ENPER-EXIST

Applying the EPBD to improve the Energy Performance Requirements to Existing Buildings – ENPER-EXIST

WP1: Investigation of alternatives

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ENPER-EXIST project information

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The Energy Performance of Building Directive (EPBD) sets a series of requirements specifically dedicated to existing buildings but the member states are facing difficulties to implement quickly these requirements. The main goal of the ENPER-EXIST project is to support the take off of the Energy performance of building directive (EPBD) in the field of existing buildings.

ENPER-EXIST has 4 main objectives:

1. To de-fragment technical work performed on existing buildings. Indeed actions already launched in CEN to apply the EPBD are de-fragmented but mainly focus on new buildings. On the other hand different projects on certification procedures are going on at the European level but are not coordinated.
2. To de-fragment work on legal, economical and organisational problems such as the analysis of certification on the market, the human capital and the national administrations.
3. To achieve a better knowledge of the European building stock.
4. To define a roadmap for future actions regarding existing buildings.

ENPER-EXIST uses an intensive networking of existing national and international projects to reinforce efforts to solve these issues. It works in close coordination with the Concerted Action set up by Member States to support the application of EPBD. The work program is split in 4 technical work packages in addition to dissemination and management activities.

WP1: Tools application
WP1 analyses how existing buildings are taken into account in technical tools such as CEN standards, national calculation procedures. Recommendations on how to improve the consideration of existing building are be defined.

WP2: Legal economical and organisational impact
WP2 analyses the impact of the certification procedures and regulations of existing buildings on the market, on the human capital and on the national administration. Surveys are carried out in the different member states and recommendations are drawn up.

WP3: Building stock knowledge
WP3 analyses the level of information available in each country regarding the existing building stock. A procedure enabling to refine this information and ways to use the certification procedure as a tool to collect data regarding this stock is developed.

WP4: Roadmap
An overview of possible legal measures for existing buildings is written. Indications are given about alternative strategies to improve on a wide scale the energy efficiency of existing buildings. Possibilities (including pro's and cons) to widen the scope of the EPBD in case of a future revision of the requirements of the directive are described.

A website, newsletters and workshops enable a strong interaction between ENPER-EXIST and different interest groups and a wide dissemination of ENPER-EXIST results. The workshops are organised with the different actors involved in the application of the EPBD.More information on the project website: www.enper-exist.com

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Executive Summary

The CEN working groups have done a tremendous job to deliver a huge amount of EPBD CEN standards to guide the implementation of the EPBD in the member states. Because of lack of time and priority it has been inevitable that most of the working groups had more focus on new than on existing buildings. ENPER Exist has jumped into this gap and has provided assistance to the EPBD CEN standards.

Within ENPER Exist various courses have been taken to provide this assistance:

- The expert knowledge of the participants of the project is used to analyse the most important CEN standards. This has been a desk research.
- The usability of the CEN standards on existing buildings has also been tested in practice in a pilot test which focussed on the gathering of the input data.
- The third practical test has been the performance of some detailed calculations with the CEN standards.
- The knowledge of the developers of existing EP methods for existing buildings (on national level and on EU level) is used to find alternative solutions for gaps which were found in the previous tasks.

This document provides the knowledge gained by the experience of the developers of existing EP methods for existing buildings (on national level and on EU level). Various possible solutions, learned from these existing methods are discussed. These solutions often are a compromise: there are almost always pro’s and con’s to the different approaches. These pro’s and con’s are given. CEN standards on ventilation, lighting, heating systems and hot water systems are considered. This document contains a wealth of experiences and suggestions how to solve possible problems with the assessment of energy use for existing buildings.

The main issues which have been addressed in this report are alternative methods when input data is not available, alternative methods when input data is available but it will take too much time to gather all the details and alternative methods when the situation typical for existing buildings are not addressed by the calculation method for new buildings.

Most alternative methods describe a way to simplify the method and with this reduce the amount of input data. Often the introduction of default values or tables is suggested. The main advantage is that the method is easier usable in practice; the main disadvantage is the loss of accuracy. A method which deals with this in a full extend is the ‘Reduced Data SAP’ method, which uses exactly the same calculation tool as developed for new dwellings (SAP), but with the difference that by using a shell which provides default values, a greatly reduced set of data inputs is required.

The disadvantage of losing accuracy can be discussed. Incorrect measurements or observations are also a potential source of large errors. Using more detailed input data introduces the appearance of accuracy, but it can be questioned if this accuracy is met in practice. Less input means less accurate results, but also less measurement and observation errors. It is important to realise that there is an optimum between these two:

- Too simple approaches will lead to too inaccurate assessment of the energy use of existing buildings
- A too academic approach in fear of losing too much accuracy will lead too input errors which will result in inaccurate results after all.

The study performed with the UK-approach addresses this balance and shows that a simplified approach can indeed result in comparable results to a detailed method.

Because a lot of problems with the assessment of energy use of existing buildings have already been addressed we recommend the developers of EP tools for existing buildings (CEN experts and national experts) to take into account this existing experience. The risk of not using this experience is that the methods will become too academic or, by trying to avoid this, too simple. By running case studies, like the one which is performed for the UK situation, this risk can be reduced.

1. Introduction

Within ENPER Exist a lot of work has been done to test a selection of the most important CEN standards to see if they are suitable for the existing building practice. On various points problems with the methods have come forward and suggestions are given to solve the problems based on the experience of the experts involved in the project.

Beside this expert knowledge, there is also experience within Europe with methods to calculate the energy performance of existing buildings: some countries like Denmark and the Netherlands have developed such calculation methods in the past. Also methods like these have been developed within European projects like SAVE project or within projects on national level. These calculation methods somehow must deal with the problems which have risen to the surface within this project. Because CEN and the national bodies who will develop EP calculation methods on national level can learn from the experiences, we have searched for solutions to some of the problems within these existing methods. This document describes the results of this search.

The following chapters within this document sum up various problems in the CEN calculations and give possible solutions, learned from existing methods. These possible solutions often are a compromise: there are almost always pro's and con's to the different approaches. These pro's and con's are given.

CEN standards on ventilation, lighting, heating systems and hot water systems are considered. To be more precise, problems within the following CEN standards are discussed:

- prEN ISO DIS 13790 (WI 14) "Energy performance of buildings – Calculation of energy use for space heating and cooling"
- prEN 15241 (WI 20/21) "Ventilation for buildings : calculation methods for energy losses due to ventilation and infiltration in commercial buildings"
- prEN 15242 (WI 18/19) "Ventilation for buildings : calculation methods for the determination of air flow rates in buildings including infiltration"
- prEN 15316-4-1 (WI 9) "Space heating generation systems. Combustion systems"
- prEN 15193-1 (WI 13) "Energy performance of buildings – Energy requirements for lighting – Part 1: Lighting energy estimation"
- prEN 15316 3-1 (WI 11) "Domestic Hot water system part 3-1 : characteristics for needs"
- prEN 15316 3-2 (WI 11) "Domestic Hot water system part 3-2 : Distribution"
- prEN 15316 3-3 (WI 11) "Domestic Hot water system part 3-3 : Generation"

2. prEN ISO DIS 13790 (WI 14) “Energy performance of buildings – Calculation of energy use for space heating and cooling”

This chapter describes alternative ways to assess (parts of) the energy use for space heating and cooling.

2.1 Local heating system

Possible problem:

Typical problem in old dwellings having local heating units in only one or two rooms is that these dwellings have very poor thermal comfort but, as a result, also a very low energy consumption. When the local heating units are being replaced by a more up-to-date central heating system (with up-to-date thermal comfort) the energy consumption will most probably increase considerably, thus not being an energy saving measure.

Possible solution for existing buildings:

EPA-W discerns two types of calculations:

1. standard calculation, which is a calculation under standard conditions (e.g. standard interior temperature, number of people present etc.) to determine the energy label
2. advice calculation, which is a calculation under actual conditions (e.g. actual interior temperature, number of people present etc.) to determine an energy saving scenario which is optimally related to the actual energy consumption (and therefore very recognizable for the building owner, e.g. when comparing with measured energy consumption).

For the standard calculation a local heating system (for space heating and/or DHW) is regarded as a simple central heating system with conventional efficiency also taking care of DHW. This implies that the result of the standard calculation is a higher energy consumption than in the actual situation and thus a poorer energy label (a penalty for the out-of-date thermal comfort).

For the advice calculation the intention is to optimally approach the actual energy performance of the dwelling, i.e. a dwelling with poor thermal comfort causing a lower interior temperature than in centrally heated dwellings. Therefore in the advice calculation a comfort correction is applied for dwellings with poor thermal comfort as a result of local heating units in a few rooms. In that case the interior temperature for the locally heated dwelling is set to 1,9 degrees Celsius lower than the centrally heated dwelling. The figure of 1,9 degrees Celsius is a result of research in the Netherlands.

Pro’s of the alternative:

- Poor thermal comfort is taken into account in a simple way.

Con’s of the alternative:

- The calculated energy use is not corresponding with the ‘real energy use’.

2.2 U-value for wall, roof, slap etc.

Possible problem:

It is difficult to know the U-value of existing constructions. It is very difficult and time consuming to detect the actual construction in detail and calculate the U-value.

Possible solution for existing buildings:

Use tabular U-values for typical constructions. Describe typical constructions in buildings from different time period dependent on type of building.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice

2.3 U- and g-value for windows

Possible problem:

It is difficult to know the U- and g-value of existing windows. It is very difficult and time consuming to detect the actual window construction in detail.

Possible solution for existing buildings:

Use tabular U- and g-values for typical constructions. Describe typical window constructions in buildings.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice

2.4 g-values (2)

Possible problem:

Reference to other standards to determine the g-value.

Possible solution for existing buildings:

EPA-W , EPA-ED , [EPA-U , EPA-NR : use contruction or material libraries with (amongst others) g-values.

