Consultation paper: CONSP:05

Amendments to SAP's lighting calculation

Issue 1.0

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DOCUMENT REVISION LOG

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1. INTRODUCTION

SAP 2012 contains a series of equations to estimate energy use for lighting. The present method calculates a ‘base’ light energy requirement, a function of floor area and number of occupants, based on light being provided by traditional tungsten bulbs, then applies correction factors to account for the proportion of light being provided by low energy lamps, and for the level of available daylighting. It has been suggested that this is too simplistic in the following respects:

- Does not differentiate between different types of ‘low energy lights’
- Does not take account of the provision of excessive (or insufficient) lighting

This document considers options for improving the lighting calculation in these respects. It proposes separate approaches for new build and existing housing, with the aim of balancing the incentive toward greater energy efficiency with the practicality of data gathering.

2. OVERVIEW OF PROPOSED CHANGES

The proposed changes to the SAP lighting calculation affect the correction factor C_1, which is modified to consider the capacity of fixed lighting installed versus a reference requirement, and to top up the provision within the calculation if necessary so that the required level of lighting is always supplied. Conversely, if fixed lighting greater than the requirement is installed, this will now be accounted for in the energy performance of the building. The lighting requirement is expressed as a range so there is enough flexibility to account for different dwelling layouts (open plan / many rooms), dwelling sizes and lighting design choices.

3. EVIDENCE BASE

The existing SAP 2012 equation is based on data from the Energy Follow Up Study 1998 (Ref 1), which was used along with data from DECADE and Electricity Association to derive a lighting demand calculation (Ref 2).

DECC published the results of the Household Electricity Survey (HES) in June 2013. The study monitored 250 dwellings for lighting and appliance use from 2010 to 2011 (Ref 3). It:

- Confirmed that the best indicators of lighting energy demand were treated floor area and occupancy, as are used in the existing SAP equation.
- Found no evidence for the rebound effect (increased lighting demand due to efficiency improvements).
- Provided W/m^2 figures for average installed lighting capacity across the sample.

BRE has also undertaken some additional modelling (see Appendix B) to provide the basis for the thresholds of low and high lighting used in the methodology.

4. PROPOSED CHANGES FOR SAP 2016

The lighting calculation in SAP 2012 begins by calculating the base lighting energy consumption (E_B, kWh/yr) assuming no low-energy lighting is used. It is proposed to use this same starting point, but convert this to a lighting load, rather than an energy load, by multiplying by the efficacy of traditional tungsten lamps. Tungsten lamps are no longer widely available, but this is only used to generate the lighting requirement to which the correct efficacy can then be applied.

The first step of the proposed method for SAP 2016 is therefore to calculate the annual base lighting requirement, Λ_B (klmh/yr):

$$\Lambda_B = 11.2 \times 59.73 \times (TFA \times N)^{0.4714}$$

Where:

- TFA is the total floor area in m^2
- N is the assumed number of occupants
- 11.2 W/lm is the assumed efficacy of traditional tungsten bulbs
- The coefficient and power constants are unchanged from SAP 2012

In SAP 2012 a correction for the level of daylighting in the dwelling, C_2, is then applied. This can vary between approximately 96% and 143% depending on glazing characteristics. It is proposed that this daylighting correction remains unchanged for SAP 2016, except for a change in symbol to $C_{daylight}$ (dimensionless).

The total lighting requirement is subdivided into two parts for further consideration: fixed lighting and portable lighting. The fixed lighting requirement, Λ_{req} (klnh/yr) is assumed to be 2/3rds of the total:

$$\Lambda_{req} = 2/3 \times \Lambda_B \times C_{daylight}$$

The procedure then differs slightly for new and existing buildings as described further below. Portable lighting is treated the same way in both cases.

Portable lighting

The specific lamps to be considered are only those associated with **fixed fittings** within the dwelling (as assumed in SAP 2012). Portable fittings are not assessed as part of the dwelling and so are assigned an average efficacy of 21.3 ln/W[1] in all cases. As in SAP 2012, portable lighting is assumed to account for 1/3 of the total lighting. Therefore the energy required for portable lighting, $E_{L,portable}$ (kWh/yr), is:

$$E_{L,portable} = 1/3 \times \Lambda_B \times C_{daylight} / 21.3$$

This applies to assessments of both new and existing homes.

