feasibility as well as of cost-effectiveness, technical feasibility is often in practice a question of cost-effectiveness. Under the method proposed here, challenges to the technical feasibility of an EED building measure are incorporated as increases in costs or removal of energy savings benefits in the cost-effectiveness assessment, considered together as "assessment modification criteria". In either case the change may, or may not, cause the cost-effectiveness calculation to deliver a negative result, equivalent in effect to indicating that the building measure is not passing the combined test of being both technically feasible and cost-effective.

The example described as "technically complicated and costly" in EED recital 29, where there is more than one set of pipes entering a dwelling or other building unit, is dealt with by including costs for more than one heat meter per dwelling, which may nevertheless in some cases be a cost-effective solution.

The list of **assessment modification criteria** in the Appendix shows the energy saving or cost parameter affected. These changes can be incorporated in a calculation aid such that a landlord answers simple questions and the

¹⁶ Personal communication from Prof. Cholewa at the Warsaw regional cluster workshop, November 2016.

calculation is automatically modified. The list may change, for example when a technical solution for hot air heating becomes available, and should therefore be subject to periodic review. Input for such a review could be sought from equipment provider associations and other market players who have an interest in removing items from the list or modifying their impact, allowing more cost-effective solutions with their products.

3.6 Accounting period and discount rate

The discounting of future cost and revenue streams is usual practice. Where up-front investment is required, high rates would impede the impact of the EED, whose intentions would be best served by a zero discount rate. Based on such considerations, and in line with conclusions drawn under similar circumstances elsewhere, it is recommended here that a discount rate of up to 4 % is used¹⁷. The precise discount rate used is unimportant where, as allowed by the assessment procedure described here, prices are applied for sub-metering and information provision services on the market which require no up-front investment.

For systems which require no maintenance for long periods, the accounting period chosen should not be too short. 10 years is the period set for the same purpose in a recent detailed analysis for the German government¹⁸ based on the replacement duration for heat cost allocators. Where a building is scheduled to be demolished or otherwise taken out of use (but not in cases of plans to sell), a shorter accounting period may well be appropriate.

3.7 Guideline on building assessment (BA01 - BA09)

It is recommended that Member State authorities take action as follows:

- BA01 to accept that a positive result of applying the building assessment procedure defined here below with competitive costs ("pass", "PBA") is equivalent to the statement that the EED building measure is technically feasible and cost-efficient.
- BA02 to declare that assessment is passed if the net present value of one-off and annual costs for the EED building measure ("PVC") is no higher than the net present value of annual benefits of provision of the measure ("PVB"), so that $PBA = PVC \leq PVB$.
- BA03 to allow that a failure to pass is evidence that the building is exempt from a requirement to implement the EED building measure.
- BA04 to require that the accounting period applied is a minimum of 10 years.
- BA05 to allow a discount rate of up to 4 %.
- BA06 to specify that the annual benefits of the EED building measure is to be the sum of annual benefits for each of the component measures of the EED building measure.
- BA07 to require that the annual benefits in local currency (AB) for heating and cooling taken into account in assessment are savings in the cost of purchasing fuel $AB = FP(FT) * (AV + AT) / SE$, and for domestic hot water also the saving in the cost of purchasing cold water $AB = FP(FT) * HC * (UE1 + NU * UE2) / SE + WP * (UE1 + NU * UE2)$, where

AV is the annual ventilation energy saving $AV = VE * 24 * DD * AC$ in kWh/a.

VE is the ventilation effect of the building measures in changes of air per hour.

DD is the number of annual degree days expected at the location of the building in Kelvin-days per year.

AC is the heat capacity of the air in the building, given by the volume of the building and the heat capacity of air in kWh/m³/K

¹⁷ Compare also the recommendation of 4 % in EC Better Regulation Guidelines SWD(2015) 111 http://ec.europa.eu/smart-regulation/guidelines/index_en.htm p375 or JRC (2012) Guidelines for conducting a cost-benefit analysis of Smart Grid projects

¹⁸ BBSR(2015) Wirtschaftlichkeit von Systemen zur Erfassung und Abrechnung des Wärmeverbrauchs, p57

AT is the annual temperature energy saving given by $AT = TE * TL * PD$ kWh/a.

TE is the temperature effect of the building measures in Kelvin.

TL is the thermal loss rate of the building in kWh per Kelvin and day.

PD (production days) is the number of days on which the heating or cooling system is expected to run at the location of the building.

SE is the efficiency of the system delivering thermal energy, in thermal energy out (kW) for consumption (kW) of fuel of type FT, in percent.

FP(FT) is the price of the fuel of type FT used to deliver the thermal energy.

NU is the number of users of domestic hot water in the building.

HC is the average amount of thermal energy in domestic hot water at 52 deg Celsius compared to the cold water in-feed at yearly average temperature in kWh per cubic metre.

UE1, UE2 is the hot water saving effect of the building measure in cubic metres per year and per building unit and per person respectively (total effect in cubic metre per year: $UE1 + NU * UE2$).

WP is the price of cold water per cubic metre.

- BA08 to clarify that the values of the savings effects for ventilation, temperature settings and hot water use (VE, TE and UE1/UE2) are to be the values resulting from the evidence base for the building measures concerned, modified if relevant as per BA09.
- BA09 to take into account the implications of any of the building characteristics listed as Assessment Modification Criteria (Annex, Section 11.1) that may apply to the building concerned.

4 Competitive and reference costs

4.1 Introduction

This section introduces two categories of cost: reference costs and competitive costs. Reference costs are used for a first-cut assessment of individual buildings and for building class exemption decisions. Competitive costs can be applied to the assessment of individual buildings in open building classes.

4.2 Competitive costs

Competitive prices, particularly for services, tend to vary over time, to vary across different locations or markets, according to the circumstances of the provider, by the size of a customer order, etc. Such prices are effectively only revealed when quotations are obtained from suppliers interested in delivering the service for a specific customer, expecting competition, and these prices typically fall below published "list" prices. Competitive prices are considered the proper level of price to apply when determining the cost of an EED building measure.

4.3 The use of reference costs

A national or European reference for the cost of EED building measures is proposed for two roles: for the definition of exempted building classes, and for minimising the burden of quotations which are not accepted.

Reference costs are used for the definition of exempted building classes unless competitive prices can be discovered for the test case building. Where the use of competitive costs is not practicable, some estimate or approximation will be needed. In line with the minimum standard set by EED, these reference costs should not be "financially conservative" estimates, in the sense of "conservative" that is usual for investment decisions, but should be "savings conservative", that is, not unduly excluding buildings from the application of the requirements of the Directive. Consequently, these reference costs should be lower than competitive costs.

Where an open building class is declared, requiring all building assessment to be based from the outset on competitive costs could result in a significant burden on suppliers if the many requests for quotation were not followed by orders. Reference costs are used here to inform landlords whether an EED building measure is close to cost-effectiveness, so that only a reasonable proportion of buildings go out to quotation, and the vast majority of requests for quotation are followed by an order (to one of the suppliers). Here, too, reference costs must be lower than competitive costs, otherwise at least some buildings will be exempted from implementing cost-effective EED building measures. When online support is provided, Member States can additionally request entry of the prices revealed when orders are placed and use this data on competitive costs to adjust the level of the reference costs.

It is clearly important to specify which costs are to be taken into account, to avoid unnecessary costs - "gold plating" - tipping the cost-effectiveness balance into the negative when it should be positive. Costs which should be taken into account comprise the cost of providing a cost allocation service or a service for information and allocation, and the initial costs of the purchase and installation of the necessary devices. For devices which can be expected to operate significantly longer than the chosen accounting period with very low expected cost of replacement or major repair, only the proportion of one-off costs should be applied which corresponds to the proportion of the lifetime falling in the accounting period.

Reference costs should not include unnecessary duplication. Since collecting data and providing the services may be possible for two uses of thermal energy - e.g. for hot tap water and space heating - at very little more than the cost for one use, the cost of an allocation service or an information and allocation service is to be counted once only for any EED building measure. Similarly, if the same physical meter can be deployed to measure more than one use, e.g. hot water and heating or heating and cooling, then the cost of only one meter should be included in assessment. Where reference costs are being applied to an individual building in an open building class, costs will be corrected, if need be, at the quotation stage.

Initial values for reference costs are offered in the appendix, section 11.3. If there is evidence that competitive costs in a region differ significantly from these, a regional reference cost table might be built on quotations solicited for buildings of different sizes from active suppliers of relevant products and services. The buildings chosen should be representative in the sense that they present no unusual impediment to the implementation of the EED building measures. The selection of buildings should allow determination of how capital costs and annual running costs vary with the number of building units and radiators in a building, so that costs can be estimated for a building of any size. Costs estimated this way should be reduced by 5 % or otherwise adjusted to ensure that they fall below competitive prices for all buildings.

4.4 Requirement for quotation to determine competitive costs

The first step in determining which metering and information measures might be cost-effective in a particular building is to apply the building assessment calculation using reference costs. When this building assessment returns a viable result, the obligated actor may go ahead and implement the EED building measure indicated. Alternatively, the obligated actor may obtain quotations and perform building assessment once more, applying competitive costs. A calculation aid can make the second step particularly easy to perform.

The determination of competitive costs is recommended to be based on quotations from suppliers, requested by the landlord or other obligated actor to equip a particular building. The content of a quotation should be standardised and comprise a complete implementation of the EED building measure with no additional services. The way prices are quoted should be aligned to building assessment, that is, requiring payments of a one-off amount and yearly amounts unchanging for at least 10 years. Provision is also made to enable assessment of implementation of components, based on a quotation which may comprise more than one energy use and/or both levels of provision. Costs will be incurred by suppliers providing quotations which are then not followed by an order. There is nothing to prevent suppliers including the cost of this unsuccessful quotation activity in the prices quoted, so that the costs are recovered where quotation is successful.