Pro's of the alternative:

- very simple

Con's of the alternative:

- may be less accurate
- possibly not all constructions/materials are part of the library.

2.5 Transmission heat transfer coefficients: Reduction factor b for adjacent unconditioned spaces

Possible problem:

A lot of information of the unconditioned space needs to be collected.

Possible solution for existing buildings:

EPA-U uses simplified calculation of factor b for adjacent unconditioned spaces:

unconditioned space, adjacent on same level: b = 1 / (1+Uk/10)

unconditioned space, above: b = 1 / (1+Uk/3)

crawl space: b = 1 / (1+Uk)

Where Uk = thermal transmittance of partition construction [W/m2K]

EPA-NR offers both an elaborate calculation and the simplication as shown above.

EPA-W uses comparable simplified calculation:

unconditioned space, adjacent on same level: b = 1 / (1+Uk/5)

Pro's of the alternative:

- simple

Con's of the alternative:

- less accurate. Simplifications are valid for the Netherlands (but analogue simplifications can be made for other MS) .

2.6 Thermal bridges

Possible problem:

Time consuming to collect all data necessary

Possible solution for existing buildings:

EPA-W , EPA-ED , EPA-U all neglect thermal bridges due to complexity.

EPA-NR uses a simplification by increasing the U-value of envelope elements by a constant term:

$H_D = \sum_i A_i.U_{i,corr}$

$U_{i,corr} = U_i + \Delta U_{tb}$

where

*H*D is the direct heat transfer coefficient between the heated or cooled space and the exterior through the building envelope, in W/K;

Ai is the area of element *i* of the building envelope, in m2;

Ui,corr is the thermal transmittance of element *i* of the building envelope, incorporating the

influence of thermal bridges, in W/(m2K);

Ui is the thermal transmittance of element *i* of the building envelope, in W/(m2K)2;

Δ*U*tb is the constant correction term for thermal transmittance of each element of the building envelope, in W/(m²K); the value is a national constant. This quantity is a correction factor taking into account the effect of linear thermal bridges. In the Netherlands, a value of 0.1 W/m2K is used.

Pro's of the alternative:

- Simple

Con's of the alternative:

- Less accurate

2.7 External shading reduction factors

Possible problem:

The calculation method for the external shading reduction factor is time consuming.

Possible solution for existing buildings:

EPA-W : external shading is neglected. Fixed shading reduction factor dependent on orientation (and only for vertical or horizontal surfaces) and fixed obstruction angle of 20 degrees.

EPA-U : default shading reduction factors for three fixed situations: no overhang, overhang type 1 and overhang type 2. Which overhang to chose depends on the dimensions of the overhang

EPA-ED : external shading is neglected.

Pro's of the alternative:

- simple

Con's of the alternative:

- less accurate

2.8 Frame factor

Possible problem:

Determination of frame factor.

Possible solution for existing buildings:

EPA-U : fixed frame factor (=0,75)

Pro's of the alternative:

- very simple

Con's of the alternative:

- less accurate
- value only for the Netherlands (but for other MS an alternative value can be determined)

2.9 Absorption coefficient, Internal heat capacity, external surface heat resistance

Possible problem:

Determination of material or construction characteristics.

Possible solution for existing buildings:

EPA-U : construction / material library

Pro's of the alternative:

- very simple

Con's of the alternative:

- may be less accurate
- not all constructions / materials may be present in library

2.10 Set point temperature

Possible problem:

Determination of set point temperature.

Possible solution for existing buildings:

EPA-W , EPA-ED : fixed set point temperature for entire building (single zone)

EPA-U : fixed set point temperatures depending on type / use of zone

Pro's of the alternative:

- simple

Con's of the alternative:

- less accurate
- value only for the Netherlands (but analogue simplifications can be made for other MS)

2.11 Cooling load in non A/C buildings

Possible problem:

The CEN methodology proposes to calculate the cooling load of the buildings. This means that the building is considered under thermostatic control. This is only the case for A/C buildings. By applying such a technique in non A/C buildings we overestimate the real needs for additional comfort while we pass the message that A/C is necessary at a certain degree. In my opinion this is wrong message and it has to be avoided. In parallel, such a methodology can not take into account the possible contribution of altrenative and passive cooling techniques, while when it accounts for it it serious underestimate it as an A/C building operates at much lower temperature than an non A/C one. Thus, the contribution of passive cooling techniques that may happened at temperatures higher than the set point temperature is not considered

Possible solution for existing buildings:

For N/V buildings use the balance point as an alternative for the classification of the building

Pro's of the alternative:

In my opinion by using the cooling load is wrong message and it has to be avoided. In parallel, such a methodology can not take into account the possible contribution of altrenative and passive cooling techniques, while when it accounts for it it serious underestimate it as an A/C building operates at much lower temperature than an non A/C one. Thus, the contribution of passive cooling techniques that may happened at temperatures higher than the set point temperature is not considered

Con's of the alternative:

- None?

2.12 Input data in general

Possible problem:

Most input data come from other standards (WI18/19, WI 13/WI9/EN envelope). Sometimes not all input are known.

Possible solution for existing buildings:

For residential buildings due to input data problems, in France a modified degree –day method is developed.

For non residential buildings an hourly method to calculate the heating/cooling needs is used (conform the prEN 13790). Various default values and tables are developed. Also a guide book for the expert to facilitate the use of the method is developed

Pro's of the alternative:

- follows the standard as far as possible even if input data are less accurate

Con's of the alternative:

- sometimes less accurate

3. prEN 15241 (WI 20/21) “Ventilation for buildings : calculation methods for energy losses due to ventilation and infiltration in commercial buildings”

This chapter describes alternative ways to assess (parts of) the energy losses due to ventilation and infiltration.

3.1 Design flow rate

Possible problem:

The flow rate is unknown and very hard to estimate.

Possible solution for existing buildings:

Use default flow rates required by building regulations or norms. (Flow rate could also be measured as part of the ventilation inspection. If actual flow rate is lower than required by building regulations or norms use flow rate required by building regulations or norms.)

Pro’s of the alternative:

- Simple to do. Doesn't require measurement of ventilation flow rate as part of the building energy audit.
- Doesn't encourage too low ventilation flow rates.
- These defaults might not be very accurate, but more detailed methods of estimating the flow rate will probably not be much more accurate because the flow rate depends on too many unknown factors (e.g. user behaviour). This approach does not give apparent accuracy.

Con’s of the alternative:

- In some cases too high ventilation flow rates will not be detected by the building energy audit. In the case of larger ventilation systems it will be detected by measurement during the ventilation inspection. But measurement will not detect higher amount of natural ventilation rates.
- Building regulations and norms often relate to a minimum ventilation capacity of the measures, not to a minimum ventilation rate that really has to be present. So the actual ventilation rate can be lower than the required capacity.

3.2 Duct flow losses

Possible problem:

Duct flow loses are unknown. It is unknown where in the system the losses might be.

Possible solution for existing buildings:

Skip the registration of duct flow losses. Duct flow losses has for many years in Denmark been very well controlled as part of putting new systems into operation. Is therefore not usually a problem.

Pro's of the alternative:

- Simple to do.

Con's of the alternative:

- Risk of not detecting duct flow losses with significant influence on the indoor climate in the building. Duct flow losses normally only cost significant extra energy in the case of mechanical cooling.

3.3 Temperature drop in ducts

Possible problem:

Temperature drop in ducts are unknown.

Possible solution for existing buildings:

Skip the registration of temperature drop in ducts. In severe cases record instead the heat loss from ventilation plant or ducts. The temperature drop in ducts is in it self not of interest, but the heat loss from plant or duct might be in special cases e.g. with un-insulated heated ventilation plants or ducts on the roof.

Pro's of the alternative:

- Simple to do.

Con's of the alternative:

- None.

3.4 Flow control and fan power

Possible problem:

Difficult to know the exact lay out and function of the ventilation system and the actual flow, control and power curve of the system.

Possible solution for existing buildings:

Use linear approximation to calculate the power consumption and don't distinguish between the different types of flow control.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- Theoretical loss of accuracy

3.5 Fan Power (2)

Possible problem:

CEN method requires specific input on fan power. These data may not be available in a quick inspection of an existing building.

Possible solution for existing buildings:

In stead of requiring specific input on fan power, the fan power can be bases on default values.

There are various levels of detail possible:

1. Default values for the yearly energy use per m^2 floor area of the building, based on:
   - ventilation principle (exhaust or balanced ventilation)
   - ventilator type (distinction between alternating current or AC/DC)
2. Default values for the yearly energy use per m^2 floor area of the building, based on:
   - ventilation principle (exhaust, balanced ventilation (alternatively including e.g. the presence or absence of heat recovery and/or air cooling)
   - ventilation flow by the mechanical system

Pro's of the alternative:

- The default method is very simple.
- The input parameters are much easier to obtain than the input in the CEN method.
- The input can be obtained by a non-expert.
- Because the input is easy, the change that a mistake is made is less.
- The recognition of efficient ventilator types in the marked is promoted by the alternative system.

Con's of the alternative:

- The alternative method is less flexible: specific systems may not be taken into account. New systems can be taken into account in the default method, but it will take a while before the method is adjusted (the user has to wait on a revision of the standard).
- The method gives only gives a global result, so it will not be 100% accurate.

3.6 Duct length and specific heat loss of ducts

Possible problem:

In an existing building it is hardly possible to determine the duct length and specific heat loss of ducts in an acceptable inspection time.

Possible solution for existing buildings:

In EPA-NR the energy loss by the ventilation system and the air-handling units is neglected.

Pro's of the alternative:

- Simple

Con's of the alternative:

- Less accurate

3.7 Heat exchanger efficiency

Possible problem:

It may be difficult to determine the efficiency for the heat exchanger unit for mechanical ventilation.

Possible solution for existing buildings:

EPA-U uses default values based on the type of heat exchanger.