New Build

Following lighting modelling undertaken by BRE for this purpose (see Appendix B), a reference fixed lighting capacity, CL_{ref} (lm), was defined based upon supplying adequate illumination to all rooms.

$$CL_{ref} = 330 \times TFA$$

A record is made of the number and type of lamps in the dwelling, including rated power (W) and luminous efficacy (lm/W) for each. This data is available from the EU energy rating certificate for light bulbs, or may be inferred (see Appendix A) from energy efficiency class (i.e. the A-G band). The power and efficacy data entered may apply per lamp or per circuit (circuit Watt) if the control gear incurs a significant additional demand (EU energy ratings labels offer default control gear factors). The capacity of the fixed lighting provided, $C_{L,fixed}$ (lm), is calculated as:

$$C_{L,fixed} = \sum (\text{luminous efficacy}_{Lamp} \times \text{Watts}_{Lamp})$$

Note that the efficacy of a fitting would be halved to allow for the light absorbed by any shade or diffuser (see Appendix A).

The average efficacy of fixed lighting provided, ε_{fixed} (lm/W), is calculated as:

$$\varepsilon_{fixed} = C_{L,fixed} / \sum \text{power of fixed lighting outlets}$$

[1] This was the average for all lights derived from DECC's Household Energy Survey

The fixed lighting provision, Λ_{prov} (klmh/yr), is calculated as:

$$\Lambda_{prov} = \Lambda_{req} \times C_{L,fixed} / C_{L,ref}$$

If the capacity of lighting provided is less than required for adequate lighting top-up lighting will be assumed to be used such that sufficient lighting is provided. However, to accommodate different lighting designs and dwelling layouts, a range of installed capacity is allowed for from 110 lm/m² to 330lm/m². Only if the installed capacity is less than the bottom of this range is top-up lighting assumed to be required. The amount of lighting supplied by top-up lighting, Λ_{topup} (klmh/yr), is:

If $\Lambda_{prov} < \Lambda_{req}/3$

$$\Lambda_{topup} = \Lambda_{req}/3 - \Lambda_{prov}$$

If $\Lambda_{prov} \geq \Lambda_{req}/3$

$$\Lambda_{topup} = 0$$

The energy required for fixed lighting, $E_{L,fixed}$ (kWh/yr), excluding the top-up, is then calculated by dividing by the average efficacy of the fixed lighting provided.

If $\Lambda_{req} \geq \Lambda_{prov}$

$$E_{L,fixed} = \Lambda_{req} / \varepsilon_{fixed}$$

If $\Lambda_{req} < \Lambda_{prov}$

$$E_{L,fixed} = \Lambda_{prov} / \varepsilon_{fixed}$$

The energy required for top-up lighting, $E_{L,topup}$ (kWh/yr), is assumed to be provided by lamps of average efficacy (from portable lamps).

$$E_{L,topup} = \Lambda_{topup} / 21.3$$

The total energy required for lighting, E_L (kWh/yr), is the sum of the fixed, top up and portable components:

$$E_L = E_{L,fixed} + E_{L,topup} + E_{L,portable}$$

Worked examples are provided in Appendix C.

Existing Housing

For existing housing, auditing and recording the number and type of fixed lamps in the building may not be practical. Therefore, a generic factor to calculate installed lighting capacity should be applied:

$$C_{L,fixed} = 185 \times TFA$$

185 lm per m^2 of floor area is the average lighting capacity derived from the Household Electricity Survey.

For new homes the precise details of lamp efficacies should be obtainable, but for existing homes this may not be the case. Hence it is acceptable to use the generic figures based on lamp technology (e.g. CFL, LED…) from Table 2 in Appendix A.

Otherwise, the procedure is the same as given for new build above.

5. CONCLUSION

The approach described above for new build is a progression towards meeting a standard of comfort and better reflecting actual lighting energy demand. It builds upon and maintains consistency with the existing SAP lighting calculation.

The proposed amendment affects lighting energy demand and heat gains only. It is based upon a required lighting capacity figure as suggested by modelling (supported by some field data), and lighting demand is still related to TFA and number of occupants; but it allows for the flexibility to accommodate different lighting designs and dwellings of different layouts.