4.5 Guideline on competitive and reference costs

It is recommended that Member State authorities take action as follows:

CE01 where, in a building in an open building class, an EED building measure is viable using reference costs, to require the determination of competitive costs, through solicitation of a quotation from the most competitive supplier.

CE02 to specify the standard content of a quotation, in particular that the quotation

1. offer a complete implementation of the EED building measure
2. offer no additional services and take account of the specification of allowable costs below
3. require payments of a one-off amount and yearly amounts only
4. specify that yearly amounts remain unchanged for 10 years
5. provide a one-off and yearly amount for each component and for any combination of component which can be offered at lower net present value of cost than the sum of the same amounts for constituent components;

and to specify that such a quotation is free of any charge to the obligated actor, whether or not the offer is accepted.

CE03 to help ensure obligated actors identify the most competitive supplier by ensuring final customers are given access by the obligated actor to data necessary for building assessment and are supported in carrying out building assessment as if obligated actor, including obtaining quotations for delivery to the obligated actor of the relevant services. An obligated actor would be required a) to accept a positive building assessment delivering a higher expected energy saving, b) promptly to provide final customers

with details of building assessment and c) to set a reasonable deadline for notification of an improved building assessment before entering into commitments concerning the EED building measure.

CE04 to provide a table of reference costs, ensuring that reference costs are marginally lower than competitive costs.

CE05 to declare that allowable costs for EED building measures are as follows:

Service level	Thermal energy / device	capital costs	running costs (opex) for
Consumption information service +	heating using heat cost allocators	service set-up, one heat cost allocator per radiator ¹	information and allocation service ³
	heating or cooling using heat meters	service set-up, one heat meter per building unit ^{1,2}	information and allocation service
Consumption based cost allocation	hot water using water meters	service set-up, one hot water meter per building unit ^{1,2}	information and allocation service
Consumption based cost allocation	hot water using water meters	one hot water meter per building unit ^{1,2}	allocation service
	heating using heat cost allocators	one heat cost allocator per radiator ¹	allocation service
	heating or cooling using heat meters	one heat meter per building unit ^{1,2}	allocation service

1 Costs include purchase price and installation, and are limited to those necessary given the heating or other thermal energy system is properly set up and maintained¹⁹.

2 For reference costs, the costs of two such meters are allowed if multiple pipes deliver the thermal energy to the unit or their location is unknown.

3 "Allocation service": a service delivering *consumption-based cost allocation* and responding to any queries from final customers on the correctness of invoiced amounts promptly and fully. "Information service": *consumption information service*.

CE06 where usable radiator valves are not installed, to allow one third²⁰ of the additional cost of installation of modern valves on radiators to be included under CE05 above and to include under BA07 above an equal amount to account for the additional benefits of comfort and energy saving²¹.

¹⁹ For example, a heating system should already have proper hydraulic balancing in place, ensuring that outlying apartments can draw sufficient heat at minimum supply temperatures.

²⁰ One third is 10/30 based on an estimated 30 year usable life of a valve.

²¹ The studies providing the empirical evidence base for the method applied in these guidelines varied in the extent to which TRVs/other controls were present before and after the introduction of consumption based cost-allocation

5 EED building measures

5.1 Introduction

This section introduces building measures as variants of consumption-based cost allocation and consumption information service - two "levels of service" - applied to three types of use of thermal energy - for space heating, space cooling and hot tap water. These define 6 "components", the cells of the table below.

	Space heating	Space cooling	Hot tap water
Consumption based cost allocation			
Consumption information service provision (basic or state-of-the-art)			

5.2 EED building measures and their components

An EED building measure comprises one or more "components", each component being a combination of a thermal energy use (e.g. space cooling) and a service level (e.g. consumption-based cost allocation). For example, the introduction of consumption-based cost allocation for both hot tap water and space heating would be an EED building measure with two components. Where the components of a building measure share costs but independently contribute to the flow of benefits through reduction in energy consumption, the combination of components would tend to be viable even if the individual component measures were not. The reverse is also possible, that when a combination of components - here space heating and hot tap water - is not viable, this does not exclude the possibility that one of the components may be viable. In such cases any cost sharing does not outweigh the high costs of one component (see guideline BC06).

There may be reasons, e.g. to avoid giving incentives to meddle with piping, to allow inclusion of two components, here heating and hot water in buildings fed from district heating, in an EED building measure only together. If these components are bundled, measures will not be taken in some buildings e.g. where consumption-based cost allocation for heating is viable but heating and hot water together are not. The resulting loss of energy savings should be monitored in order to review this approach (see guideline BC11).

5.3 Guideline on building classes (BC10 - BC11)

It is recommended that Member State authorities take action as follows:

- BC10 to require that heat meters are used where building assessment of the EED building measure required for implementation under BC06 is positive using heat meters.
- BC11 for the minimisation of fraudulent activity or other important reasons, to allow particular components to be implemented together only, monitor the energy savings lost as a result and to report these to the Commission.

5.4 Levels of service: consumption-based cost allocation and consumption information services

Consumption-based cost allocation and consumption information services - two "levels of service" in support of energy saving - are defined in line with EED provisions and the requirements of evidence-based cost-benefit assessment. Consumption information services are understood in a basic form as compliance with the information provisions of Directive 2012/27/EU Annex VII and in a state-of-the-art form as a comprehensive exploitation of the potential of information and communication systems to generate useful information that guides how to optimise energy saving in a particular setting.

It is not expected that the savings achieved by consumption-based cost allocation depend significantly on detail of the way costs are allocated, provided those affected know their behaviour will impact significantly on the payments they will have to make. The situation is different in theory for information provision, but given the current evidence base, no different in practice.

It is expected that savings achieved would increase as information is provided more frequently, from bi-annual to quarterly to monthly, or more accessibly - via in-home device, online or on paper - or in more detail - such as changes in consumption over annual or shorter periods that are pre-set or user-selected. Savings may depend on whether the costs incurred are notified with or without requiring interim payments, and whether the amount billed is aligned to consumption annually, quarterly or more often. All these variables affect the quality of the information stream, its effectiveness in drawing attention to and informing about what has happened, and most importantly the effectiveness of the support given to learning how to optimise future behaviour and energy saving.

Viability assessment relies on evidence of benefits, and it is clear that constructing and maintaining an evidence base for savings for these many different increments in the quality of the information stream to building users would be a significant challenge. At the same time, where modern technology is in use, the cost of providing the highest quality of information is not significantly different from the lowest.

For (annual) cost allocation for billing (requiring payment), the obligated actor must also ensure that the total costs of energy provision are calculated. Because the calculation of these costs is often subject to statutory and contractual provisions, the exact calculation can be expensive. It is recommended therefore that such provisions for billing for payment are avoided when providing consumption information services.

The benefits expected will not be achieved by installation alone, but will require continued, quality operation of the necessary service. That is why a requirement to implement a building measure is specified also as a requirement to set up, operate and maintain the quality of the relevant services for continuous operation.

5.5 Guideline on EED building measures (BM01 - BM04)

It is recommended that Member State authorities take action as follows:

- BM01 to clarify that an **EED building measure** is any component or combination of six components given by three types of use of thermal energy - heating, cooling and hot water - and two levels of service provision, "consumption-based cost allocation" and "consumption information services".
- BM02 to describe **consumption-based cost allocation** as a service to final customers in the building implementing fair and transparent *allocation rules for thermal energy costs* where allocation is based on individual consumption measured by appropriate measurement devices. The service obtains data once per year from (hot) water meters, heat meters or heat cost allocators and, on receipt of the amount to be allocated, applies the previously set allocation rules and delivers the necessary information for each final customer to the invoicing entity²² in digital form directly printable and able to be delivered with the annual invoice. Adequate accuracy of the allocation is to be assured, in particular by permitting the use of only those measurement devices that have been shown as compliant with relevant public standards²³.
- BM03 to describe **consumption information services** as providing all final customers in the building with accessible information useful for improving understanding of the environmental and economic impact of the use of ventilation facilities, the setting of valves for controlling heating and the drawing of hot water (energy saving performance). The minimum functional specification for a basic and for a state-of-the-art

²² Often the obligated actor but potentially a different legal entity

²³ Relevant public standards for heat cost allocators and heat meters include EN 834 and EN 1434 respectively. It is recommended that equipment conforming to these European standards is always taken to provide adequate accuracy.

service is provided in Annex 11.2. Consumption based cost allocation for the same use of thermal energy must be in operation.

BM04 to clarify that a requirement to implement a building measure is a requirement to set up, operate and maintain the quality of the relevant services for continuous operation.

6 Evidence base

6.1 Introduction

Consumption based cost-allocation and consumption information have in many studies and projects been observed to trigger energy savings through behavioural changes by the users of individual building units. While the effect may vary with the particular circumstances and the starting point, the evidence base is generally consistent in reporting sizeable savings.

This section introduces the evidence base used in these guidelines and its role in building assessment. In particular it identifies an approach whereby data from a range of studies, subject to a range of caveats, may be extrapolated to other situations in a way that allows taking account of differences in climate, building insulation levels and other important parameters. This approach "translates" observed percentage savings in energy consumption into underlying changes in temperature and ventilation patterns which are more directly and generically related to changes in the behaviour of occupants with respect to temperature settings and use of windows or other means of ventilation.

