Technical Papers supporting SAP 2009

Review of auxiliary energy use and the internal heat gains assumptions in SAP

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Review of auxiliary energy use and the internal heat gains assumptions

Executive Summary

In order to assess the heating energy needs of a home SAP needs an estimate of the amount of heat being provided by sources other than the heating system. In energy efficient homes the heat supplied by incoming solar energy and internal sources of heat gains can meet the majority of the heating load. This makes the assessment of the amount of heat required from the heating system very sensitive to the levels of gains assumed. Given the government's intentions that all new homes should be built to increasingly tough energy efficiency standards it is more important than ever that estimates of internal sources of heat are modelled as well as possible in SAP.

This note reviews the internal heat gains evidence and equations in SAP and proposes improvements that could be made.

The most significant changes suggested are:

- New equations for calculating the energy use of lights and appliances
- The inclusion of previously ignored internal heat losses
- The proposal that a lower level of gains might be used for the calculation of the Dwelling Emission Rate for the purposes of showing compliance with the building regulations

The changes suggested here are put forward as part of the SAP 2009 consultation.

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1 Introduction

In simplified terms SAP [1] estimates the space heating energy requirements of a dwelling as follows:

1. Calculation of the dwelling's specific heat loss (W/°C)
2. Calculation of average internal temperature (°C)
3. Multiply specific loss by difference between internal and external temperature to get heat requirement
4. Calculate heat provided by solar gains and internal heat gains
5. Subtract heat provided by gains from heat required and assume the shortfall is met by the heating system

In the majority of dwellings in the UK the heat provided by solar and internal gains is a small but not insignificant proportion of the total, with the majority of heat being provided by the dwelling's heating system. However, in very well insulated homes the gains can make up the majority of the heating needs. Thus the assessment of the space heating energy required from the heating system becomes very sensitive to the assumptions made about the level of solar and internal heat gains.

Given the intention that new homes are to become very much more efficient over the next decade, it was therefore felt important to review the gains assumptions used in SAP. The assessment of solar gains is physically based and is not likely to have changed significantly over time. On the other hand, the level of internal heat gains is very strongly occupant dependant and is based on rather old data. This note therefore concentrates on reviewing the internal heat gains assumptions of SAP.

Several sources of internal heat gains are considered:

- Metabolic
- Appliances
- Lighting
- Cooking
- Water heating
- Pumps and fans
- Internal heat losses

Each of these is considered in turn in the following sections.

2 A review of typical levels of internal heat gains by source

2.1 Metabolic

The present assessment of metabolic gains is based on the assumption that each occupant emits heat at the rate of 60W on average. 100W is the accepted instantaneous figure for an adult, so the reduction to 60W takes account of the fact that an occupant is likely to be out for some of the time and that some occupants (e.g. children) emit rather less heat.

The review found no evidence for changing the present assumptions on metabolic gains.

2.2 Lights and Appliances

2.2.1 Estimating L&A energy consumption in 1997

The Energy Follow Up Survey (EFUS) to the 1996 English House Condition Survey [2] collected electricity meter readings in 1996 and in 1998, giving a data-set centred around 1997. From this it has been possible to derive a relationship between L&A use and the floor area and occupancy level of the dwelling.

The equations derived for 1997 are as follows.

Total energy used for lights and appliances:

L&A = 263.1*(TFA*Occ)^0.4714

Based on estimates from DECADE [3] and Electricity Association data [4], we believe about 21% of the total was used for lighting (though this figure is uncertain). Therefore, assuming that percentage doesn't vary with floor area and occupancy (it may, but we have no way of knowing) we can derive the following formula for lighting energy:

For lighting:

L = 55.25*(TFA*Occ)^0.4714

Assuming the rest is for appliances:

A = 207.8*(TFA*Occ)^0.4714

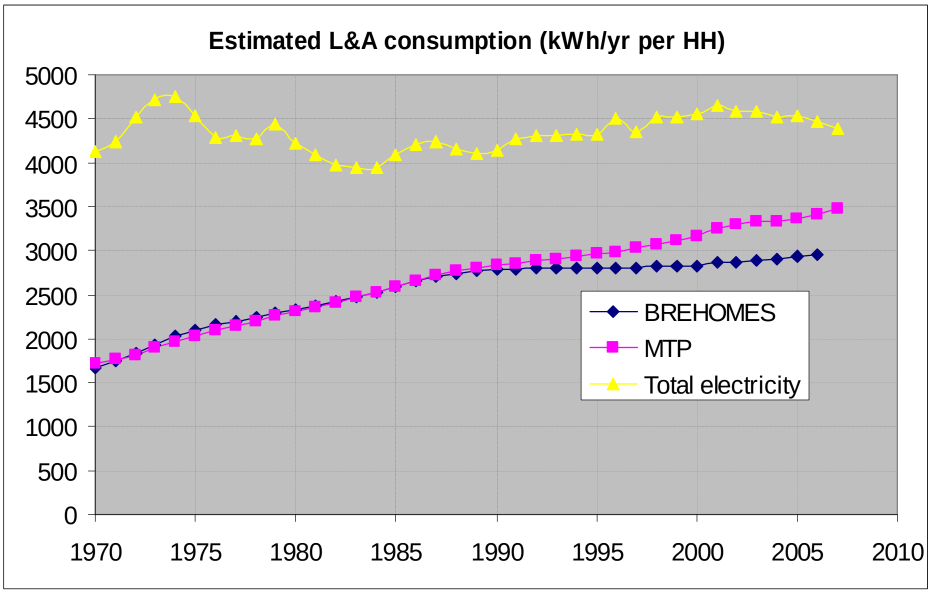
In 1997 about 10% of lighting was thought to have been provided by low energy lights. By using the low energy lighting correction factor formula in SAP 2005, we can derive a formula for a home with no low energy lights (which is a more practical starting point for calculation purposes):

L = 59.73*(TFA*Occ)^0.4714

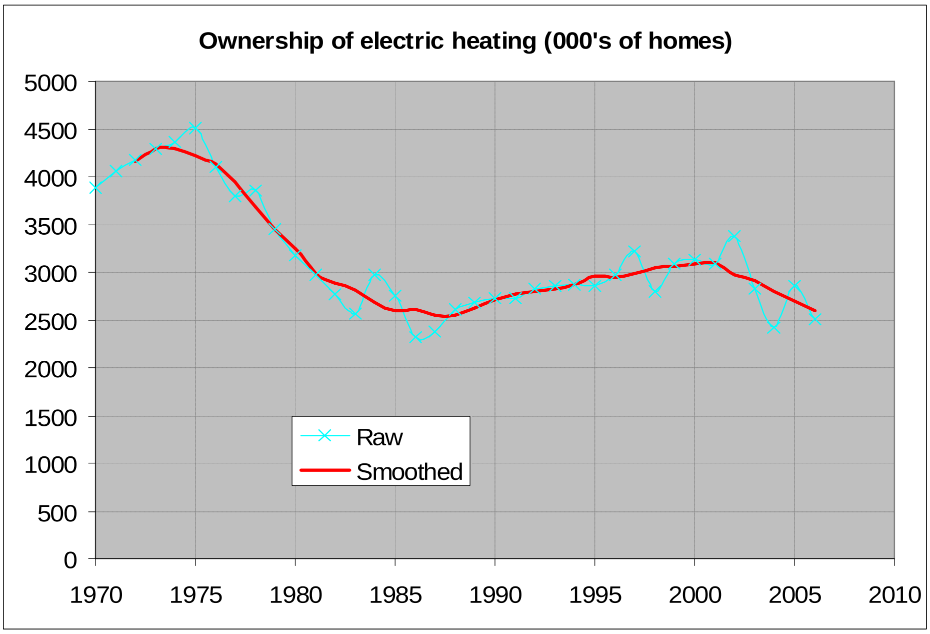
MTP provided a figure, based on recent research by the Lighting Association, showing that 15% of lighting energy is used in external lights, so that portion should be removed for the purposes of calculating the internal heat gains.

2.2.2 Estimating how L&A consumption has changed since 1997

We know the total amount of electricity consumed each year by UK households with good accuracy from DUKES [5], but we have no definitive way of estimating what proportion in each year was used for L&A. Estimates have been made of the proportion used for space heating, water heating, cooking and L&A for each year since 1970 in BREHOMES [6], though there is some uncertainty in each of the results. Also available is a time series of the estimated energy use for L&A from MTP [7], based on bottom-up modelling, which can be used to give a comparable time series of data.