A dwelling may incur higher lighting costs if a greater capacity of lighting is installed than the top end of the reference level for the floor area. Conversely, if the lighting provision is particularly low, the shortfall is assumed to be supplied by portable lighting with typical efficacy.

Existing dwellings are assigned a default installed illumination. This approach recognises the difficulty of recording the lighting specification through survey but otherwise is consistent with the approach for new build.

6. REFERENCES

1. Department of Energy and Climate Change and Building Research Establishment, Energy Follow Up Survey, 1998

2. Building Research Establishment, STP09/AUX01 Review of auxiliary energy use and the internal heat gains assumptions in SAP
   http://www.bre.co.uk/filelibrary/SAP/2012/STP09-AUX01_Auxiliary_energy__use_and_internal__gains.pdf

3. Department of Energy and Climate Change, Household Electricity Survey
   https://www.gov.uk/government/publications/household-electricity-survey--2

4. Come on Labels (EU Contract N°: IEE / 09 / 628) EU Ecodesign and Energy label Regulation for Domestic Lighting
   http://www.come-on-labels.eu/download/new-energy-labelling-legislation-for-light-sources-explained

5. Lighting Europe, Guide for the application of the commission regulation (EU) no. 874/2012 with regard to energy labelling of electrical lamps and luminaires
   http://www.lightingeurope.org/uploads/files/LightingEurope_Guide_-_Regulation_874_2012_ENERGY_LABELLING__Version_1_23_May_2013.pdf

Appendix A – PROPOSED DEFAULT EFFICACIES

There is a lack of data on the most typical ratings for lamps of each type used in a domestic setting. The following proposed default efficacies have been developed from the EU energy labelling guidance (Ref 5), with Lighting Europe guidance on applying the regulations (Ref 6). It is a very broad categorisation – in practice the efficacy as given on the individual lamp energy rating label should be used where available.

Table 1 is calculated from the average of the efficacy required of the energy rating, using a flux range of 300-2000 lumens, and assuming each category achieves the average EEI in the band for that category. Note that the efficacies are calculated including correction for control gear.

Table 1 Proposed default efficacies for lighting energy ratings

Rating	Typical lamp types	Average Lumens/Watt
A++	None at present	146.2
A+	Best LEDs, linear fluorescent, CFLs	94.0
A	Average LEDs, CFLs and least efficient linear fluorescent	66.9
B	Least efficient CFLs and LEDs, best halogen	32.6
C	Least efficient low-voltage halogen	19.6
D	Halogen lamps and best incandescent	15.7
E	Average Incandescent	11.2

From these bands, Table 2 has been derived as reasonable defaults for lamps of each type.

Table 2 Proposed typical luminous efficacy for lamp types

Typical lamp types	Average Lumens/Watt
Linear fluorescent	80.5
LEDs, CFLs	66.9
Halogen LV	26.1
Halogen lamps	15.7
Incandescent	11.2

Appendix B – ESTIMATING REASONABLE LEVELS OF LIGHTING PROVISION

In the method described in this paper, the lighting is compared with a reference capacity based on the floor area. If there is less lighting, additional top-up lighting (of fairly poor efficacy) is assumed to be used to meet the shortfall. The method therefore penalises under-provision of lighting as well as over-provision. Lighting energy can be minimised by providing a level of lighting that falls within the reference band, as well as by the use of efficient lamps.

Within such a method, selecting the right reference level for lighting provision becomes critical. Setting a low reference level could encourage housing developers to provide inadequate lighting levels, and penalise responsible developers who want to build well-lit homes. However, setting too high a reference level could encourage developers to over-provide lighting, and penalise those offering well designed, energy efficient lighting.

This appendix explains how reasonable levels of lighting provision in homes have been established. It is based on examples of lighting designs to meet recommendations for lighting levels (illuminances) in domestic and quasi domestic interiors.

Lighting levels in homes

Guidance on lighting in domestic type interiors is given in the CIBSE 'Lighting Guide 9: Lighting for communal residential buildings' (ref D1) and the SLL Lighting Handbook (ref D2), which include lighting recommendations for different spaces in quasi-domestic buildings. For example, the recommended maintained illuminance, averaged across the working plane, is 100 lux at floor level in corridors and stairs, 150 lux at floor level in lounges, and 150 lux at table height (typically 0.8m) in dining halls, study areas, kitchens and utility rooms.