Deriving values for temperature and ventilation effects triggered by EED building measures is an essential part of the proposed pan-European approach to building an evidence base. The values applied correspond to savings in older buildings in climates typical of Western Central Europe of 20 % for *consumption based cost allocation*, an additional 3 % for basic and a further 3 % for state of the art *consumption information services*. Importantly, the estimated effects relate to situations where building users have control over temperature and may open windows etc. In buildings where these conditions are different, the estimates should be modified²⁴.

These figures are at the disposal of European regulators who, it is recommended, should review new evidence emerging from the research community.

6.2 Temperature and ventilation effects through consumption-based cost allocation

The energy savings achieved by change of user behaviour caused by introduction of consumption based cost allocation are summarised in two values: firstly, the average reduction (increase) of room temperature across the year by 1.1 Kelvin for heating (cooling); secondly, the air change rate is reduced by 0.25 per hour. Below it is explained how these values were derived.

6.2.1 Basis and model for savings effects

The values are based on research and models originally developed by Professor B. Oschatz in an analysis of the energy saving potential of low energy buildings²⁵. An analysis of 22 studies documented average savings of 20.2%²⁶ after consumption based cost allocation has been introduced. The buildings in the studies were taken to have thermal insulation in accordance to the 1977 Heat Insulation Ordinance (WSVO 1977).

Oschatz calculated the changes necessary to achieve 20.2 % savings for terraced houses and multi-apartment buildings²⁷ along two dimensions: temperature reduction and reduction of air flow, on the basis that these were

²⁴ Necessary modifications are described in section 3.5 and specified in the table in section 11.1

²⁵ Oschatz, B (2004) Heizkostenerfassung im Niedrigenergiehaus, published in BBSR Heft 118.

²⁶ An almost equal value has been documented by: Loga, T., Großklos, M., Knissel, J. (2003) Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten – Konsequenzen für die verbrauchsabhängige Abrechnung, Institut für Wohnen und Umwelt, Darmstadt

²⁷ DIN V 4108-6: 2003-06 Wärmeschutz und Energieeinsparung in Gebäuden, Teil 6 Berechnung des Jahresheizwärme- und des Jahresheizenergiebedarfs.

the dimensions inhabitants were able to control. Attributing the savings to either temperature control or ventilation alone did not fit the behavioural data as well as attributing half of the savings to each dimension²⁸.

The approach introduced by Oschatz of using two dimensions of savings effect has subsequently been used to assess the viability of introducing EED measures on frequent billing information in German building stock²⁹.

6.2.2 Temperature effect

Where tenants or other building users have control over the heating in individual rooms, consumption-based allocation of heating costs has, by changing economic incentives, been shown to lead to more careful behaviour, in particular:

- lowering temperature levels in occupied rooms
- local restriction of heating, lowering temperature levels in unoccupied rooms
- temporal limitation of heating, e.g. the closing of valves at night or during holidays

All three types of change in user behaviour combine in contributing to a reduction in the average temperature in the building. There is no reason to suppose that the change in behaviour varies significantly with the quality of building insulation³⁰, so the temperature effect of 1.1 Kelvin observed in more than 20 studies is taken to be valid across buildings of varying quality in any location.

In highly insulated buildings, a change in average inside building temperature of 1.1 Kelvin has little impact on the rate of thermal energy loss from the building and therefore the temperature effect of consumption-based cost allocation contributes little to energy saving. For such buildings, application of guideline BA07 will show that the primary impact of consumption-based allocation of heating costs is through the ventilation effect.

6.2.3 Ventilation effect

Tenants and other building users can usually influence heating energy demand through adjustments to ventilation, by opening windows or by equivalent methods of natural ventilation. Even where mechanical ventilation systems have been installed, users may well influence ventilation flows by opening windows in addition.

Ventilation behaviour of many building users has been observed to become more careful when consumption-based allocation of heating costs is introduced. On average, over the multiple studies summarised, Oschatz estimates that the effect of changed ventilation behaviour is a reduction in changes of air per hour of 0.25. In the absence of evidence to the contrary, there is no reason to suppose that the change in behaviour varies significantly with location or type of building, provided natural ventilation is possible. Therefore, the ventilation effect of 0.25 per hour is assumed to be valid across buildings of any insulation quality in any location.

For sustainable building management, sufficient ventilation should take place to ensure the building environment remains healthy. In the case of risk of mould formation, minimum safe ventilation rates depend on moisture generation (numbers of occupants, time in building, uses of cold and hot water etc.), temperature, wall surface finish, thermal bridges etc. The assumption made in the approach recommended here is that management of minimum ventilation in buildings studied was adequate to avoid health risks or building deterioration (see section 6), and the documented energy savings were achieved nevertheless. On measures to discourage excessive reduction of heating and ventilation, see also section 8.

²⁸ This conforms with measurements documented in: Rouvel, L. (1981) Einfluss von Nutzergewohnheiten und Abrechnungsart auf den Heizenergieverbrauch, Dokumentation zur Tagung „Einfluss des Verbrauchsverhaltens auf den Energiebedarf privater Haushalte“ München, Springer-Verlag 1982

²⁹ BBSR(2015) Wirtschaftlichkeit von Systemen zur Erfassung und Abrechnung des Wärmeverbrauchs

³⁰ Oschatz (2004), p10 applying norms and calculations documented in DIN V4701-2, DIN-V4108-6, EnEV2001

6.3 Temperature and ventilation effects through consumption information services

Where consumption-based cost allocation has been introduced, additional savings have been shown to be attainable by providing the user with additional relevant information on consumption. Evidence for the quantitative impact of consumption feedback, enabling estimation of benefits, is taken from a recent meta-study and an online evaluation database of R&D projects.

Togebly and Zvingilaite³¹ recently performed a meta-analysis of 40 completed studies of the energy savings triggered by providing building users with feedback on their energy consumption. The studies included a range of modes of provision of heating consumption information, from information provided directly on in-building displays, to printed energy consumption information provided through the post. All studies were assessed for quality using a range of criteria:

- Duration of feedback study – minimum one year's duration.
- Sample size – minimum 100 participants (with some exceptions where results were statistically significant).
- Test design – with control group and with data on consumption before and after service introduction.
- Socioeconomic factors and participant self-selection are controlled for either using a control group or by statistical analysis of background data.
- Statistical significance of results.

The median of percentage savings in heating consumption found across all studies was some 3 %. To apply this result to estimate the impact of future feedback provision, it is assumed that a basic consumption information service comprising the provision of billing information to the specification in EED Article 10 and Annex VII can achieve savings of this magnitude (compare section 11.2).

Given ongoing research and development effort in this field, it can reasonably be assumed that the level of saving achieved in studies reaching back some years can be increased by improvements in service provision. Consumers can now be provided with feedback through state of the art services exploiting ubiquitous connectivity and personal digital devices.

The proportion of energy saved from advanced consumption information services can reasonably be expected to be not at the median but in the upper range of the studies analysed by Togebly and Zvingilaite. Given the variation in study results, the figure is not unlikely to be twice as high as the median. This supposition is corroborated by recent research on high quality consumption information services reflected in study data uploaded into the repository of the eeMeasure online evaluation tool. The 25 pilot services across a range of sites in the EC funded ICT-PSP programme provided advanced energy awareness and decision support services to residential users. The median of eeMeasure study³² results is close to the 6% suggested above, and implies that advanced consumption information services can indeed double the impact of basic consumption information services.

Percentage figures cannot be applied across all climate zones and ranges of building quality, and are therefore here used to deduce an estimate of the effect of the underlying behavioural change, again in terms of changes in average indoor temperature and air exchange rates. The additional behavioural impact to be expected from a basic consumption information service comprises a temperature reduction of $1.1 * 3 \% / 20 \% = 0.165$ Kelvin (temperature effect) and a reduction in exchange of air with the building environment of $0.25 * 3 \% / 20 \% = 0.0375$ per hour (ventilation effect). For state-of-the-art consumption information services, the values are 0.33 Kelvin and 0.075 per hour respectively.

This translation of percentage savings found in studies into behavioural components is valid provided it can be assumed that the buildings in the study had a thermal performance comparable to the 1977 building standard

³¹ Togebly, Mikael, Zvingilaite, Erika (2015): Impact of Feedback about energy consumption.

³² <http://eemeasure.smartspaces.eu/>

applied in calculations by Oschatz (see section 6.2.1). Applying these results also requires that all studies set out from a baseline where consumers were billed on the basis of their consumption but were not receiving any of the billing information now required under EED provisions. Documentation on both issues is not complete.

On the first point, it would clearly be very helpful if those planning the evaluation of improved consumption information services would make information available on the insulation and ventilation characteristics of the buildings in their samples, and also attempt to directly monitor at least temperature behaviour.

6.4 Hot tap water usage effects

The values given above of the expected effects of EED building measures for space heating and space cooling are drawn from studies directly aimed at estimating savings in consumption of energy for these measures. In the absence of dedicated studies, the approach taken for hot tap water usage is to assume that the proportional behavioural effects on hot tap water usage, when economic (cost-allocation) and information measures are introduced, are similar in magnitude to those for space heating. Based on figures for hot water consumption researched in the UK (DEFRA/energy saving trust³³), delivered at an average temperature of 52 degrees Celsius³⁴, and in an analysis of 13 studies by Sønderslund et al.³⁵, an equivalent 20 % saving for consumption-based cost allocation is applied to a baseline consumption of hot tap water of 46 and 26 litres per day, per dwelling and per person respectively (total dwelling consumption = 46 + 26N litres / day). This translates to 3.4 and 1.9 cubic metres per year, per dwelling and person respectively. The additional 3 % for basic consumption information services translates to 0.5 and 0.27 cubic metres per year, per dwelling and person. Twice as much, i.e. a total of 6%, is assumed to apply to state-of-the-art consumption information services.