Pro's of the alternative:

- Simple.

Con's of the alternative:

- It may take some time to determine the default value for a new system on the market.

4. prEN 15242 (WI 18/19) “Ventilation for buildings : calculation methods for the determination of air flow rates in buildings including infiltration”

This chapter describes alternative ways to assess (parts of) the infiltration and ventilation air flow rates.

4.1 General

Possible problem:

The assessment of the ventilation and infiltration rate via the CEN method is too complex. In France this standard is not used.

Possible solution for existing buildings:

A list of default values of flow rate based on sanitary regulation is developed in France. These values are then corrected by a coefficient depending on the type of ventilation system

Pro’s of the alternative:

- simple
- accurate

Con’s of the alternative:

- none

4.2 Level of details

Possible problem:

There are far too many details required by this standard to be able to make an audit and a calculation in practice within a reasonable time in both new and existing buildings. There is no attention on the level of knowledge to be expected by the energy consultants that have to do the building energy audit.

Possible solution for existing buildings:

Limit the number of data required and the detailed differentiation between different systems and controls, by introducing default values for details which are not easy to assess.

Pro’s of the alternative:

- To be able to perform an audit and a calculation of a building with in a relevant time effort.

Con's of the alternative:

- In theory loss of accuracy but not necessarily in practice.

4.3 Calculation of individual zones (rooms)

Possible problem:

Very time consuming to calculate the ventilation in each zone of a building. The problem mainly originates in distinguishing between the infiltration and airing in each zone.

Possible solution for existing buildings:

Assume same infiltration and airing in all zones in a building, if there are no very large and significant differences. Use average values where ever possibly. Only split the building in different ventilation zones if significant different ventilation system or conditions.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice

4.4 Building surface

Possible problem:

Very time consuming to calculate the building surface, especially if for each zone.

Possible solution for existing buildings:

Use floor area instead. Doesn't matter if it is gross or net floor area, but use one that anyhow is used for other purpose.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice

4.5 Infiltration

Possible problem:

Very time consuming to calculate the infiltration from building surface and location, especially if this needs to be done for each zone.

Possible solution for existing buildings:

Use tabular values for infiltration depending on significant parameters as window, wall and ceiling construction and tightening.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice because more detailed calculations are not necessarily more accurate because various influencing factors are unknown, e.g. construction aspects largely determine the amount of infiltration.

4.6 Ventilation rate through infiltration (2)

Possible problem:

The ventilation rate through infiltration is dependent on the airtightness of a building. This might be hard to determine in an existing building.

Possible solution for existing buildings:

In EPA-U this has been solved by discerning three simple categories of airtightness of the building envelope: a closed envelope, an open envelope and a very open envelope. Based on these categories and three categories of building height default values for the nominal ventilation rate through infiltration are given (source of default values: …….).

Pro's of the alternative:

- Only simple measurements necessary (building height)
- Fast
- The determination of the two parameters is simple and therefore the chance for mistakes by the building inspector is decreased,

Con's of the alternative:

- Building inspectors need to have some insight in how to recognize the three categories of airtightness of building envelopes.
- Default values have been determined for Dutch situation. Not known if also applicable for other countries.
- The accuracy of the final result is decreased because of the less accurate determination method.

5. prEN 15316-4-1 (WI 9) “Space heating generation systems. Combustion systems”

This chapter describes alternative ways to assess (parts of) the generation efficiency of combustion systems for space heating.

5.1 Characteristics of boiler

Possible problem:

The data required by the boiler directive to characterize the boiler cannot be obtained in most cases (depending on the boiler age)

Possible solution for existing buildings:

Use default values of characteristics for three different types of boilers: standard, low temperature and condensing

In France a typology of common boilers and corresponding efficiency values has been developed. In the case where the boiler type is unknown one default value is used.

Pro’s of the alternative:

- simple

Con’s of the alternative:

- determination by the expert of the boiler typology
- less accurate

5.2 Additional characteristics

Possible problem:

The method does not take into account sizing, operation and aging of the boiler

Possible solution for existing buildings:

Use correction factors. (In the French approach, these parameters are not taken into account either).

Pro’s of the alternative:

- More accurate

Con’s of the alternative:

- Can the correction factors be determined accurate enough?

5.3 Data for existing heating boilers

Possible problem:

CEN labeling type of data for existing heating boilers is unknown.

Possible solution for existing buildings:

Use tabular data based on type, age and maintenance of the boiler. Use data from more detailed inspection of boiler if available.

Pro's of the alternative:

- Solves the problem of data for existing heating boiler using the same structure as necessary for new heating boilers

Con's of the alternative:

- None

6. prEN 15193-1 (WI 13) “Energy performance of buildings – Energy requirements for lighting – Part 1: Lighting energy estimation”

This chapter describes alternative ways to assess (parts of) the energy use for lighting.

6.1 Determination of installed power

Possible problem:

This task is lengthy as it requires checking all lighting system. Often the information is not available

Possible solution for existing buildings:

A default list of installed power (W/m²) can be determined according to main type of lamps and type of use of zone.

Pro’s of the alternative:

- simple

Con’s of the alternative:

- still relatively lengthy task (not if only type of zone is taken into account)
- the choice has a big impact on results

6.2 Power consumption by auxiliary

Possible problem:

Power consumption of glow switches, coils, controls etc. is unknown. Only relevant if detailed method is used. This does not always makes sense in a simple method, at least not for Danish buildings.

Possible solution for existing buildings:

Use tabular values for different type of systems.

Pro’s of the alternative:

- Solves the problem of power consumption for auxiliary

Con’s of the alternative:

- None

6.3 Daylight factor

Possible problem:

It is difficult and time consuming to calculate the daylight factor. The daylight factor is only of interest where it influences the power consumption for lighting.

Possible solution for existing buildings:

Assume a daylight factor of 2 % if certain conditions are fulfilled e.g. window area, location and type.

Pro's of the alternative:

- Solves the problem of calculating the daylight factor and power for lighting in many often seen typical rooms.

Con's of the alternative:

- Can not cover more special situations related to e.g. window location.
- Don't cover additional power saving due to very large window area.

7. prEN 15316 3-1 (WI 11) “Domestic Hot water system part 3-1 : characteristics for needs”

This chapter describes alternative ways to assess (parts of) the energy needs for domestic hot water.

7.1 Domestic hot water consumption

Possible problem:

Domestic hot water consumption is unknown. Domestic hot water consumption is seldom measured.

Possible solution for existing buildings:

Use standard values dependent on building type and floor area.

Pro’s of the alternative:

- Solves the problem of data for domestic hot water consumption.

Con’s of the alternative:

- Don't detect the actual domestic hot water consumption.

8. prEN 15316 3-2 (WI 11) “Domestic Hot water system part 3-2 : Distribution”

This chapter describes alternative ways to assess (parts of) the energy use for distribution of domestic hot water.

8.1 General

In France this standard is not used.

Possible solution for existing buildings:

A distribution efficiency coefficient depending on the type of DHW generation is developed.

Pro’s of the alternative:

- simple

Con’s of the alternative:

- distribution heat losses are not properly considered since characteristics of distribution network are not taken into account
- list of efficiency values is not exhaustive

8.2 Pipe lengths

Possible problem:

Pipe lengths are unknown and difficult to measure.

Possible solution for existing buildings:

Limit the pipe lengths to be measured to only include pipes with significant heat loss e.g. pipes with constant circulation or tracing.

Pro’s of the alternative:

- Simple to do
- Possible in practice

Con’s of the alternative:

- In theory loss of accuracy but not in practice

8.3 U-value for pipes

Possible problem:

Difficult to know the U-value of existing pipe insulation. Difficult and time consuming to detect and calculate the actual U-value.

Possible solution for existing buildings:

Use tabular U-values for typical pipe sizes and insulation thickness.

Pro's of the alternative:

- Simple to do
- Possible in practice

Con's of the alternative:

- In theory loss of accuracy but not in practice

9. prEN 15316 3-3 (WI 11) “Domestic Hot water system part 3-3 : Generation”

This chapter describes alternative ways to assess (parts of) the energy use for generation of domestic hot water.

9.1 General

In France this standard is not used. A generation efficiency coefficient depending on the type of DHW generation is developed.

Pro’s of the alternative:

- simple

Con’s of the alternative:

- less accurate
- list of efficiency values is not exhaustive

9.2 Heat loss from boiler

Possible problem:

Difficult to know the heat loss from boilers. Difficult (if not impossible) to calculate the actual heat loss.

Possible solution for existing buildings:

Use tabular values for heat loss from boilers dependent on boiler type and sizes and insulation thickness.

Pro’s of the alternative:

- Simple to do
- Possible in practice

Con’s of the alternative:

- None

10. Umbrella approach: UK-experience (SAP-RDSAP)

The previous chapters have looked at alternative solutions for different parts of the EP calculation which are difficult to use for existing buildings. These parts are simplified or sometimes even totally different alternative methods are suggested. In stead of changing parts of the calculation method for existing buildings separately it is also possible to keep the calculation method unchanged and use a shell around the method which allows for a reduced amount of input data.

This approach has been chosen in the UK (at least for England and Wales): The approach proposed for energy rating existing dwellings in the UK is to use the same calculation tool already developed for new dwellings, but with the difference that a greatly reduced set of data inputs is required. The intention is that the reduced data requirement will enable the following:

- The assessment time and hence cost can be kept to a reasonable level.
- The expertise demanded of assessors will be compatible with the potential pool of people wishing to become assessors and the scope of training programmes that can realistically be put in place.
- Last, but by no means least, the results will be less prone to data input errors and hence achieve better repeatability.

There is a general belief amongst modellers that the more comprehensive and complete a model is then the more reliable will be its predictions. Particularly as the computational facilities available to modellers have increased so too has the tendency to develop ever more complex representations of the situation. However it is not self obvious that the more comprehensive and complex model will actually result in a better performance - in the sense of giving more reliable predictions of building performance.