These values are recommendations for multi-residential buildings like student accommodation occupied by young people. For quasi-domestic buildings where elderly people predominate, particular recommendations are provided by the Pocklington Trust (ref D3) in their Good Practice Guide 5, Good Housing Design – Lighting. This guide recommends higher average illuminances at floor level in different rooms, such as, for example, 100-300 lux in lounges, 200-300 lux in kitchens, 100-300 lux in bathrooms, 100-300 lux in bedrooms, and 100-200 lux in stairs (on treads).

However, existing recommendations may overestimate actual illuminances in private residences. Simpson and Tarrant (ref D4) surveyed 101 homes in Surrey and found median illuminances of 70-80 lux in kitchens, 20 lux at the bottom of the stairs, 30 lux in the hall and 70 lux in the living room. These are well below the recommended values. This study does date from over 30 years ago, and modern lighting practice may well give higher illuminances, for example in kitchens where provision of down-lighting would be expected to result in illuminances above 70-80 lux. Nevertheless it appears that in some situations the good practice guidance may propose illuminances that are above those people would normally expect in their homes. For example the recommended 100 lux for bedrooms may be relevant to old people's homes and student accommodation where such rooms are more likely to be occupied for longer period, but may overestimate lighting provision in typical bedrooms in private residences which are mainly used for sleeping.

<u>Design studies</u>

Lighting design analysis was carried out using specialist lighting design software (Dialux 4.12) for six types of standard dwelling as described in the BRE Report 'Standard dwellings for energy modelling' (ref D5):

- Large detached house
- Small detached house
- Large semi-detached house
- Modern mid-terrace
- Detached bungalow
- Two-bedroom flat

Target average illuminances were chosen for the different spaces in the standard dwellings based on the existing guidance on lighting in domestic type interiors. These illuminances are shown in Table 4.

Table 4 Average maintained illuminance considered for each room type

Room	Living room	Dining room	Kitchen	Utility	Study	Bedroom	Bathroom	Hall	Stairs
Target illuminance	150 lux	150 lux	200 lux	100 lux	200 lux	100 lux	150 lux	100 lux	100 lux
Reference plane	Floor	Table	Worktop	Floor	Desk	Floor	Floor	Floor	Treads

For each room in the six dwelling types several design schemes were considered:

- Design 1: High efficiency scheme consisting only of LED downlights / spotlights, in which light was emitted directly downwards towards the reference plane. The average luminaire efficacy of this scheme was in the range 84-87 luminaire lumens per circuit Watt.
- Design 2: Average to high efficiency scheme consisting of surface mounted LED luminaires with some additional LED downlights / spotlights, in which light was emitted both downwards towards the reference plane and sideways towards walls. The average luminaire efficacy of this scheme was in the range 82-89 luminaire lumens per circuit Watt.
- Design 3: Low to average efficiency scheme consisting of a combination of suspended and ceiling / wall mounted LED luminaires, giving omnidirectional light that reached both the reference plane and room surfaces i.e. walls and ceiling, thus contributing to an improved visual comfort. The average luminaire efficacy of this scheme was in the range 73-80 luminaire lumens per circuit Watt.
- Design 4: Low to average efficiency scheme consisting of a combination of suspended and ceiling / wall mounted fluorescent luminaires, giving omnidirectional light that reached both the reference plane and room surfaces i.e. walls and ceiling, thus contributing to an improved visual comfort. The average lamp efficacy of this scheme was in the range 65-69 lamp lumens per circuit Watt.

Table 5 shows typical examples of luminaire used in the lighting modelling studies for the different types of room.

Table 5 Examples of luminaires used in the design analysis for each room type

Room type	Design 1	Design 2	Design 3	Design 4
Living room, dining room			 	
Kitchen, utility room		 		
Bedroom, study			 	
Bathroom, WC				
Halls, stairs			 	 

Designs 1-3 (fully LED lighting) were considered for all six dwelling types, whereas design 4 (consisting of fluorescent lighting) was only considered for the large detached house and the two-bedroom flat to provide data for the largest and smallest properties in the range considered.