6.5 Evolution of the European evidence base

The current evidence base can be improved through further research, particularly research which takes explicit account of the use made of results in viability assessment and predictions of impact e.g. on climate change. Given the wide variation in quality of building stock today, the usual practice of estimating percentages saved in particular building types and locations increasingly limits the applicability of the research results; the percentages apply only to similar collections of buildings in the same locations. Research in future should instead aim to estimate the value of parameters of models of behavioural change, such as the simple one reported here. Such a model then allows evidence-based estimation of the absolute saving in energy - and water - intake per year to be derived for any building in any location.

6.6 Guideline on evidence base (EB01 - EB02)

It is recommended that Member State authorities take action as follows:

EB01 Unless and until the evidence base is improved, to require that for building assessments the following estimation of average savings effects of the components of an EED building measure be used (and modified where relevant as per BA08 and BA09):

For the introduction of consumption based cost allocation for heating and cooling, a temperature effect (TE) of 1.1 Kelvin and a ventilation effect (VE) of 0.25 per hour.

For the introduction of consumption based cost allocation for hot water, hot water effects of 3.4 cubic metres per year and dwelling or other building unit (UE1) and an additional 1.9 cubic metres per year and person (UE2).

³³ DEFRA(2008) Measurement of Domestic Hot Water Consumption in Dwellings

³⁴ Adherence to the recommended minimum temperature for standing hot water of 60 degrees - see WHO (2007) "Legionella and the prevention of legionellosis" - will increase savings effects.

³⁵ Sønderslund, A.L., Smith, J.R., Hutton, C., Kapelan, Z. (2014) Using Smart Meters for Household Water Consumption Feedback: Knowns and Unknowns, *Procedia Engineering* 89, 990-997.

For the introduction of basic consumption information services in a building already provided with consumption based allocation of costs, a temperature effect (TE) of $1.1 * 3 \% / 20 \%$ Kelvin and a ventilation effect (VE) of $0.25 * 3 \% / 20 \%$ per hour for heating and cooling and hot water effects of 0.5 cubic metres per year and dwelling or other building unit (UE1) and an additional 0.27 cubic metres per year and person (UE2).

For the introduction of state-of-the-art consumption information services add the same values as quoted in bullet point above (on top of the basic consumption information service effects).

EB02 to require that for building assessment the temperature, ventilation or hot water effect of an EED building measure be calculated as the sum of the same effect for each of the above components included in the measure.

7 Supporting and monitoring EED implementation

7.1 Calculation aid

Rapid, easy assessment of the cost effectiveness of EED building measures in a specific building is key to keeping administrative burden down for obligated actors - where open building classes are used - and for regulator staff dealing with proposals for exempted building classes.

An online service or downloadable spreadsheet tool can be provided for building assessment, as was shown in the UK in 2015. This kind of facility is referred to here as a "calculation aid". The guideline recommends that an online calculation aid for building assessment is developed, for use with both reference costs and competitive costs, and is made available to obligated actors.

It is seen as useful to combine the calculation function with a monitoring function - especially to monitor price developments. This is the justification for adding a recommendation to gain permission to access price information. Use of the calculation function also discloses the building and cost data entered, which is necessary to analyse the prices and check these against current reference prices.

The disclosure of data will enable the regulator to track programme performance, and also assist in making the assessment more efficient. It is specifically proposed that the cost data entered is monitored and analysed to reveal opportunities to declare wider viable building classes or exempted building classes. An important function of online monitoring of cost data is to detect where reference costs may be higher than competitive costs and must be corrected downward.

7.2 Guideline on support and monitoring (SM01 - SM03)

- SM01 to develop and make available to obligated actors an online calculation aid for building assessment with reference costs and with competitive costs, and the key assumptions of which are transparently made accessible to interested users.
- SM02 to require obligated actors through use of the calculation aid or otherwise to disclose to the competent authority the building and cost data used for building assessment and to sign a declaration of the accuracy of such data and to make this declaration and the data available to all building users.
- SM03 to monitor and analyse the cost data entered into the online calculation aid to reveal opportunities to declare wider viable building classes or to exempt building classes and to identify cases where reference costs may be higher than competitive costs and must be corrected downward.

8 Allocation rules for thermal energy costs

8.1 Introduction

This section introduces the role of allocation rules for thermal energy costs, provides examples of current use and, based on a distinction between fixed and variable costs of provision, develops recommendations for allocation rules appropriate to a transition from fixed allocation³⁶ to consumption-based allocation of thermal energy costs.

The third paragraph of Article 9 (3) EED allows for the voluntary provision of allocation rules:

"Where multi-apartment buildings are supplied from district heating or cooling, or where own common heating or cooling systems for such buildings are prevalent, Member States may introduce transparent rules on the allocation of the cost of thermal or hot water consumption in such buildings to ensure transparency and accuracy of accounting for individual consumption. Where appropriate, such rules shall include guidelines on the way to allocate costs for heat and/or hot water that is used as follows:

- (a) hot water for domestic needs;*
- (b) heat radiated from the building installation and for the purpose of heating the common areas (where staircases and corridors are equipped with radiators);*
- (c) for the purpose of heating apartments."*

8.2 The role of allocation rules

Introducing hot water meters, heat meters or heat cost allocators in a building allows the allocation of costs of thermal energy use to take place on the basis of consumption, where previously charging would not have been different for final customers with more careful or more wasteful behaviour. As detailed above, the introduction of cost allocation with a significant consumption-based component is key to achieving significant energy savings through the metering provisions of EED.

On the other hand, well-designed cost allocation rules should also reflect that individual units in multi-apartment/purpose buildings are not entirely independent of each other. As internal walls are rarely well insulated, fairness may be seen as impaired if heating charges are made exclusively dependent on individual consumption measurements, especially as these in turn may be influenced significantly by neighbours' heating behaviour³⁷, or on a building unit's relative position in a building.

Whereas many different approaches to cost allocation exist and have been proven to work more or less smoothly once in place for some time, the *transition / change* to that new situation itself is often prone to cause controversy among building users. Allocation rules can be used to make the transition fair to all building users. Allocation rules may also be designed to take into account energy poverty issues where such exist. Though the implementation of the EED in the way recommended here can be expected to alleviate energy poverty in general (because there will be savings for the building as a whole), allocations rules involving compensatory transfers may need to be applied to avoid worsening the situation of individual disadvantaged families, e.g. in peripheral apartments more exposed to the outdoor climate.

Reports from Member States suggest that the chosen allocation rules should be very well communicated before their introduction. They should also not be changed without very good reason, as any change typically will increase the charge to at least one apartment in a building, and higher bills are reported to be the main trigger for complaints.

Examples of national cost allocation rules from Germany, Denmark and Slovenia are described in the following sections, to provide ideas for emulation by other Member States.

³⁶ Typically done on the basis of the shares of floor area or volumes of flats/units, or other fixed characteristics or factors for each unit in building.

³⁷ Dependence on neighbours' behaviour is of course often more acute when consumption is not taken into account at all in allocating costs.

8.3 Allocation rules in Germany

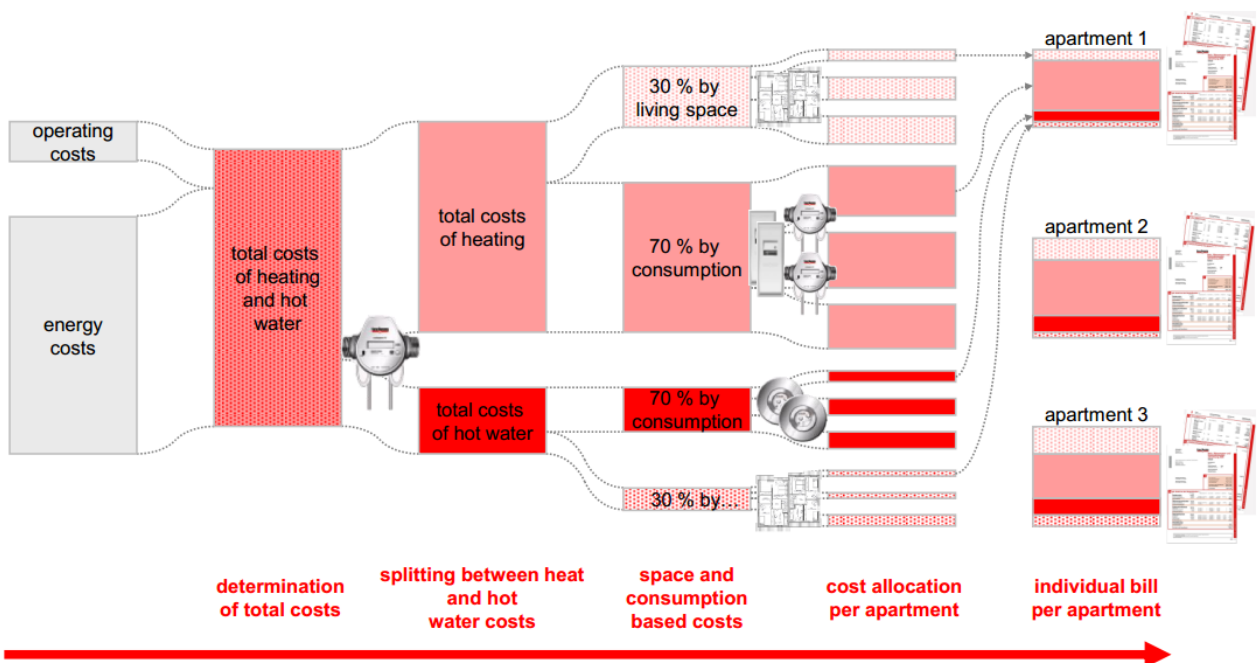
The German regulation “Heizkostenverordnung”³⁸ allows for some flexibility in the distribution of costs depending on dwelling size and level of consumption. The building owner can decide in the rental contract with tenants the share of the “total costs of heating and hot water” to be allocated by living space, provided this is set in the range 30 to 50 %, corresponding to distribution of 50-70 % of these total costs by consumption. In some cases it is required that 70% is consumption-based.