It is fairly well known that when the same building is analysed by different models a significant variation in predicted energy consumption results. It is also known that when a number of people familiar with a model enter the same building then another large variation in results occurs. The second case is more problematic since with the same building and the same computer model the variation is entirely due to differences in the data input. The differences in data input are due to either differences in interpretation, or measurement error or keyboard error - or some combination of all of these. Inevitably, the reliability of a data set decreases as more data is required from the user.

To investigate if this approach is workable for existing buildings, to see what possible difficulties might arise and to see whether the approach for existing buildings will lead to comparable results related to the more comprehensive method, a study has applied the UK energy rating methodologies for both new and existing dwellings to 4 existing dwellings. Details of the two methods (SAP and RDSAP) are descriped in annex A of this document. In this annex also a description and the results of this study are presented.

The main conclusion from the study are the following (putting to one side whether the evidence from such a small sample of the housing stock can be generalized):

1. With considerable care and attention to detail, it is likely that the results from the two approaches will be close.
2. The reduced set of data inputs does seem to strike a reasonable balance between capturing sufficient detail to enable a reasonably representative energy rating, while minimizing data capture requirements to a practical level.
3. Keyboard data entry human errors are inevitable even with a greatly reduced number of data entries. Quality control for such errors is possible but tedious.
4. Incorrect measurements or observations are also a potential source of large errors. Quality control is expensive as it generally would require an expert assessor to duplicate the assessment.
5. Especially for more complex properties, obtaining even the reduced set of data inputs can be a time-consuming task. Constraints on the time available for assessors to complete an assessment will impact directly on the reliability of the assessment and the accuracy of the final Energy Rating band attributed to the property. In this exercise the authors have invested 1 person day or more on the assessments of each property, whereas an inspector is unlikely to be able to spend more than one hour.
6. The real test will come when home energy ratings become statutory in England and Wales and assessments of existing dwellings begin to be conducted for real on a mass scale.

11. Conclusions and recommendations

Conclusions

There is a lot of experience with tools for existing buildings. The main issues which have been addressed in this report are:

- Alternative methods when input data is not available.
- Alternative methods when input data is available but it will take too much time to gather all the details.
- Alternative methods when the situation typical for existing buildings are not addressed by the calculation method for new buildings

Besides this last issue, which often needs a different approach for existing buildings compared to new buildings, most alternative methods describe a way to simplify the method and with this reduce the amount of input data. Often the introduction of default values or tables is suggested. The main advantage is that the method is easier usable in practice; the main disadvantage is the loss of accuracy. Another disadvantage can be that by using other methods for assessing parts of the energy use for existing buildings, the results for new and existing building will be different due to the use of different methods. Because new buildings become existing buildings soon, this is hard to explain to the marked. An approach to deal with this is suggested in the UK, where exactly the same calculation tool developed for new dwellings is used for existing buildings, but with the difference that by using a shell which provides default values, a greatly reduced set of data inputs is required. It might seem that this approach will not address situations which are typical for existing buildings, but this can be solved by extending the main method with these aspects. In this way the main method exists of a comprehensive calculation structure, for new buildings as well as for existing buildings a shell is used to incorporate default values and to close down routes which are not relevant for existing buildings.

The disadvantage of losing accuracy can be discussed. Incorrect measurements or observations are also a potential source of large errors. Using more detailed input data introduces the appearance of accuracy, but it can be questioned if this accuracy is met in practice. Less input means less accurate results, but also less measurement and observation errors. It is important to realise that there is an optimum between these two:

- Too simple approaches will lead to too inaccurate assessment of the energy use of existing buildings
- A too academic approach in fear of losing too much accuracy will lead too input errors which will result in inaccurate results after all.

The study performed with the UK-approach addresses this balance and shows that a simplified approach can indeed result in comparable results to a detailed method.

Recommendations

Because a lot of problems with the assessment of energy use of existing buildings have already been addressed we recommend the developers of EP tools for existing buildings (CEN experts and national experts) to take into account this existing experience. The risk of not using this experience is that the methods will become too academic or, by trying to avoid this, too simple. By running case studies, like the one which is performed for the UK situation, this risk can be reduced.

This document contains a wealth of experiences and suggestions how to solve possible problems with the assessment of energy use for existing buildings. The scope of this document is not large enough to go into too much detail. When developers of existing building energy assessment methods want to know more about the suggestions given in this document, the formula structures self are probably the best source. The formula structures of EPA-ED can be found on www.epa-ed.org. The formula structure for EPA-NR will be available on the internet shortly at www.epa-nr.org. Detailed information about the UK method (RDSAP) can be found on: www.rdsap.info.

12. Sources

Input has been given from the experience from the development of national and European existing EP calculation methods:

- EPA-ED: European EP calculation tool for residential buildings, developed within a European SAVE project (www.epa-ed.org)
- EPA-NR: European EP calculation tool for non-residential buildings, developed within a European SAVE project (www.epa-nr.org)
- EPA-W: Dutch EP calculation tool for residential buildings
- EPA-U: Dutch EP calculation tool for non-residential buildings
- Danish calculation tool for EP calculations for residential buildings
- Danish calculation tool for EP calculations for non-residential buildings
- French EP calculation tool for existing buildings
- Greek experience with calculation of cooling load in buildings
- RDSAP, British EP calculation method for residential buildings (www.rdsap.info)

Annex A: Rating the energy performance of dwellings in England and Wales: Comparison of the methodologies proposed for new and existing dwellings

ENPER EXIST

WP1: Tools and Standards

Rating the energy performance of dwellings in England and Wales:

Comparison of the methodologies proposed for new and existing dwellings

Draft Report

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A. Executive Summary

The Energy Performance of Buildings Directive (EPBD) requires, inter alia, all existing buildings to be given an energy performance rating when they are sold or let. The approach proposed for energy rating existing dwellings in the UK (at least for England and Wales) is to use the same calculation tool already developed for new dwellings, but with the difference that a greatly reduced set of data inputs is required, other inputs being assumed by the model at default values dependent on, for example, the age and type of property. The present study has applied the UK energy rating methodologies for both new and existing dwellings to 4 existing dwellings (more or less selected at random) and analysed the difficulties arising and the differences in the results. The assessments were undertaken by energy experts who also lived in the dwellings concerned and thus had an intimate knowledge of their characteristics.

Putting to one side whether the evidence from such a small sample of the housing stock can be generalized, the main conclusions are:

1. With considerable care and attention to detail, it is likely that the results from the two approaches will be close.
2. The reduced set of data inputs does seem to strike a reasonable balance between capturing sufficient detail to enable a reasonably representative energy rating, while minimizing data capture requirements to a practical level.
3. Keyboard data entry human errors are inevitable even with a greatly reduced number of data entries. Quality control for such errors is possible but tedious.
4. Incorrect measurements or observations are also a potential source of large errors. Quality control is expensive as it generally would require an expert assessor to duplicate the assessment.
5. Especially for more complex properties, obtaining even the reduced set of data inputs can be a time-consuming task. Constraints on the time available for assessors to complete an assessment will impact directly on the reliability of the assessment and the accuracy of the final Energy Rating band attributed to the property. In this exercise the authors have invested 1 person day or more on the assessments of each property, whereas an inspector is unlikely to be able to spend more than one hour.
6. The real test will come when home energy ratings become statutory in England and Wales and assessments of existing dwellings begin to be conducted for real on a mass scale.

A1. Introduction

The Energy Performance of Buildings Directive (EPBD) requires, inter alia, all existing buildings to be given an energy performance rating when they are sold or let. Until now, energy assessments of existing buildings have generally been undertaken for existing occupiers by energy survey methods: examining how much energy the building uses, investigating what the energy is used for and analysing potential energy saving measures. The EPBD requirement is more to inform a potential new occupier about the intrinsic energy efficiency of the building and hence, it has been concluded, should be based on a standardized calculation of energy performance, assuming standard occupancy and use. Furthermore, since the energy performance of a new building can only be predicted by calculation, in order to be able to compare new and existing buildings on the same basis, a calculation tool must be used for both.

Many calculation tools have been developed for designers to analyse the energy performance of new buildings. Here more time and expertise is available for such exercises and full information about the building is readily available. The challenge is therefore to create a tool suitable also for existing buildings where the resources available are highly cost constrained and at the same time the information required is potentially harder to obtain. For dwellings, in particular, this creates the need for an energy rating tool which is both cheap and reliable to use, suitable for application in a new mass market, and readily used by assessors who typically will have to be trained from scratch.

The approach proposed for energy rating existing dwellings in the UK (at least for England and Wales) is to use the same calculation tool already developed for new dwellings, but with the difference that a greatly reduced set of data inputs is required. The intention is that the reduced data requirement will enable the following:

- The assessment time and hence cost can be kept to a reasonable level.
- The expertise demanded of assessors will be compatible with the potential pool of people wishing to become assessors and the scope of training programmes that can realistically be put in place.
- Last, but by no means least, the results will be less prone to data input errors and hence achieve better repeatability.

There is a general belief amongst modellers that the more comprehensive and complete a model is then the more reliable will be its predictions. Particularly as the computational facilities available to modellers have increased so too has the tendency to develop ever more complex representations of the situation. However it is not self obvious that the more comprehensive and complex model will actually result in a better performance - in the sense of giving more reliable predictions of building performance.

It is fairly well known that when the same building is analysed by different models a significant variation in predicted energy consumption results. It is also known that when a number of people familiar with a model enter the same building then another large variation in results occurs. The second case is more problematic since with the same building and the same computer model the variation is entirely due to differences in the data input. The differences in data input are due to either differences in interpretation, or measurement error or keyboard error - or some combination of all of these. Inevitably, the reliability of a data set decreases as more data is required from the user.