The fluorescent luminaires used in the analysis had a LOR (light output ratio, or the ratio of the luminous flux emitted by the luminaire to the luminous flux emitted by all the lamps that it contains) in the range 0.42-0.58, which are considered typical for this type of luminaire. The fluorescent pendant had a considerably higher LOR of 0.89, but given its direct-indirect distribution, in which around half of the light was emitted upwards, the proportion of useful light reaching the reference plane was estimated to be in the range mentioned above.

<u>Results</u>

Iterative lighting design modelling was carried out in each room until the adequate arrangement of luminaires of the types described above was determined so that the recommendations listed in Table 4 were met. The installed load and luminous flux were noted for each room. For each dwelling and design considered, the total installed load is shown in Table 6 and the summed luminous fluxes installed in all rooms was then divided by the summed areas of all rooms to determine the lm/m^2 values as shown in Table 7.

Table 6 Installed load (expressed in circuit Watts) for each type of dwelling and design scheme

Design scheme	Large detached house	Small detached house	Semi-detached house	Mid-terraced house	Detached bungalow	Two-bedroom flat
1	314	206	177	161	159	131
2	430	305	278	232	217	176
3	562	383	335	323	293	247
4	1271	-	-	-	-	506

Table 7 Reference lm/m^2 value for each type of dwelling and design scheme

Design scheme	Large detached house	Small detached house	Semi-detached house	Mid-terraced house	Detached bungalow	Two-bedroom flat
1	185	177	176	176	200	185
2	245	259	266	264	291	248
3	309	289	292	309	321	325
4	611	-	-	-	-	542

Installed luminous flux is expressed in luminaire lumens for designs 1-3, which fully consist of LED lighting, and in lamp lumens for design 4, which uses fluorescent lighting. As expected, the installed load increased progressively from design 1 to design 4, with average values across all six dwelling types of 191 W, 273 W and 357 W for designs 1 to 3 (all LED) respectively, and 889 W for design 4 (fluorescent). The specific load per unit floor area, averaged across all six dwelling types, also increased progressively from design 1 to design 4, with average values of 2.1 W/m^2, 3.1 W/m^2, 4.0 W/m^2 and 8.6 W/m^2 respectively.

Discussion

The results of the analysis indicate that there is a range of values of lighting provision (in lamp lumens per square metre) that meet the recommended illuminances in domestic interiors. This is due to a combination of factors:

a) More lighting is needed per unit floor area in small rooms. This is because walls absorb some of the light.
b) Luminaires that give omnidirectional light require more lamp lumens for the same horizontal illuminance compared to downlights. This extra light is not necessarily wasted, because it lights the walls and ceiling and can result in a brighter, more attractive interior.
c) Conventional luminaires (tungsten, halogen, compact fluorescent and fluorescent) are fitted with shades or diffusers which block some of the light emitted by the lamp (typically around half). In contrast, in most LED luminaires (fittings) the light source (LED) is an integral part of the luminaire and the lumen output quoted by the manufacturer is the actual amount of light that comes out of the luminaire. (This does not apply to LED bulbs that are intended to be used in conventional

luminaires or lamp shades). In the studies (option 4 for the large detached house and the flat) this results in much higher totals of lamp lumens required to deliver the recommended illuminances.

Recommendations

It is recommended that the SAP methodology adopts a range of values (of lumens per square metre) for good practice lighting provision. If the amount of lighting in the dwelling is within the range, the SAP lighting energy requirement depends only on the efficacy of the lighting provided. If the amount of lighting exceeds the upper limit of the range the lighting energy requirement is proportional to the extra energy use. If the amount of lighting is below the lower end of the range, additional top up lighting (of a lower efficacy) is assumed to be brought in by the occupant, and the lighting energy requirement goes up.

The studies using efficient LED luminaires (options 1, 2 and 3) gave lighting provisions in the range 176 to 325 lumens per square metre. To allow for special cases, it would be appropriate to choose a slightly wider range for lighting provision without penalty for under- or over-lighting: 165 to 330 lumens per square metre. Because these design studies used LED lighting where the lamp is an integral, non-removable part of the luminaire, these values represent luminaire lumens (the total amount of light emerging from the luminaire).

The analysis carried out above assumes that no additional portable lighting is provided. However, the SAP methodology assumes that one third of the lighting is portable. Accordingly it would be appropriate to reduce the lower end of the range to 110 lumens per metre (two thirds of 165) to avoid counting this lighting twice. This results in a range of 110-330 lumens per square metre.