The diagram below summarises the typical process in a German multi-apartment building. Energy costs and the operating costs of the heating system are combined in the “total costs of heating and hot water”. A meter near the boiler measures the total consumption of energy used to heat water and is used to determine the respective shares of hot water and space heating in the overall costs. In the next step, 30 % of each of these sums is distributed according to the tenant’s share of the total living space. Hence, a larger flat will have to cover a greater part of the heating cost as it benefits more from heat being radiated through walls etc. Applying correction factors is not allowed.

The remaining 70 % of the costs are distributed according to the tenant’s individual share of the consumption. For example, if the total costs for space heating were to be €100, €30 would have been distributed according to the tenant’s share of living space. The remaining €70 would be distributed according to the consumption of all residents. If there are 3 apartments and the first and the second apartment consumed 30 % of the total heat units each, they would have to pay €21 whilst the third apartment would pay €28 of the heating. Consumption in commonly used rooms does not have to be recorded separately³⁹ but is covered by distribution of total consumption to individual share and share of living space.

The same principle applies to water consumption: the total consumption is recorded as the total amount of water consumed in m³.

Exhibit 1 – Example of allocation without regard to apartment location



³⁸ Verordnung über die verbrauchsabhängige Abrechnung der Heiz- und Warmwasserkosten (Verordnung über Heizkostenabrechnung - HeizkostenV)

³⁹ Unless a room is the reason for significantly higher consumption such as a swimming pool, sauna etc.

8.4 Allocation rules in Denmark

The basic consumption allocation is comparable to the approach used in Germany. A minimum of 40 % of the total heating costs (including heating of hot water) must be allocated according to individual meters. If only the space heating is considered (making it comparable with the illustration above), a minimum of 60 % must be allocated according to individual heat meters or heat cost allocators. The approach in Denmark additionally specifies correction factors to compensate for heat transfers between dwellings as well as for unequal exposure to the outside world (heat loss). Radiator sizes, consumption in previous years and values from comparable buildings can be used to determine correction factors, if the original heat loss calculation is not available.

Correction factors are applied either on the share of the consumption or the share not directly dependent on the individual consumption. Correction factors must be updated whenever the building is significantly changed and can only be disregarded if heat loss has already been taken into consideration when determining the rent or the evaluation would be too expensive (or unnecessary). Examples of correction factors for a larger multi-apartment building are depicted below.

Exhibit 2 – Example reduction of fixed costs to correct for heat losses

<i>Top floor:</i>	50 %	40 %	40 %	40 %	40 %	40 %	40 %	40 %	50 %	<i>Top floor:</i>	50%	40 %	40 %	40 %	40 %	40 %	40 %	40 %	50 %
<i>Middle floor(s):</i>	30 %	0	0	0	0	0	0	0	30 %	<i>Middle floors:</i>	30%	0	0	0	0	0	0	0	30 %
	(30)	0	0	0	0	0	0	0	(30)		(30)	0	0	0	0	0	0	0	(30)
<i>Ground floor:</i>	40 %	15 %	15 %	15 %	0	0	15 %	15 %	40 %	<i>Ground floor:</i>	30%	0	0	0	50 %	50 %	0	0	30 %
					(heated)						40 %	15 %	15 %	15 %	(gateway)	15 %	15 %	40 %	

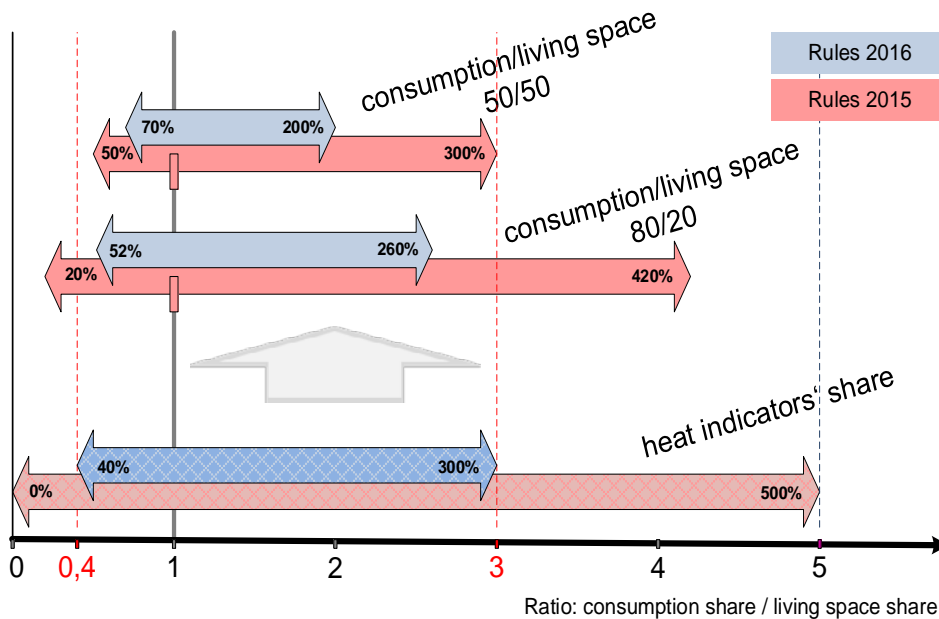
8.5 Allocation rules in Slovenia

In the case of Slovenia, Danish-style correction factors are applied to dwellings, and 50 % - 80 % of total costs are distributed based on measured consumption - the remainder are distributed in proportion to dwelling size or living space.

Along with several other Eastern European countries, Slovenia additionally introduced limits to the share of costs allocated to an individual unit. Limits were introduced in Slovenian regulation⁴⁰ in response to complaints about very high charges for some dwellings, and to counter excessive attempts to save on heating bills. In 2016, the rules were modified and the limits changed (see Exhibit 3). Under the new rules, the maximum share of consumption is limited to 300% of the average. This value takes account of typical heat flows between apartments and was derived from modelling the case where all dwellings are heated at least to the statutory minimum temperature. The minimum level of 40% of the average was set to remove any incentive to turn off the heating completely and reflects an estimate of the minimum consumption level necessary to keep the entire building at an adequate minimum temperature considered safe for the building. This way all occupants regardless of their actual behaviour can be seen as paying for that level of heating, and the consumption-dependent charge in turn reflect the additional heating required to reach the comfort levels they choose.

⁴⁰ Energy Act 2016, <http://www.energetika-portal.si/>, marko.suhadolc@gov.si

Exhibit 3 – Example of changing allocation rules including the introduction of limits



Dwellings for which consumption could not be measured, not because of a technical fault, but because necessary access was not granted or a device had been tampered with, are charged based on the highest recorded consumption measurement in the building.

8.6 Variable and fixed costs of thermal energy provision

For any building, costs of provision of space heating, space cooling and hot tap water comprise fixed and variable costs.

The variable costs comprise primarily the cost of fuel, thermal energy or other form of energy purchased⁴¹.

Fixed costs⁴² for providing space heating, space cooling and hot tap water are costs which are incurred substantially independent of the usage behaviour of building users and the severity of a winter or of a summer heat wave and include:

- maintenance costs - including for heating systems flue cleaning, emission testing etc. - ,
- fixed prices sometimes charged for network access e.g. for district heating,
- energy for ancillary equipment such as pumps, and
- depreciation charges for centrally provided equipment.

The capital and running costs of services for consumption-based cost allocation and consumption information provision, where provided, are also fixed costs in this sense.

Different heating systems are associated with differing proportions of fixed and variable costs in the total cost of provision. Cases of high proportions of fixed costs are where provision of central heating via water to water heat pumps requires the drilling of wells for access to ground water, or a district heating provider providing waste heat from a power station charges a high fixed network access cost.

⁴¹ A small variable component may come from electricity use for ancillary equipment such as pumps etc., however, in most systems even these amounts are substantially independent of overall thermal energy demand and therefore to be generally regarded as fixed costs. Variable costs will theoretically be zero when all building users set the valves or other controls they have to draw no or a minimum of thermal energy from the central source.

⁴² Fixed costs are not to be misunderstood as being invariant; many components of fixed cost increase over time. However fixed costs are not dependent on the volume of thermal energy provided over a period.

Special cases of costs not controlled by final customers are thermal energy losses of poorly insulated pipe-work and the provision of thermal energy to common areas and common facilities⁴³. In both cases these uses are outside final customer premises but affect the variable costs, e.g. the amount of fuel purchased and its cost.

Distinguishing the fixed costs of thermal energy provision from other costs of providing comfortably heated or cooled buildings is not trivial. The higher costs of erecting well-insulated walls instead of poorly insulated walls are typically recovered from rental payments, rather than from any allocation of "heating costs". Any fixed costs, whether or not declared in law or otherwise to be "heating costs", can be bundled in with other costs as rent or distributed more transparently among final customers, in any number of ways. The mode of distribution may be specified in national legislation or can be free of regulation, subject only to contractual agreement between landlord and final customer (or mixed, as in the German example). The distribution calculation may be a flat rate per unit or amounts depending on the size of unit or on other parameters associated with a unit (such as number of hot water taps, radiators etc.), or dependent on consumption as measured by heat meters, heat cost allocators or other technical systems.