The present study has applied the UK energy rating methodologies for new and existing dwellings to 4 existing dwellings (more or less selected at random) and analysed the differences in the results. The assessments were undertaken by energy experts who also lived in the dwellings concerned and thus had an intimate knowledge of their characteristics.

A2. Overview of Methodology

A2.1 The Standard Assessment Procedure

The Standard Assessment Procedure (SAP 2005) is adopted by the UK Government as the methodology for calculating the energy performance and Energy Efficiency Rating of new dwellings (up to 450 m^2 floor area) in England and Wales. The SAP rating is used to fulfill the requirements of the UK Building Regulations to display an energy rating in new dwellings and to meet the requirements of the Energy Performance of Buildings Directive (EPBD) with respect to new dwellings.

The SAP model is based on the BRE Domestic Energy Model (BREDEM), which provides a framework for the calculation of energy use in dwellings. The procedure is consistent with the European standards BS EN 832 and BS EN ISO 13790.

The SAP rating is based on the energy costs associated with space heating, water heating, ventilation and lighting, less the cost savings from energy generation technologies. It is adjusted for floor area so that it is essentially independent of dwelling size for a given built form. The SAP rating is expressed on a logarithmic scale of 1 to 100, the higher the number the lower the running costs. The SAP methodology also calculates an Environmental Impact Rating based on the CO_2 emissions associated with the same set of energy uses and expresses this on another 1 to 100 scale, the higher the number the lower the CO_2 emissions.

The calculation takes into account a range of factors that contribute to energy efficiency:

- materials used for construction of the dwelling
- thermal insulation of the building fabric
- ventilation characteristics of the dwelling and ventilation equipment
- efficiency and control of the heating system(s)
- solar gains through openings of the dwelling
- the fuel used to provide space and water heating, ventilation and lighting
- renewable energy technologies.

The calculation is independent of factors related to the individual characteristics of the household occupying the dwelling when the rating is calculated, for example:

- household size and composition
- ownership and efficiency of particular domestic electrical appliances
- individual heating patterns and temperatures.

Ratings are not affected by the geographical location, so that a given dwelling has the same rating in all parts of the UK.

A2.2 Reduced Data SAP

'Reduced Data' SAP (RDSAP) has been developed for government for use in existing dwellings based on a site survey of the property, when the complete data set for a SAP calculation is not available. It has been developed to allow a rapid yet accurate assessment of the energy performance of an existing home. It consists of a system of data collection, together with defaults and inference procedures, which generate a complete set of input data for the SAP calculation.

RDSAP forms part of SAP 2005 and provides a methodology for existing dwellings that is compliant with the EPBD. It will thus be the principle vehicle for generating energy ratings and thus energy certificates for existing housing in England and Wales (and possibly Scotland and Northern Ireland).

While the methodological framework for RDSAP is now complete, its development is still so recent that approved software for generating RDSAP scores are not yet commercially available, and even training courses are currently only ‘provisional’, pending the development of an official approvals process later in 2006.

A2.3 Brief Description of Reduced Data SAP

A full list of data input requirements for the RDSAP procedure is presented in the Appendix. The following provides a brief overview of the key inputs into RDSAP. From these inputs the RDSAP model calculates average annual space and hot water heating requirements, along with electricity required for lighting, ventilation and running any pumps or other equipment associated with the heating system.

(1) Property Thermal and Heat Loss Characteristics

Eleven age brackets are defined in RDSAP, and these age brackets are used to determine a wide range of building characteristics including window and door areas, wall and floor U-values, roof U-values (where insulation levels cannot be measured), and the degree of thermal bridging. These default values are derived from the building regulations and construction trends typical of the time of construction.

A range of retrofitted insulation measures can be specified, such as cavity insulation, internal and external wall insulation, additional roof insulation, and double glazing. Additionally a limited number of ‘extensions’ and ‘additional wall areas’ can be detailed, to allow for the different construction and thermal characteristics of structural elements that have been more recently been added or differ sufficiently from the main house.

Simple measurements of the floor area and heat loss perimeter (for each storey) are required. Default values are used to translate ‘external’ measurements into the necessary ‘internal’ dimensions, again based on age bracket (and typical known wall thicknesses of the time). Internal wall measurements are not required. For flats and maisonettes, wall perimeters to unheated corridors are recorded separately, and the temperature of this unheated space assumed to lie between outside and internal temperature.

The number of habitable rooms is counted – excluding kitchens and bathrooms. The main living room area, required by full SAP, is estimated in RDSAP from the property age, floor area and number of rooms.

Glazed area is calculated by the model based on property age and total floor area. An assessor has the option to specify where glazed area is obviously ‘more than average’ or ‘less than average’ for the given property type (for instance where glazed patio doors have been fitted to replace a wooden door or window). Double glazing can be specified, including whether it is pre- or post-2002 (the biggest determining factor in glazing U-value).

Note on conservatories

Perversely (in ESD’s opinion), conservatories (even if heated) are exempt for the purposes of an RDSAP assessment, unless they are openly joined to the main house. Where there is a door between the conservatory and the main house (even for instance a simple single glazed internal door), conservatories are ignored from the assessment. Since many properties in the UK have heated conservatories that have been built as essentially low cost extensions (most conservatories are exempt from planning permission), this seems to represent a significant lost opportunity to reflect true heating costs and CO2 impacts to occupants.

(2) Heating and Hot Water Systems

As for a full SAP assessment, ‘lifestyle’ elements that relate to how an occupier might choose to heat the property are excluded from the RDSAP assessment. Thus only fixed main and secondary heating systems are included, and all portable heaters (such as electric fan heaters and paraffin heaters) are neglected. An assessment must be made of what the secondary heating system might be, and default values assume the ratio of total annual heat supplied by each.

Heating systems include the following principle options:

System Type	Fuel Type
• Radiator system • Storage heaters • Room heaters • Underfloor • Warm air	• Gas (mains) • LPG • Oil • Coal • Anthracite • Smokeless • On-peak electricity • Off-peak electricity

Table 1: Main heating system types

A range of further options are available such as district heating and ground source heat pumps. For boilers, make, model and boiler ID are recorded and referenced against the UK’s extensive SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) database to determine seasonal efficiency.

(3) Lighting and Ventilation

Ventilation characteristics are estimated by the RDSAP model based on the property’s age. The percentage of low energy lighting is specified (based on the ratio of low energy lamps to the total number of lamps, in fixed light fittings).

A3. Comparison of Properties

This section presents the results of the four different properties, for which full SAP and RDSAP scores were calculated and compared.

A3.1 Highlights

The overview is that the RDSAP scores matched relatively closely with the full SAP scores, as summarised by the table below.

Dwelling	Age	Address and Type	Floor area (m²)	Full SAP Score	RDSAP score	% difference	Energy Cost Rating
1	pre-1900	17 St James Square 2 storey maisonette	183	48	47	-3%	E
2	1930-49	9 Devonshire Road Semi-detached bungalow	125	66	65	-2%	D
3	1950-66	102 Catherine Way 2 storey end of terrace	80	53	55	5%	E/D
4	1967-75	9 Damy Green 2 storey detached house	160	63	64	1%	D

Table 2: Highlights of results on 4 properties

In each case the RDSAP score differed from the full SAP score by only 1 or 2 SAP points (out of 100). In only one case (property 3) did this represent a change of Energy Rating band (from an E to a D). The following table shows the boundaries for Energy Rating bands selected for use in England and Wales.

SAP Rating	Rating band
92 or more	A
81 to 91	B
69 to 80	C
55 to 68	D
39 to 54	E
21 to 38	F
1 to 20	G

Table 3: Energy Rating band boundaries in SAP

A3.2 Limitations of the Analysis

This analysis is a selective ‘snapshot’ of four discrete examples of dwellings and does not represent an exhaustive or rigorous analysis of the merits of RDSAP as compared to full SAP. Rather it should be seen as highlighting a selection of potential issues between the two.

Furthermore, a ‘full SAP analysis’ of an existing house is in the vast majority of cases simply not technically possible. This is because determining with accuracy the true characteristics of constructional elements in an existing dwelling requires an unacceptable level of disruption to that dwelling (for instance, drilling through the wall to check actual brick and cavity thicknesses hidden behind plasterwork and external render). ‘Full SAP’ has been designed for new dwellings, when constructional characteristics are available ‘off-plan’ with a high(er) degree of certainty and reliability.

Therefore, in this analysis, a number of default values have been used in the ‘full SAP analysis’, which are drawn from those derived for RDSAP – for instance, for wall and ground U values, where true U values can only be assumed.

Where possible however, U values have been based on known actual values, or values computed using first principles from British Standards (which would be used in the case of full SAP analyses on new dwellings). Also actual areas of heat loss elements such as windows, doors and walls have also been accurately measured and recorded for the purposes of the full SAP analysis. Full characteristics of ventilation, space heating and hot water systems are also accounted for in full SAP.

Therefore the ‘full SAP analysis’ is likely to give a higher degree of resolution on overall dwelling energy performance in the following areas:

- Ventilation characteristics
- Internal gains (including solar gains and daylighting)
- Window and door areas.
- Constructional characteristics and U values for heat loss elements – especially walls, windows, and heat-loss ground area - where these are either known or can be calculated.

But may simply replicate energy performance characteristics input into RDSAP in the following areas:

- U values for some heat loss areas – especially walls, heat-loss ground area, roof, windows, doors.

A3.3 Results

A3.3.1 Property 1: 17 St James Square

This is a pre-1900 2 storey, 3-bed maisonette, located on the lowest 2 floors of an historic Georgian stone terrace in the centre of Bath.

Type of residential building: single family 2 storey maisonette.

Location: city centre location

Owner (optional): owner occupied.

Year of construction: pre-1900

Total conditioned area (m²): 183

Number of occupants : 4 (3 part-time).

Short description: south facing, 2 storey maisonette, occupying basement and ground floor of 5 storey historic terrace (Grade I listed).