In addition, in calculating the lumens per square metre provision it would be appropriate to take account of the light blocked by shades and diffusers in conventional light fittings. Accordingly it is recommended that in calculating the lighting provision from lamps in conventional fittings, the lamp lumen output (or lamp efficacy) be halved before being input into the total. This applies to all lamps (including LED bulbs) placed inside a fitting of unspecified light output ratio, or where a bare lamp is provided over which the householder would be expected to place a shade.

The calculation method would therefore be as follows:

1. Calculate annual base lighting requirement, Λ_B (klmh/yr)[2]

   $\Lambda_B = 11.2 \times 59.73 \times (TFA \times N)^{0.4714}$

   where TFA is the total floor area in m² and N is the assumed number of occupants

2. Calculate the daylighting correction factor, $C_{daylight}$, as per the current method.

3. Calculate the fixed lighting requirement Λ_{req} (klmh/yr)

   $\Lambda_{req} = 2/3 \times \Lambda_B \times C_{daylight}$

4. Calculate the capacity of the fixed lighting provided, $C_{L,fixed}$ (lm). This is the sum over all fixed lighting outlets of the product of the power (Watts) and efficacy (lm/W) of each outlet. Where a lamp is intended to be placed in a shade or diffuser of unspecified light output ratio (including where a bare lamp is provided), the efficacy is halved to allow for the light absorbed by the shade or diffuser.

5. Calculate the reference fixed lighting capacity, CL_{ref} (lm)

   $CL_{ref} = 330 \times TFA$ (this is the top of the range)

6. Calculate the fixed lighting provision Λ_{prov} (klmh/yr)

   $\Lambda_{prov} = \Lambda_{req} \times C_{L,fixed} / C_{L,ref}$

7. Calculate top-up lighting requirement, Λ_{topup} (klmh/yr)

   If $\Lambda_{prov} < \Lambda_{req}/3$ (only have top up lighting if lighting provision below bottom part of range)

   $\Lambda_{topup} = \Lambda_{req}/3 - \Lambda_{prov}$

   If $\Lambda_{prov} \geq \Lambda_{req}/3$

   $\Lambda_{topup} = 0$

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[2] *lm* denotes lumens; so the unit in this case is '*kilo lumen hours per year*'.

8. Calculate the average efficacy of the fixed lighting provided, ε_{fixed} (lm/W)

   $\varepsilon_{fixed} = C_{L,fixed} / \Sigma$power of fixed lighting outlets

9. Calculate the energy required for lighting

   a. Calculate the energy required for fixed lighting, $E_{L,fixed}$ (kWh/yr)

      If $\Lambda_{req} \geq \Lambda_{prov}$

      $E_{L,fixed} = \Lambda_{req} / \varepsilon_{fixed}$ (if installation is within the 'good practice' range, or below it, energy for fixed lighting does not depend on how much lighting is provided, only on its efficacy. There is no benefit from providing less lighting (or more). There is still a penalty for going below the bottom of the range, see top up lighting in (7) above)

      If $\Lambda_{req} < \Lambda_{prov}$

      $E_{L,fixed} = \Lambda_{prov} / \varepsilon_{fixed}$ (if more lighting is provided than the top of the range, energy for fixed lighting is proportional to installed load. So there is still a penalty for installing too much)

   b. Calculate the energy required for top-up lighting, $E_{L,topup}$ (kWh/yr)

      $E_{L,topup} = \Lambda_{topup} / 21.3$

   c. Calculate the energy required for portable lighting, $E_{L,portable}$ (kWh/yr)

      $E_{L,portable} = 1/3 \times \Lambda_B \times C_{daylight} / 21.3$

   d. Calculate the total energy required for lighting, E_L (kWh/yr)

      $E_L = E_{L,fixed} + E_{L,topup} + E_{L,portable}$

References to Appendix B

D1. CIBSE, 'Lighting Guide 9: Lighting for communal residential buildings', London, 2013.

D2. SLL, 'Lighting Handbook', Society of Light and Lighting, London, 2009.

D3. Pocklington Trust, 'Good Practice Guide 5, Good Housing Design – Lighting', London, 2010.

D4. Simpson J and Tarrant A, 'A study of lighting in the home' Ltg Res & Technol 15 (1) 1-8, 1983.