The EED makes clear that the cost of operation of EED building measures and their maintenance can be allocated to final customers, as can any other costs reasonably incurred to enable the continued use of the thermal energy and the continued operation of the EED building measures. The mode of allocation - fixed per unit, by area, by consumption etc. - is not specified in the EED, but the requirements regarding consumption based billing in Article 10 clearly imply that the allocation approach must contain an element that is dependent on individual consumption (subject to cost-effectiveness and feasibility conditions).

Except for an allocation of costs proportional to a measure of consumption, none of the particular modes of allocation of fixed costs of thermal energy provision are expected to have an impact on energy saving behaviour. The interpretation of the current evidence base is that saving effects have been shown in cases where a significant proportion of costs have been allocated based on measured consumption. The guideline therefore focuses on this as the only known necessary content of allocation rules to ensure the expected contribution to energy saving objectives.

In buildings where the occupants or users of individual units are also the owners or decision-makers when it comes to investments in the building such as envelope improvements or heating installation renewal, the transition to consumption based cost allocation may affect the incentives that individual users of units have to agree to such investments. In devising the allocation method, it is important that such effects are considered, and any risk of loss of incentive for other energy efficiency improvements is mitigated. This is notably an argument against allocating too large a sum based on consumption, or at least for not doing so without adding other compensation and incentives for appropriate investments and for other action improving energy efficiency. The wrong distribution of costs and benefits can create free rider effects and reduce energy efficiency overall. Under individually favourable circumstances, such as location in the centre of a building or frequent and long absence during the heating season, a building user may lose any incentive to agree to decisions on building improvements, even where these would deliver cost-effective savings for the building as a whole.

Similar concerns arise where the split of incentives is changed from a "warm rent" regime to consumption-based cost allocation, such that without compensatory measures landlords may be without adequate incentives to make building improvements. As with the allocation of costs between co-owners, the allocation of costs between landlord and tenant and the principles by which rents are negotiated or set should be adapted to ensure appropriate incentives are in place and therefore that energy efficient action is taken by the relevant actors.

8.7 Guideline on allocation rules for thermal energy costs

It is recommended that Member State authorities take action as follows:

⁴³ Where some radiators in apartments, e.g. in bathrooms, are not fitted with control valves, their consumption of thermal energy are not to be included in the variable costs, as defined here.

- AR01 to ensure that allocation rules for thermal energy costs have the effect, compared to allocation by size of building unit, of a credible and significant increase in dependency of the costs incurred by final customers on the energy saving performance⁴⁴ of building users, for example by allocating all variable costs of provision of the thermal energy in proportion to the consumption measured in each building unit and not to allocate excessive proportions of fixed costs in proportion to the consumption measured.
- AR02 to allow or require application of correction factors related to the location of a building unit (or, exceptionally, individual rooms) in a building in cases where the introduction of consumption-based cost allocation will otherwise result in a significant increase of charges to one or more final customers, despite the expected energy savings, or to phase in over 2-3 years the full application of AR01 above. AR03 to allow or require that rents for all units are changed, whenever an improvement is made to the building which is cost-effective in that it will yield an energy saving to the building whose net present value at least matches the cost of the improvement, such that the changes in rent provide adequate economic incentive, in favour of the improvement, to all individuals empowered to take the decision.
- AR04 to include in allocation rules appropriate and effective penalties for tampering with devices or refusing access to install or read devices.
- AR05 to ensure widespread and thorough understanding among users of affected buildings of allocation rules, and of any changes to existing allocation rules, well before their introduction.

⁴⁴ "Energy saving performance" is behaviour of building users affecting energy consumption (see glossary).

9 Glossary

Calculation aid for building assessment: an online service or downloadable software package which supports the user input and provides the algorithms and data required to deliver the result of building assessment, that is, a verdict on the cost-effectiveness of a particular building.

EED building measure: any combination of consumption-based cost allocation and consumption information services for the thermal energy usage types heating, cooling and hot water ("components")

Energy saving performance (of building users): the use of ventilation facilities by building users, their setting of controls or valves for controlling heating and their drawing of hot water, and the ecological and economic impact of this action.

Fixed costs of thermal energy provision: costs of providing heating (or other thermal energy) which do not vary appreciably with the behaviour (energy saving performance) of building users, for example maintenance costs.

Variable costs of thermal energy provision: the cost of fuel or other source of energy for providing heating, cooling or hot water and other costs which vary appreciably with changes in the energy saving performance of building users. Variable costs will theoretically be zero when all building users set the valves or other controls they have to minimum.

Cost-effectiveness: The terms cost-efficiency and cost-effectiveness are used interchangeably.

Viable (of building measure in a building): technically feasible and economically cost-effective using competitive costs

Building assessment: A test of a building in respect of a building measure which returns a positive result if the measure is technically feasible and economically cost-effective, that is, when the saved costs of energy through the building measure exceed the cost of the building measure, using competitive costs.

Thermal energy provision: the provision of heating, cooling and/or hot water by means of flows of heat to final customers in a building.

10 Guideline development

10.1 Development process

These guidelines have been developed under contract to the European Commission in the "Analysis of good practices and development of guidelines for accurate and fair allocation of costs for individual consumption of heating, cooling and domestic hot water in multi-apartment and multi-purpose buildings to support the implementation of relevant provisions of the Articles 9-11 of the Directive 2012/27/EU on energy efficiency" MBIC (ENER/C3/2013-977). The recommendations are an expression of the views of the authors and must therefore be without prejudice to interpretation of the EED by the European Court of Justice.

The process of development set out from thorough analysis of key national background documents and of existing regulatory approaches across the EU. Options for a common approach and the deficits of existing approaches were discussed with experts and with key stakeholders, including the European sub-metering industry organised in EVVE. A workshop in Berlin with leading experts and national representatives ratified key aspects of the approach: multi-level (class and individual building) assessment and the generalisation of the world evidence base using two dimensions of effect enabling application to various building characteristics and climates. The main content of the guidelines was presented and discussed with national regulators, experts and some stakeholders at a further workshop in Brussels, then taken into thorough discussion with representatives of most Member States in 5 regional workshops across the EU. The guidelines were subsequently revised to address the issues raised.

10.2 Acknowledgements

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11 Appendix

11.1 Appendix 1 Assessment modification criteria

Characteristic	Implication
Building users are prevented from allowing any ingress of outside air except through a heat exchanger with waste heat utilization.	The ventilation effect (VE) is deemed to be zero, reducing energy saving for heating and cooling
Building users are prevented from affecting the rate of flow of water through unit radiators or other unit heat exchangers ⁴⁵ .	The temperature effect (TE) is deemed to be zero, reducing energy saving for heating and cooling
Consumption based cost allocation without consumption information services was introduced before the end of 2016 ⁴⁶ and no device replacement or other major work is required to maintain the service for at least 12 months.	All benefits from consumption based cost allocation are deemed to be zero/already realised.
Consumption based cost allocation not conforming to the guidelines but accepted by building users was introduced before the end of 2016 and no major work is required to maintain the service for at least 12 months.	All benefits from consumption based cost allocation are deemed to be zero/already realised.
Consumption information services not conforming to the guidelines but accepted by building users was introduced before the end of 2016 and no major work is required to maintain the service for at least 12 months.	All benefits from basic consumption information services are deemed to be zero/already realised.
Air conditioning is provided from a common point to one or more units.	VE and TE are deemed to be zero for all units supplied.
Heated air is provided to one or more units e.g. via a separate heat source or through mechanical ventilation during cold weather.	VE and TE for heating are deemed to be zero for all units supplied.
Cooled air is provided to one or more units e.g. through mechanical ventilation during hot weather.	VE and TE for cooling are deemed to be zero.
There are multiple pipes into units for heating or cooling or the location of pipes is unknown.	<i>Reference costs</i> for a heat meter based solution may be increased to include two heat meters per unit.
The heating system uses under-floor heating or fans.	The costs of consumption based cost allocation for heating using heat meters but not using radiator-mounted heat cost allocators are to be taken into account.
Usage is as a hotel or other accommodation where most building units are occupied by the same person for one or two days	All effects from EED building measures (VE, TE, UE1, UE2) are deemed to be zero

⁴⁵ This represents an extension of the argument in EED recital 28 which appears to suggest that the only means by which final customers can control their consumption is a thermostatic radiator valve; however, valves which operate without thermostatic control can also be used and have been used to control heating consumption.

⁴⁶ 2016, or other appropriate cut-off date, after which full assessment and conformant systems should be required.

Usage is such that residents **lack control** of temperature settings or ventilation to meet their preferred comfort and cost level. All effects from EED building measures (VE, TE, UE1, UE2) are deemed to be zero

Usage is such that dwellings cannot adequately be closed off to heat flows to and from **common areas**. All effects from EED building measures (VE, TE, UE1, UE2) are deemed to be zero

One or more **heat exchangers** heat more than one dwelling or other building unit, e.g. under-floor delivers significant heat through the ceiling of the premises below. All effects from EED building measures for heating (VE, TE) are deemed to be zero

11.2 Appendix 2 Specification of consumption information services

Consumption information services provide all final customers in the building with accessible information useful in improving understanding of the environmental and economic impact of the use of ventilation facilities, the setting of valves for controlling heating and the drawing of hot water. Based on compliance with Directive 2012/27/EU, a minimum service specification for a basic consumption information service is the following:

The service is such that billing information is made available at least quarterly, on request or where the consumers have opted to receive electronic billing or else twice yearly and the billing information includes clear and understandable information on current actual prices, actual consumption of energy, comparisons of current energy consumption with the same period in the previous year in graphic form, comparative end-user profiles and benchmark profiles for energy consumption and includes contact information for organisations offering independent consumer advice, information on energy efficiency improvement, and advice on available energy efficiency measures.