Construction: solid stone (sandstone) construction, solid ground floor, single glazed throughout.

Heating / cooling / ventilation / lighting systems: gas fired central heating, non-condensing floor mounted boiler, insulated hot water cylinder supplied by gas boiler. 11% low energy lighting.

Its full SAP score is 48, with RDSAP score 47, making it in both cases an Energy Rating band E. Key features determining its relatively low SAP score include:

- Solid stone construction, single glazed throughout (Grade I listed (historic) status restricts or prevents certain improvement measures such as internal and external wall insulation and double glazing.)
- Older gas boiler, (assumed) 65% efficiency.
- Large ceiling heights (typical of this age of property), which increase assumed space heating requirement.

<u>Comparison of SAP and RDSAP results.</u>

The 1 point difference between the SAP and RDSAP scores represents only a 3% difference. ESD is still awaiting the full detail of the RDSAP input parameters, which will enable a more detailed comparison. However, the key reasons for the discrepancy are likely to include the following:

- Possible **boiler efficiency** (we have taken the value from a standard input table based on boiler age whereas RDSAP software may use the official known boiler efficiency which may be lower than 65%).

- Possible discrepancy in **window area** between measured area and RDSAP default area (U values of walls and floor tie up with RDSAP quite closely, so windows are the only heat loss elements that could be considerably out).
- Possible discrepancy in U value used for **wall area exposed to unheated corridor**.
- Possible discrepancy in overall dwelling floor area – between measured floor area and that calculated by RDSAP (this is not likely to be large as the same value was used as the input to both models.

A3.3.2 Property 2: 9 Devonshire Buildings

This is a 1930's 3-bed semi-detached bungalow with a part timber framed extension to the rear, plus basement room conversion and room in the roof.

Type of residential building: Single family semi-detached bungalow. **Location**: village location, 3 miles from city centre of Bath, UK. **Owner (optional)**: owner occupied. **Year of construction**: 1935. **Total conditioned area (m²)**: 125 **Number of occupants (approximately)**: 2 adults and 1 infant. **Short description**: south facing, single storey bungalow, pitched roof, with rear extension, conversion of a basement room, and converted room in the roof. **Construction**: Stone cavity construction, retrofitted cavity insulation, tiled roof, double glazed throughout. Rear extension (completed 2006) is part timber frame construction.	**Heating / cooling / ventilation/ lighting systems**: Gas fired central heating, high efficiency condensing combi boiler, fully programmable, supplemented by open (coal) fireplace in living room. 13% low energy lighting. 

Its full SAP score is 66, with RDSAP score 65, making it Energy Rating band D. Key issues affecting its typical to slightly higher than typical SAP score for this age and type of property include:

- Filled cavity walls and double glazing throughout (retrofitted by owner).
- High efficiency condensing gas boiler (90.1%), with full controls.
- Highly insulated rear extension.

<u>Comparison of SAP and RDSAP results.</u>

The 1 point difference between SAP and RDSAP score represents a 2% difference between the two. ESD is still awaiting the full detail of the RDSAP input parameters, which will enable a more detailed comparison. However, the key reasons for the discrepancy are likely to include the following:

- Firstly, this property was quite complex to assess, given that its two 'extensions' and one room in the roof all differ considerably in age and construction characteristics (for instance from filled 1930's cavity wall to modern cavity construction, timber frame construction, and solid brick wall). One of the limitations of RDSAP is that it is difficult to account for this level of constructional detail, and generalizations must be made. (However, this is also one of its strengths, in that assessments can be made quickly, by focusing only on the main elements likely to have the biggest influence on the final score). It is possible that RDSAP has overestimated the heat loss from certain constructional elements.

- In particular the window types varied considerably throughout the house, with different double glazing characteristics depending on age and frame type. RDSAP does not allow for this level of resolution, and only one choice on glazing type can be made. Therefore the property was assumed by RDSAP to have pre-2002 double glazing throughout with a U value of 2.2 W/m2K (even though the large rear patio doors were actually installed in 2006 and have a U value of 1.8 W/m2/K).

A3.3.3 Property 3: 102 Catherine Way

This is a 1950s 2 storey 3-bed end of terrace house, with a small single storey flat roofed extension. It is electrically heated by night storage heaters.

Type of residential building: Single family 2 storey end of terrace house. **Location**: village (country) location 3 miles from city centre of Bath, UK. **Owner (optional)**: owner occupied. **Year of construction**: 1955 **Total conditioned area (m²)**: 80 **Number of occupants (approximately)**: 2 adults, 1 child. **Short description**: east-facing, 2 storey, pitched roof, ex-council house, with small single storey flat roofed 'extension' converted from original coal storage shed.	
Construction: masonry construction, cavity wall, cavity insulation retrofitted, tiled roof, loft insulated with 100mm mineral fibre located at joists, recently installed double glazing throughout. Single storey extension is flat roofed, single brick construction with internal insulation.	**Heating/ cooling/ ventilation/ lighting systems**: Electric storage heating throughout, supplemented by single room heater (log fired stove) located in main living room. No mains gas connection to property. Electric immersion water heating. 64% low energy lighting.

Its full SAP score is 53, with RDSAP score 55, making it Energy Rating band E (according to full SAP) or D (according to RDSAP). Key issues affecting its slightly lower than typical SAP score for this age of property include:

- Electric storage heating, which is expensive compared with gas, and so gives a lower SAP rating than for a similar property heated by gas.
- Electric (immersion) water heating, which again is expensive compared with gas heating.

- The high expense of electric space and water heating have the effect of offsetting certain other measures which have been retrofitted to the property such as cavity wall insulation and post-2002 double glazing.

Comparison of SAP and RDSAP results.

The 2 points difference between the SAP and RDSAP scores represents a 5% difference, which is the biggest of the four properties assessed. ESD is still awaiting the full detail of the RDSAP input parameters, which will enable a more detailed comparison. However, the key reasons for the discrepancy are likely to include the following:

- Note there is still a question as to whether double glazing (post-2002) was assumed in the RDSAP assessment (since the box was mistakenly not ticked on form) – however this would have the effect of giving a lower RDSAP score, rather than a higher one, so it is possible that double glazing was in fact assumed.
- It is possible that window and door areas have been slightly underestimated by RDSAP, particularly in relation to the extension which although small has two external doors.
- The assumed fraction of on-peak electric hot water provision could make a significant difference (full SAP assumes a ratio of 60:40 on-peak:off-peak, which may differ from the ratio used by RDSAP).
- In the case of this property the RDSAP assessment assumes that since the age of the single storey extension was given by the assessor as post-2002, it will conform to current Building Regulations (in terms of U values for walls and flat roof). However, this is in fact not the case. The 'extension' is in fact essentially a 1950's single skin brick construction that has had internal insulation applied to walls and flat roof. The specification by the owner has ensured that U values of these elements are reasonable (0.6 W/m2K for walls and 0.27W/m2K for the flat roof), but these still fall short of the 0.35W/m2K and 0.25 W/m2K that would be required for this structure under current UK Building Regulations. With hindsight this 'extension' should have been described by the assessor as a 1950's single brick construction, with internal insulation applied. This would have resulted in a more appropriate RDSAP default U-value being used, which would have lowered the final RDSAP score.

A3.3.4 Property 4: 9 Damy Green

This property is a mid-1960s detached 2 storey 4-bed family house, with several small single storey extensions.

Type of residential building: single family, detached 2 storey house. **Location**: village/countryside location **Owner (optional)**: owner occupied. **Year of construction**: 1967 **Total conditioned area (m²)**: 160 **Number of occupants (approximately)**: 2 adults, 2 children. **Short description**: north facing, 2 storey, pitched roof, with 2 small single storey flat roofed extensions. **Construction**: masonry construction, filled cavity wall, tiled roof with 250mm insulation at joists, double glazed throughout. **Heating / cooling / ventilation / lighting systems**: gas fired central heating, wall	 mounted condensing gas boiler, supplemented by log fired room heater in living room. Insulated hot water storage supplied by main gas condensing boiler. 72% low energy lighting

Its full SAP score is 63, with RDSAP score 64, making it Energy Rating band D. Key issues affecting its relatively average SAP score for this age of property include:

- Cavity wall construction, much of which has been retrofitted with cavity insulation.
- High level of loft insulation (250mm).
- Relatively high efficiency condensing gas boiler (86%).
- Double glazing in most windows (although pre-2002).
- However, uninsulated floor, and unfilled cavity walls in all 3 of the single storey extensions, offset this.
- This property is also detached which will result in a higher relative heat loss (through walls) than the other 3 dwellings considerably offsetting the effect of other improvement measures.

Comparison of SAP and RDSAP results.

The 1 point difference between the SAP and RDSAP scores represents only a 2% difference. However, since ESD has received for this property a full list of RDSAP input parameters we are able to pinpoint with some accuracy the key areas of discrepancy between the two scores. The following table and graph show the calculated values in SAP and RDSAP for which the discrepancy between the two was >5%.