D5. BRE, 'Standard dwellings for energy modelling', updated August 2012.

Appendix C – WORKED EXAMPLES

All worked examples are for new build housing.

Example 1

A 60m^2 dwelling with more lighting specified than required.

- Existing SAP energy demand E_B (assuming daylighting factor 1) = 568.1 kWh/yr

	Tungsten[3]	**Fluorescent**	**CFL**
Number of bulbs	6	1	17
Efficacy (lm/W)	11.2	80.5	66.9
Circuit Watts/lamp	60	14	14
Installed Watts	360	14	238
Installed Lumens	4,032	1,127	15,922

- $Lumens_{Installed}$ = 21,081 lm *(greater than lighting requirement)*
- $Watts_{Installed}$ = 612 W *(less than tungsten despite greater lighting)*
- Base total lighting requirement = 6,362.79 kLnh/yr
- Total lighting requirement = 6,362.79 kLnh/yr
- Fixed lighting requirement = 4,241.86 kLnh/yr
- Portable lighting requirement = 2,120.93 kLnh/yr
- Reference fixed lighting capacity = 19,800 Ln
- Fixed lighting capacity ratio = 1.06
- Fixed lighting provision = 4,516.34 kLnh/yr
- Top-up lighting requirement = 0 kLnh/yr
- Energy used for fixed lighting = 131.11 kWh/yr
- Energy used for portable lighting = 99.57 kWh/yr
- Energy used for top-up lighting = 0
- Total lighting energy = 230.69 kWh/yr

[3] Tungsten lamps are no longer widely available to use for general lighting use, but this example still illustrates the procedure.

Example 2

A 90m^2 dwelling with less lighting specified than requirement

- Existing SAP energy demand E_B (assuming daylighting factor 1) = 785.3 kWh/yr

	Tungsten	**Fluorescent**	**CFL**
No. bulbs	3	1	3
Efficacy (lm/W)	11.2	80.5	66.9
Circuit Watts/lamp	60	14	14
Installed Watts	180	14	42
Installed Lumens	2,016	1,127	2,809

- $Lumens_{Installed}$ = 5,952 lm
- $Watts_{Installed}$ = 236 W
- Base total lighting requirement = 8,795.78 kLnh/yr
- Total lighting requirement = 8,795.78 kLnh/yr
- Fixed lighting requirement = 5,863.85 kLnh/yr
- Portable lighting requirement = 2,931.93 kLnh/yr
- Reference fixed lighting capacity = 29,700 Ln
- Fixed lighting capacity ratio = 0.2
- Fixed lighting provision = 1,175.3 kLnh/yr
- Top-up lighting requirement = 759.77 kLnh/yr
- Energy used for fixed lighting = 46.59 kWh/yr
- Energy used for portable lighting = 137.65 kWh/yr
- Energy used for top-up lighting = 35.67 kWh/yr
- Total lighting energy = 219.91 kWh/yr

Example 3

A 90m^2 dwelling with 100% LELs.

- Existing SAP energy demand (assuming daylighting factor 1) = 785.3 kWh/yr

	Tungsten	**Fluorescent**	**CFL**
Number of bulbs	0	0	19
Efficacy (lm/W)	11.2	80.5	66.9
Circuit Watts/lamp	60	14	14
Installed Watts	0	0	266
Installed Lumens	0	0	17,795

- $\text{Lumens}_{\text{Installed}}$ = 17,795 lm *(greater than lighting requirement)*
- $\text{Watts}_{\text{Installed}}$ = 266 W *(much less than tungsten despite greater lighting)*
- Base total lighting requirement = 8,795.78 kLnh/yr
- Total lighting requirement = 8,795.78 kLnh/yr
- Fixed lighting requirement = 5,863.85 kLnh/yr
- Portable lighting requirement = 2,931.93 kLnh/yr
- Reference fixed lighting capacity (Ln) = 29,700
- Fixed lighting capacity ratio = 0.60
- Fixed lighting provision = 3,513.45 kLnh/yr
- Top-up lighting requirement = 0
- Energy used for fixed lighting = 52.52 kWh/yr
- Energy used for portable lighting = 137.65 kWh/yr
- Energy used for top-up lighting = 0
- Total lighting energy = 190.17 kWh/yr