Based on services available at the time of writing, the minimum service specification for a state-of-the-art consumption information service, requiring remotely readable devices in the building, is the following:

The service obtains information on consumption from (hot) water meters, heat meters or heat cost allocators and enables final customers via secure internet access, on a smart phone application, in a display in the building unit or by equivalent means to access information showing whether there has been an improvement or a deterioration in the energy saving performance of building unit users compared to an appropriate reference period (performance change). The performance change is expressed at least in terms of amounts of CO₂ emissions and sums of local currency, and these values are adjusted to remove the influence of factors other than performance change, in the case of heating and cooling comprising at least the effect of differences in outside temperature between the periods (climate correction).

Development is continuing. For example, work in Natconsumers⁴⁷ sets out to improve feedback to residential consumers about energy usage and intends to develop a methodology for communicating more effectively with consumers. This will use machine-generated natural language to provide communication which is friendly, emotionally intelligent, relevant and simple, to raise awareness of energy use in homes and to give advice about how to use energy more sustainably.

The company Opower providing information services for electricity consumption tested varying platforms as field tests to improve the platform. The data was made available to scientist and results are partly made public as "White papers"⁴⁸ on the company's website (registration required). The papers provide insights into how to

⁴⁷ www.natconsumers.eu

⁴⁸ https://opower.com/resource_type/white-paper/

present information to induce behavioural change as well as a qualification of preferences on information across Europe.

11.3 Appendix 3 Reference costs - initial source

First time installation of individualised metering devices /sub-metering

The following values, reported from the German market in 2014⁴⁹, are offered as a first source of reference costs. The individual figures should be adjusted to better reflect regional prices, particularly if competitive costs for any component prove to be lower, or much higher, in that region.

Energy use / device	Service level	Capital (one-off) cost			Operational (running) cost, annual		
		per radiator	per meter / building unit	per building	per radiator	per meter / building unit	per building
Heating using HCA	Consumption-based cost allocation	30.00	0	26.00	5.60	0	80.80
Heating using meters		0	253.00	0	0	23.30	70.30
Cooling using meters		0	253.00	0	0	23.30	70.30
Hot water, metered		0	253.00	0	0	23.30	70.30
Heating using HCA	Remotely read consumption based cost allocation	39.00	0	126.00	5.20	0	75.10
Heating using meters		0	314.00	21.00	0	23.80	67.50
Cooling using meters		0	314.00	21.00	0	23.80	67.50
Hot water, metered		0	314.00	21.00	0	23.80	67.50

The cost of equipping a building with devices such as heat cost allocators (HCA) or heat meters depends on the number of devices to be installed - typically one meter per apartment, or one heat cost allocator per radiator. In some cases the price structure also includes a cost per building, for example where a data concentrator, software package, travel to the building or other cost is incurred which is substantially independent of the number of apartments in the building.

The table can be used to generate reference costs for capital cost and operational costs for any building, for either of the two levels of service and for any combination of thermal energy uses (space heating, cooling or hot tap water). The per-building and per-unit costs are applied together. For example, the reference capital cost for introducing consumption-based cost allocation using heat cost allocators in a building with 10 apartments each having 2 radiators is € 626 (€30 * 20 + €26). For the same building the reference annual cost for providing the service - reading the devices and delivering the cost-allocation ready for billing⁵⁰ - is € 193 (€5.60 * 20 + €81). Adding consumption information services for hot water in the same building would increase reference capital and operational costs by € 3161 (€314 * 10 + €21) and € 305.50 (€23.80 * 10 + €67.50) respectively.

Upgrade of existing systems to provide state-of-the-art information service

Cost might differ if a heat cost allocator system is already in place and is upgraded to provide (at least) monthly information services. The following values were reported for the German market at the Regional Workshop for Central European Countries in November 2016 and describe the necessary cost for providing advanced consumption information services as defined in section 11.2.

The table below summarises in each row typical levels for installations and which extensions are necessary to provide at least monthly information services. The cumulated cost of upgrading the system and provision of information services are summarised in the third column.

⁴⁹ 95% of price components derived from Institut für Technische Gebäudeausrüstung (ITG) Dresden "Wirtschaftlichkeit von Systemen zur Erfassung und Abrechnung des Wärmeverbrauchs", Dresden 2014, Section 3.1.5, Table 1, based on figures provided by the Arbeitsgemeinschaft Heiz- und Wasserkostenverteilung e.V..

⁵⁰ The service normally includes answering tenants' queries about the information they are provided, however, the extent of coverage is not clear from the published material.

Installation in place	Necessary extension	Yearly cost of (at least) monthly information service
Remotely readable devices Gateway + communication	-	12€ (per dwelling) or 36€ + 4*dwelling (per building)
Remotely readable devices	Gateway + communication	12-24€ (per dwelling)
Electronic device without remote reading	Replacement/Upgrade of devices Gateway + communication	18-30€ (per dwelling) ⁵¹
Evaporators	Remotely readable devices Gateway + communication	up to 36€ (per dwelling)

To minimise costs, replacement should ideally take place with end-of-life of devices. The above cost ranges are based on that assumption. Radiators prepared for evaporates can be easily upgraded to remotely readable devices without any further cost. Costs for distribution/communication of sub-annual consumption information on non-electronic media (e.g. paper) to individual units opting for/requiring that are not included in the above estimates and would be additional.

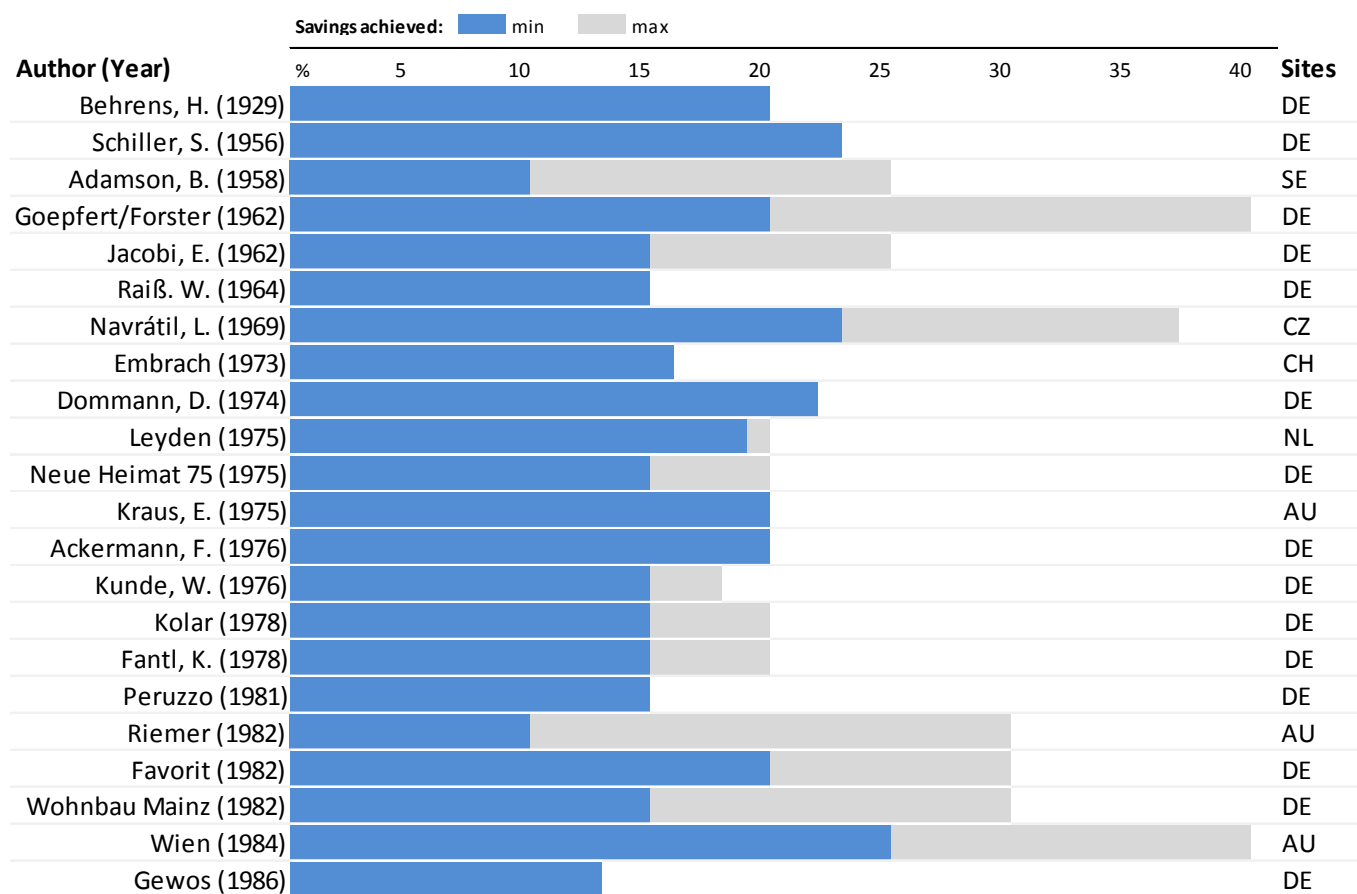
11.4 Appendix 4 Evidence base - sources and future development

Study baseline

Exhibit 4 lists the studies used to compile the evidence base of energy savings achieved through introducing consumption based cost allocation for space heating⁵². The studies selected used before-after and control group techniques to isolate behavioural changes from other influences on changes in energy consumption. Control groups were matched with experimental groups, e.g. by using buildings of the same type often in one residential area. Some studies extended over several years.