Section of SAP Analysis	Item Description	Full SAP	RDSAP	Units	% difference
4. Water-heating energy requirements	energy lost from hot water storage	914	1032	kWh/yr	+12.9
9. Space heating requirement	space heating requirement (useful)	20847	18479	kWh/yr	-11.4
3. Heat losses and heat loss parameters	fabric heat loss	343	304	W/K	-11.3
9. Space heating requirement	space heating fuel (main)	21201	18920	kWh/yr	-10.8
10a. Fuel costs - individual heating systems	space heating costs - main system	346	308	£/yr	-10.8
3. Heat losses and heat loss parameters	total fabric heat loss	402	359	W/K	-10.7
3. Heat losses and heat loss parameters	total heat loss	748	668	W/K	-10.7
3. Heat losses and heat loss parameters	ventilation heat loss	86	79	W/K	-7.9
9. Space heating requirement	efficiency of secondary heating system	65	60	%	-7.7
3. Heat losses and heat loss parameters	thermal bridging	59	55	W/K	-7.0
1. Overall dwelling dimensions	total floor area	159	148	m2	-6.6
10a. Fuel costs - individual heating systems	total energy costs	614	574	£/yr	-6.5
7. Mean Internal Temperature	living room area	30	32	m2	+5.6

Table 4: Discrepancies between full SAP and RDSAP for 9 Damy Green, Neston

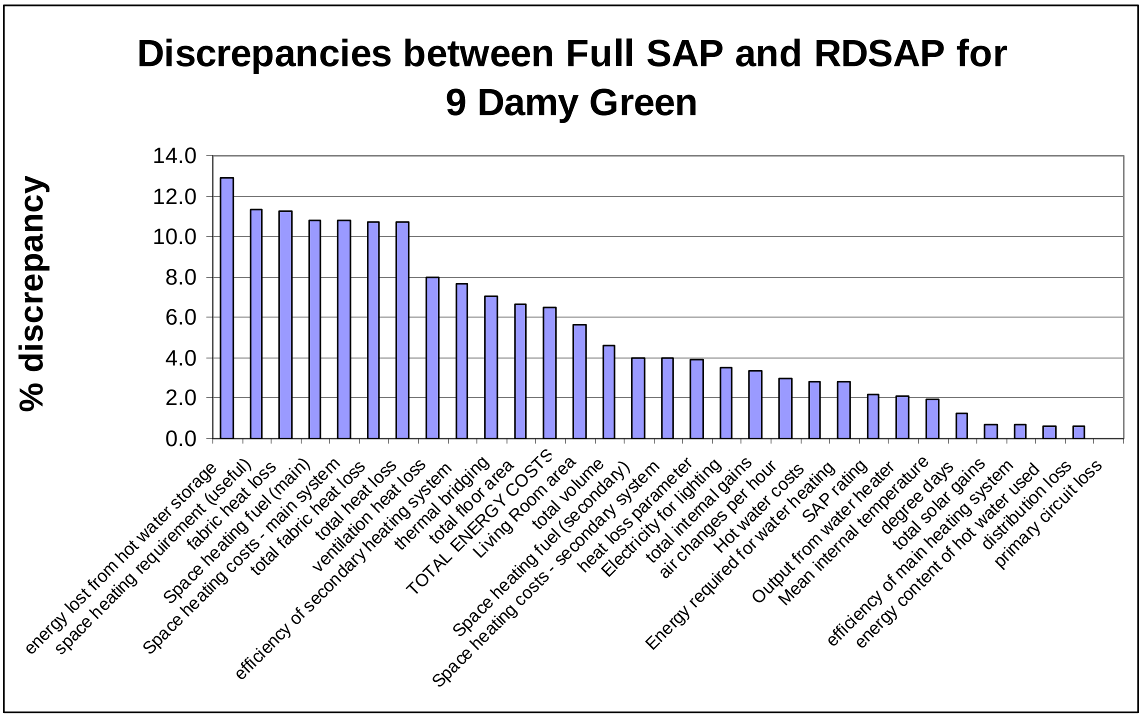

Chart 1: Percentage discrepancies between elements in full SAP and RDSAP for 9 Damy Green, Neston. NB the discrepancies have all been made positive.

Clearly the values with the biggest discrepancies will not necessarily make the biggest difference to the SAP score – in fact they may be relatively small contributory factors to the final score.

The parameters that have led to the biggest discrepancies in the final SAP score include:

- Space heating requirement (which is closely related to):
- Fabric heat loss

These are highlighted red in the above table.

As can be seen from this table, RDSAP has tended to underestimate total fabric heat loss, which has resulted in an underestimate of annual space heating requirements, and consequently an overestimation of the SAP score by 1 SAP point. Closer analysis reveals that this underestimation of fabric heat loss is fairly evenly distributed between window and door areas, walls and roof.

In the case of windows and doors, the error is mostly attributable to a discrepancy between actual and assumed (defaulted) area of windows and doors. Measured (actual) area of these heat loss elements was 40 m², while the RDSAP 'default' window and door area for this size and age of property was only 30 m².

In the case of the roof, RDSAP underestimates the heat loss area again, while errors in U values for different portions of the roof have the effect of canceling each other out. (The roof value of one extension is underestimated by RDSAP, while another is overestimated).

For the walls, U values are generally well represented by RDSAP, but a small discrepancy in wall area leads to a more significant discrepancy in fabric heat loss.

A4. Overview of results

Overall, the convergence between the RDSAP and the SAP results for the four properties studied is relatively high. The authors on the whole have been encouraged by the broad level of agreement between the two models. Given that the core calculation used by both models is the same, the study suggests that the RDSAP approach to data input is capable of achieving a close estimate of the energy performance predicted using the far more detailed and precise data inputs required by the SAP model.

However, one conclusion is that this may simply prove that the RDSAP achieves a close result to the 'full SAP analysis' when a user spends time ensuring their inputs are mutually consistent. Certainly where large discrepancies originally seemed to occur, the 'full SAP analysis' was revisited by the authors to examine possible areas of error, and adjustments were made. It is possible (or even likely) that a conscious or unconscious desire to see the two results converge has influenced the choice of input parameters to the 'full SAP analysis' (where uncertainty necessitated choices) and therefore compromised the objectivity of the exercise.

One important finding is that the authors have invested considerable time in undertaking both the RDSAP and full SAP analyses. Performing a full SAP analysis of an existing dwelling is a complex task which requires a high number of man-hours to complete effectively. Undertaking an RDSAP assessment certainly reduces this time commitment, by focusing only on the key areas that make a real difference to the overall dwelling energy performance. In this sense the methodology can be concluded to be effective.

However, an RDSAP assessment in itself can be a time-consuming task, especially for more complex properties (for instance with multiple extensions, featuring multiple construction types), and in many cases to complete it effectively (and therefore accurately) is likely to take well in excess of the '15 minutes' it was designed to take for the purposes of the England and Wales Home Information Pack. Time constraints arise not only from consideration of the cost of the process; there is also the very real issue of how long an assessor will be welcome in someone's home

The time necessary to complete an RDSAP will impact directly on the reliability of the assessment and the accuracy of the final Energy Rating band attributed to the property. In this exercise the authors have invested 1 person day or more on each SAP/RDSAP analysis, whereas an inspector is likely to take a maximum of an hour. Will the RDSAP methodology be able to deliver Energy Ratings that are cost-acceptable (to owners or landlords) but also sufficiently accurate to be useful and credible?

A4.1 Sources of error

The sources of errors in an RDSAP assessment can be classified as follows:

- **Model errors** – in the core SAP methodology; these are not the subject of this study as they would be common to both SAP and RDSAP calculations.

Errors in defaults used by the RDSAP software; the values might be misrepresentative of the specific building, resulting in erroneous outputs, different from a SAP result.

- **Observational error** – where the RDSAP assessor fails to notice some aspect or detail of the dwelling being assessed; this is more likely for RDSAP where data are collected via a site survey than SAP which is usually based on plans and specifications of the dwelling.
- **Mapping errors** – where the assessor incorrectly transforms what is observed in the dwelling to what has to be entered into RDSAP. This is down to training, experience and expertise. A good quality User Manual should clarify the correct conventions for treating all situations likely to be encountered. However there will always be borderline or ambiguous situations and sometimes the assessor will not apply the correct convention.
- **Measurement errors** – these include both literal measurements and correct identification of, for example, the age of the property, the type of boiler, control system, etc. Such errors are difficult to spot without expensive quality control involving an independent expert visiting the property to take their own full set of 'measurements' for the dwelling.
- **Keyboard errors** – where the assessor collects the correct information but enters the wrong input into the computer. Such simple human errors are unavoidable and inevitably increase in proportion to the number of keystrokes required by the inputs to the model. However, quality control can be applied by a comparison of the inputs to the computer with the original information.

A4.2 Default errors

RDSAP relies heavily on the use of default values, especially for the constructional and insulation properties of principle heat loss areas such as walls, floors, windows, doors and roofs. In many areas these default values are likely to be effective short cuts, given that they are based on detailed knowledge of construction methods and material types used in the UK for property in different age brackets. It is revealing that for one property – 17 St James Square (the pre-1900 3-bed maisonette) – the external stone wall thickness (which varied throughout) was measured for the SAP analysis in all locations and used to calculate a U-value from first principles using the thermal conductivity of sandstone and surface heat transfer coefficients. The resulting average wall U-value for the property was 2.13 W/m²K. The U value default in RDSAP for a solid stone wall in a pre-1900 property is 2.1 W/m²K. It is plausible that the small discrepancy between the two should be considered highly encouraging. However, given the anecdotal nature of a single assessment, it is also conceivable that it could be mere chance.

In other aspects the RDSAP default assumptions may be less accurate. The key areas where discrepancies are most likely to occur include:

- **External and internal insulation** – due to the variations that can occur in thickness and insulant type with internal and external insulation, the RDSAP default values for these measures are likely to be less accurate in many cases than for other wall types. Where internal insulation is applied in just one or a few rooms only it is difficult to represent this in RDSAP.
- **Floor type and U value** – there are only basic categories for floor type and no details are required in an RDSAP assessment (largely because floor coverings generally make this is a difficult parameter to measure).
- **Window areas** – these are computed by RDSAP based on the area and type of the property. Clearly this is a key area where model error could occur.

- **Unheated corridor for flats and maisonettes** – RDSAP assumes that the wall type for an unheated corridor is the same as the external wall type, which can lead to error, especially if the external wall areas have been insulated, but the unheated corridor wall has not. However, the length of unheated wall area is usually small.
- **Main living area size** – this is estimated by RDSAP.

However, it is worth noting that the above parameters, providing the general characteristics of the property have been measured and recorded with accuracy, are unlikely to make more than a few SAP points difference each to the final score. For instance, a 20% error in overall window area is only likely to make 1 or 2 SAP points difference to the final score. A 20% error in the main living area size did not seem to influence the final SAP score in several of our dwelling examples.