⁵¹ See also EcoFys (2015) Die Rolle von Submetering im Kontext von Energieeffizienz und Smart Meter Rollout

⁵² This information is drawn from Oschatz, B (2004) Heizkostenerfassung im Niedrigenergiehaus, BBSR Heft 118

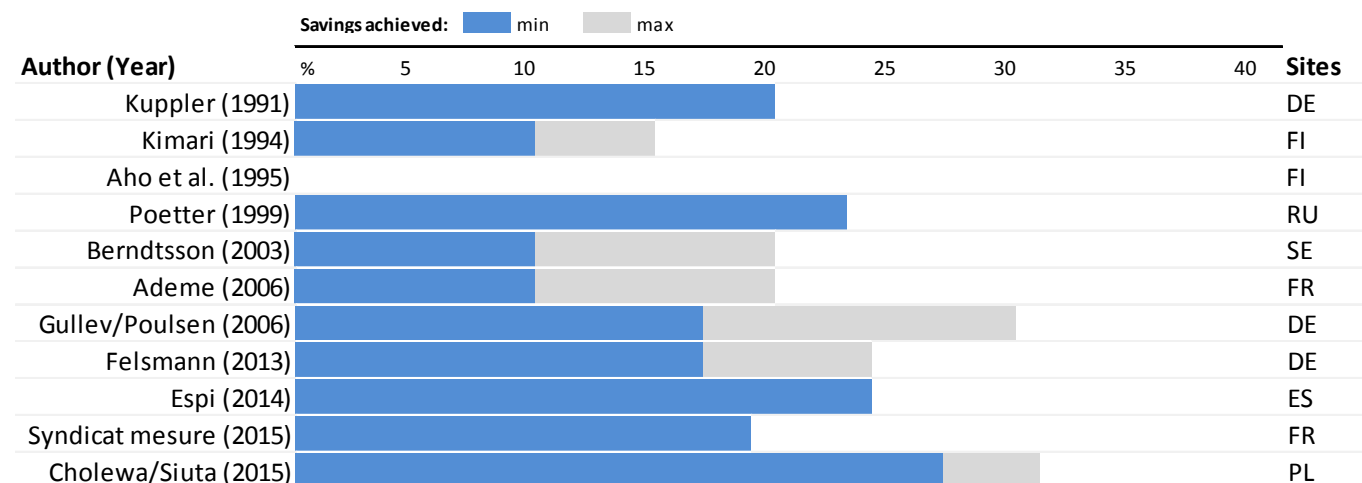
Exhibit 4 – Results of studies in the evidence base for the behavioural impact of consumption-based cost allocation**References:**

- Behrens, H. (1929) Der Bau und Betrieb von Zentralheizungen
 Schiller, S. (1956) Untersuchungsergebnisse mit Wärmemessern (Heizkostenverteilung) bei Zentralheizungen
 Adamson, B. (1958) Wärmeverteilungszählungen in Wohnhäusern
 Goepfert, Forster (1962) Herstellungs- u. Betriebskosten sowie Art der Betriebskostenabrechnung von Zentralheizungen
 Jacobi, E. (1962) Vertretbare u. erreichbare Heizungsbetriebskosten im Wohnungsbau; Bu Bau B 1., Heft 2/1962
 Raiß, W. (1964) Einsparung an Heizenergie durch wärmedichtes Bauen und Wärmeverbrauchsmessung
 Navrátil, L. (1969) Versuche und Erfahrungen mit Wärmemessern in der CSSR
 Leyden (1975) Unterlagen Clorius AG
 Dommann, D. (1974) Einfluss der Pauschalabrechnung und der Verwendung von Heizkostenverteilern auf Energieverbrauch und Heizkosten bei Fernwärmeversorgung aus einem Zweileiternetz
 Embrach (1973) Unterlagen der Wärmezähler AG
 Neue Heimat 75 (1975) Heizungs- und Warmwasserkosten und ihre Abrechnung
 Kraus, E. (1975) Erfahrungen mit der Wärmemessung und -abrechnung auf Basis von Heizkostenverteilern im Bereich der Wohnungsanlagen der Stadt Wien
 Ackermann, F. (1976) Erfahrungen mit einer Verbrauchsvariante der Fernwärmeabrechnung
 Kunde, W. (1976) Energieeinsparung durch rationelle Wärmezeugung und objektbezogene Wärmeabrechnung
 Kolar (1978) Fernwärme und End-Energie in Nürnberg; Heizkostenverteiler - optimales Mittel zum Energiesparen
 Fantl, K. (1978) Einflüsse der Heizkostenverrechnung auf den Energieverbrauch
 Peruzzo (1981) Heizkostenabrechnung nach Verbrauch
 Riemer (1982) Verbrauchsabhängige Heizkostenverrechnung
 Favorit (1982) Energieeinsparungen in Demonstrativ-Baumaßnahmen (Hagen) über 7 Jahre
 Wohnbau Mainz (1982) Energieeinsparungen in gesellschaftseigenen Wohnanlagen über 4 Jahre
 Wien (1984) Energieeinsparungen in fernversorgten Wohnanlagen
 Gewos (1986) Durchführung der verbrauchsabhängigen Heizkostenabrechnung und ihre Auswirkung auf den Energieverbrauch

The studies incorporated in the Oschatz analysis (Exhibit 4) are clearly not the most recent available. However, older studies were chosen intentionally in order to maximise the validity of necessary assumptions about the insulation and ventilation properties of the buildings studied.

Savings measured in subsequent studies in the same and different regions are comparable in percentage terms (see Exhibit 5). These percentages cannot, however, be interpreted directly as confirming or modifying the quantitative behavioural components (temperature and ventilation effects) in the evidence base.

Exhibit 5 – Some more recent studies on the behavioural impact of consumption-based cost allocation



References:

- Kuppler, F. (1991) Erste Heizkostenabrechnung nach Verbrauch in Chemnitz, in: Heizungsjournal, 3.NT-Sonderausgabe1991
- Kimari, KTM (1994) Huoneistokohtainen lämmitysenergian mittaus ja laskutus. Kauppa- ja teollisuusministeriö. Energiaosasto. Tutkimuksia D:202. 1994.
- Aho, T., Rantamäki, J. & Sormunen, T. (1995) Huoneistokohtaisen mittauksen ja laskutuksen vaikutus energian ja veden kulutukseen. VTT Tiedotteita 1644.
- Poetter, K.; Pahl, M.H. (1999) Wasser- und Wärmeeinsparung in russischen Wohnhäusern - Ergebnisse des Dubna Projekts, Euroheat&Power - Fernwärme International
- Berndtsson, L. (2003) Individuell Värmemätning i Svenska
- Ademe (2006) Maîtrise de la demande d'énergie par les services d'individualisation du chauffage
- Gullev, L. & Poulsen, M. (2006) The installation of meters leads to permanent changes in consumer behaviour", News from DBDH 3/2006.
- Espí, P. (2014) Estudio de la Implantación de Sistemas Repartidores de Coste de Calefacción en Edificios
- Syndicat de la mesure (2015) L'individualisation des frais de chauffage à l'épreuve des faits; Étude de l'impact des systems sur les consommations d'énergie en résidentiel collectif. Rapport final 12/2015
- Tomasz Cholewa and Alicja Siuta-Olcha (2015) Long term experimental evaluation of the influence of heat cost allocators on energy consumption in a multifamily building. ENERGY AND BUILDINGS 104 (2015) 122&8211;130

Given improvements made in recent decades to the insulation of older building stock, it is now more difficult to arrive at the necessary assumptions about the characteristics of buildings, such as insulation quality, which affect the degree to which the different behaviour changes result in energy saving.

To improve the evidence base, it is recommended that studies considered for future incorporation should meet new standards, ideally delivering reliable results directly in behavioural terms. Delivering results in behavioural terms would require studies to implement some additional monitoring, e.g. of building users' setting of thermostatic devices. Failing this, as a minimum, at least the building characteristics needed to replicate the analysis carried out by Prof. Oschatz should be measured. Such an approach would, however, continue to leave some uncertainty concerning the relative weight of behavioural changes relating to ventilation and heating control.

The new standards should include applying the principles of sound experimental design. Where randomisation is impracticable there should be documented protection against any undue influence on the composition of the control and experimental groups. Given motivation to save in the long run, building users studied must have every reason to believe the change studied is permanent - rather than contingent on their behaviour in the experiment. To avoid bias, the process of identifying and selecting studies for consideration as addition to the evidence base should not be affected by to the magnitude of the effects measured. Studies should be considered regardless of the size of result measured, and in particular, studies should not be ignored which show no effect or an unusually large response. To protect against a positive bias, studies intending to measure behavioural effects could register their purpose prior to performing the study. Were such registration in place, the results of all registered studies and only such should be taken into account⁵³.

The current evidence base supports an approach which not unreasonably assumes that the residents of all buildings assessed are part of an otherwise undifferentiated European population of users of multi-apartment buildings: socio-economic variables have not yet been incorporated into the evidence base. However, there are signs that energy saving behaviour may be linked to income⁵⁴, and therefore the energy savings achieved may vary by the average income in a population. Including socio-economic variables would allow any differences there may be between populations studied and the population to which the results are applied to be compensated for. Future studies might be encouraged to monitor any differences there may be across population subgroups in their sensitivity to the economic and ecological incentives of consumption-based cost allocation. Though this could be valuable for large population segments, at a smaller scale, it remains open to debate whether the cost-effectiveness assessment of a particular building should take account of the characteristics of the particular current users of the building.

⁵³ Best practice by WHO / EMA can serve as orientation here - see http://www.who.int/ictpr/trial_reg/en

⁵⁴ From data from 3.3 million metered dwellings in Germany, Felsmann/Schmidt (2013) found a negative correlation between energy saving behaviour and building quality, which probably indicates a link between socio-economic characteristics - income as ability and willingness to pay for comfort - and energy saving.