A4.3 Measurement/observational errors

What can make a much larger difference to the final score is user error, where an assessor inputs an erroneous value mistakenly or through the mis-identification of a key property characteristic. Some key examples of where the assessor could make a significant error in their inputs include:

- **Mis-identification of a heating or boiler type** – there are a wide range of heating and boiler types and correctly identifying each of them takes considerable skill and experience. For instance, many gas boilers will display their make, and possibly (if you are lucky) their model, but will often not display their model ID (or serial code) that is essential for correctly identifying their seasonal efficiency in the UK's SEDBUK database. Even if the user owns (and can locate) a manual, they are often generalized manuals for four or more serial types, and no records will exist as to which type has actually been installed. Selecting the wrong serial code can make up to a 10 percentage point difference in seasonal efficiency, or more. This will in turn have a significant impact on final RDSAP score for the property (for instance up to 5-8 SAP points or more).
- **Missing the presence of cavity wall insulation** – where a dwelling is of cavity wall construction, and this has been retrofitted with insulation, identifying and accurately recording this will be key to a property's final RDSAP score. Cavity wall insulation can make up to a 10 SAP point difference to a property (e.g. for a detached property where wall-based heat loss is very significant) so it is essential that an assessor is capable of correctly identifying this. However, it can be difficult, particularly where the drilling holes for cavity fill have been subsequently covered over with external render.
- **Incorrectly identifying the age of a property** – clearly since the RDSAP methodology relies so heavily on default values related to property age and type, getting the age right is essential to ensuring that heat loss (and other key) characteristics are accurately represented. An experienced assessor should be able to do this, or alternatively other information sources can be consulted – but constructional and architectural details vary regionally within the UK and can be a misleading guide to property age where only visual clues are used.

A4.4 Keyboard errors

Simple typing errors, or selecting the wrong box, can have a significant impact on the final score – for instance ticking the wrong age, or mis-typing or recording a dimension. An example from this analysis is one of the authors forgetting to tick a box on the RDSAP form to indicate the presence of double glazing, which could make up to 5 SAP points difference for some properties.

However, keyboard errors are far more likely when completing a full SAP analysis of a dwelling. Not only must a user then correctly identify and record all the elements described above, but they must also correctly identify and enter a much larger number of parameters. This is one of the key principles behind the success of the RDSAP methodology as a proxy for full SAP when out ‘in the field’. For instance, in the full SAP analysis of 9 Damy Green, a simple human error in inputting the ‘hot water cylinder loss factor’ (one of around 2-300 inputs required to complete a full SAP assessment, by the time full area measurements have been taken into account), combined with forgetting to enter a cost factor for hot water heating, resulted in an error of 10 SAP points. Correcting these 2 simple data entry errors had the effect of reducing the dwelling’s energy rating from a band C to a band D.

A5. Conclusions

This study has taken four existing dwellings (more or less at random) and analysed each by the SAP and RDSAP methodologies. The assessments were undertaken by energy experts who also lived in the dwellings concerned and thus had an intimate knowledge of their characteristics. Putting to one side whether the evidence from such a small sample of the housing stock can be generalized, the main conclusions are:

1. With considerable care and attention to detail, it is likely that an RDSAP result will be close to that produced by SAP.
2. RDSAP does seem to strike a reasonable balance between capturing sufficient detail to enable a reasonably representative energy rating, while minimizing data capture requirements to a sufficiently acceptable level to be practical.
3. Performing a full SAP analysis of an existing dwelling is a complex task which requires a high number of man-hours to complete effectively. Undertaking an RDSAP assessment certainly reduces this time commitment, by focusing only on the areas that make a real difference to the overall dwelling energy performance.
4. However, an RDSAP assessment in itself can be a time-consuming task, especially for more complex properties. The time necessary to complete an RDSAP will impact directly on the reliability of the assessment and the accuracy of the final Energy Rating band attributed to the property. In this exercise the authors have invested 1 person day or more on each SAP/RDSAP analysis, whereas an inspector is likely to take a maximum of an hour.
5. When the parameters for a dwelling are correctly recorded, the default values used by RDSAP are unlikely to cause substantial errors.
6. Keyboard data entry human errors are inevitable but greatly reduced by the RDSAP methodology due to the much smaller number of entries compared with the full SAP. Quality control for such errors is possible but tedious and therefore never foolproof.
7. Incorrect measurements or observations are a potential source of much larger errors. Quality control is expensive as it generally would require an expert assessor to duplicate the assessment.
8. This study has focused on a model's ability to produce an energy rating for the dwelling (to meet the requirements of the EPBD). Important by-products of this complex task are a robust list of potential measures to improve the rating and the result if they are all implemented. It has been suggested that a different approach might be possible if the objective were solely to identify the cost-effective energy saving measures. The assessment might then consist of a very simple check list of say six measures eg draught proofing, roof insulation, cavity wall insulation, replacement of single glazing, upgrading of heating system controls, replacement of boiler, etc. Such an approach might be more cost effective for social housing.

The real test will come when home energy ratings become statutory in England and Wales and RDSAP assessments begin to be conducted for real on a mass scale.

A.Appendix: Minimum Data Inputs into RDSAP

(Taken from Appendix S of SAP 2005: Full Methodology: http://projects.bre.co.uk/sap2005/)

S12 MINIMUM DATA TO BE COLLECTED

Table S19: Data to be collected

Item	Data	Comment
Built form and detachment	Classification according to S1.	
Age band	According to S2	Identify age band separately for: • main property • age extension • any rooms in roof.
Number of rooms	Number of habitable rooms If half or more of those rooms are not heated, the number of heated habitable rooms	Total as defined in S9, inclusive of main property and any extension. A heated room is one with a heat emitter in the room.
Dimension type	Measured internally or externally	Applies to areas and perimeters. Room heights always measured internally within the room. See S3.
Dimensions	Area, average room height and exposed perimeter for each floor	Measured separately for main property and any extension. For rooms-in-roof, measure floor area only, inside the dwelling.
Non-separated conservatory.	Floor area Glazed perimeter Double glazed (yes/no) Height (number of half storeys of main dwelling)	See section 3.3.3. A separated conservatory is to be disregarded.
Flats and maisonettes	Corridor, one of: • no corridor • heated corridor • unheated corridor	Refers to entrance to the flat.
	If unheated corridor, length of sheltered wall	The length of wall between flat and corridor.
	Floor level (0 for ground floor) and number of floors in block	The lowest floor level of a maisonette.
	Floor is one of: • above heated space • above partially heated space • above unheated space or fully exposed	A heated space below applies when it is above another flat. A partially heated space below applies when it is above non-domestic premises. An unheated space below applies when it is above a space not used for habitation. Where the flat is above more than one type, it is classified according to the largest floor area concerned.
Wall construction	One of: • stone (granite or whin) • stone (sandstone) • solid brick • cavity • timber frame • system build (i.e. any other)	Recorded separately for main dwelling and any extension. 2 stone types in Scotland.
Wall insulation	One of: • external • filled cavity • internal • as built • unknown	Recorded separately for main dwelling and any extension. External, cavity or internal insulation to be indicated only if added subsequent to original construction. If it has only the insulation that was part of the original construction it is 'as built'.
Alternative wall construction (if present)	• Location • Construction (as preceding item) • Insulation (as preceding item) • net area of alternative wall	Location identifies whether part of main wall or an extension wall.
Roof construction	One of: • pitched • flat • another dwelling above	Recorded separately for main dwelling and any extension.
Roof insulation (if not another dwelling above)	One of: • rafters • joists • no access	Recorded separately for main dwelling and any extension.
Roof insulation thickness	One of: • none, 12, 25, 50, 75,100, 150, 200, 250, ≥300 mm, don't know	For roof insulation at joist level and where can be accessed. Recorded separately for main dwelling and any extension.
Windows (of the dwelling only, not including any conservatory)	Area: one of • typical • less that typical • more than typical • much more than typical	'Typical' refers to normal construction for the property type and age band concerned. If assessed as much more than typical, the area of each window should be measured.
	Proportion double glazed.	As percentage
	Double glazing installed, one of: • pre year **xxxx** • during or post year **xxxx** • don't know	**xxxx** is: • 2002 in England and Wales • 2003 in Scotland • 2006 in Northern Ireland

Item	Data	Comment
Fireplaces	Number of open fireplaces	
Main heating system	Fuel for main heating	
	Boiler identification if possible, otherwise system according to Table 4a/4b*	If boiler can be identified, its characteristics are obtained via the SEDBUK system
	Heat emitter type, one of • radiators • underfloor • other	
Main heating controls	Item from Table 4e* according to main system type.	
Secondary heating system	Fuel for secondary heating, and system from room heater section of Table 4a*.	'None' if no secondary heating system
Water heating	Either • from main heating system, or • from secondary system, or • item from hot-water-only section of Table 4a*.	
	Cylinder size, one of: • no cylinder • no access • normal (90-130 litres) • medium (131-170 litres) • large (> 170 litres)	
	Cylinder insulation type, one of • no access • none • jacket • spray foam	
	Cylinder insulation thickness, one of: 0, 12, 25, 38, 50, 80, 100, 150 mm	
	If immersion, whether single or dual.	
	Cylinderstat (yes/no)	
Mechanical ventilation	yes/no, and if yes whether heat recovery	Applies to whole house balanced ventilation system only. Otherwise natural ventilation is assumed. Intermittent extract fans (kitchen and bathrooms) are not a mechanical ventilation system for SAP calculations.
Mains gas available	yes/no	Can be relevant to improvement recommendations
Solar water heating	Solar panel (yes/no)	
Photovoltaic array	yes/no	
Low energy lighting	Percentage of fixed outlets	

Note: **A few heating systems and controls will be omitted, this will be published separately.*