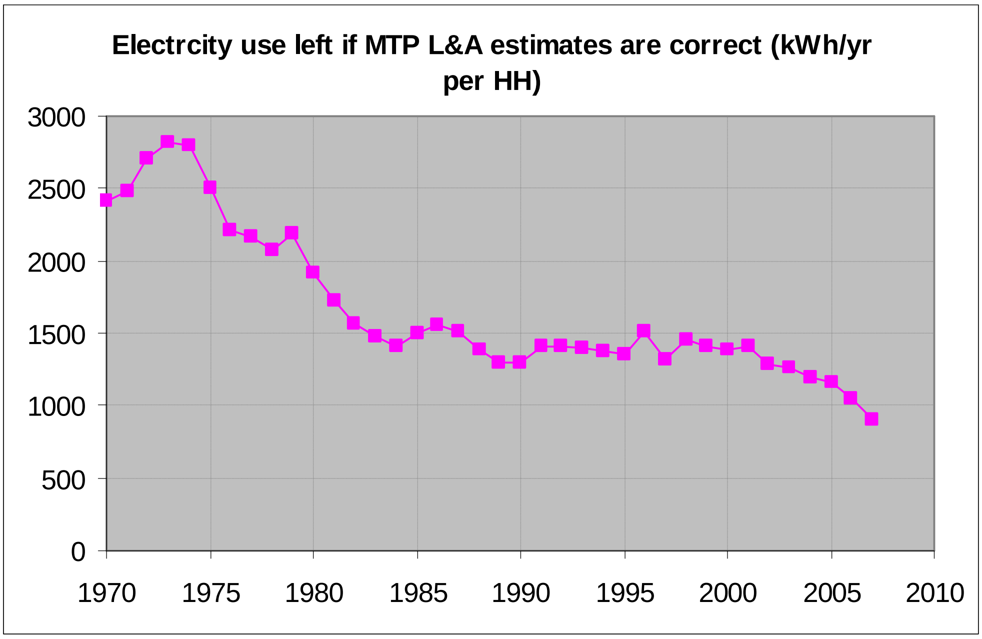
DUKES data shows the total electricity use of the housing stock per household has hardly changed since 1997. It was about 1% higher in 2007. It varies slightly each year due to variations in the weather, but the trend over the last few years appears to be slightly downwards. During this time the ownership of electric space heating has fallen by about 13%.



Electricity use for cooking and hot water is thought to have remained roughly constant during this period, or at least not increased. This suggests that L&A consumption has increased by enough to replace the energy that was previously being used for electric heating in order for the total to have remained about the same. Since electric space heating consumption per household is about a quarter as large as L&A, a 13 % reduction in the former implies a 3% rise in the latter, all other things being equal.

BREHOMES suggests a rise in the L&A consumption of 5% between 1997 and 2006. A provisional figure from BREHOMES suggests this increased to 6% in 2007. On the other hand, MTP estimates the growth of L&A consumption between 1997 and 2007 to have been 15%.

There is some reason to doubt that the increase since 1997 is as high as MTP suggests because the amount left for other end uses seems unrealistically small.



The ownership of electric heating has fallen by 13% since 1997, but is it really possible that the electricity used for space heating, water heating and cooking has fallen by about 30%? That is the implication of the rise suggested by MTP. There is so much uncertainty for each of these end uses that it is just about possible (e.g. if cooking and water heating have fallen significantly or if electric heating is becoming less prevalent in old houses but more so in new homes which need less heating), but it seems likely that it has declined by less than this. The MTP figures probably overestimate the rate of increase in the energy used for L&A. This is possibly due to the rapidly increasing ownership of appliances (as documented in recent EST publications [8], [9]), on which the MTP method is based, not translating into such a rapid increase in their energy consumption. People may now be starting to accumulate more appliances than they can possibly use simultaneously, gradually decoupling ownership from energy consumption.

On balance, it seems likely that L&A consumption has risen very little since 1997 (despite appliance ownership having risen sharply). So rather than applying a small and uncertain increase factor we should simply use the 1997 formulae. Discussions are underway about whether to undertake a new Energy Follow Up Survey, perhaps in 2010, so it may be possible at that stage to update this with much greater certainty.

2.2.3 Estimating the L&A consumption of new homes

There is an argument that energy consumption by lights and appliances in new homes may be lower because new homes are more likely to have new appliances (which will tend to be more efficient). There are a few arguments against this however.

- New homes do not necessarily have new appliances. Though we may think it is likely, we have no data showing that the average age of appliances in new homes is indeed lower. It could be that this is only a small effect.
- There may be a tendency for new homes to have a higher proportion of young families in them, potentially leading to greater use of certain types of appliance (e.g. entertainment, wet appliances). One could also argue that new homes are more likely to contain some quite significant appliances (in terms of energy use) such as dishwashers and tumble dryers.
- It seems likely that, typically, a better level of lighting will be provided in new homes involving banks of high-wattage halogen lighting in kitchens and bathrooms for example.

On balance therefore, and in the absence of any real evidence, it is difficult to argue convincingly that energy use should be significantly different in new homes than in existing homes. Thus it is recommended that the same formulae are used for both new and existing homes.

2.2.4 Seasonal variation in energy use of lights and appliances

SAP 2009 is likely to be a monthly based calculation method. Thus any heat flows with a significant variation from month to month can be taken into account.

The derivation of suitable equations to deal with this seasonal variation is show in the appendix to this note, but the resulting equations are given here:

For lighting energy:

Month factor = 1 + 50% * [cos (2 * Pi() * (month number – 0.2) / 12)]

For appliance energy:

Month factor = 1 + 15.7% * [cos (2 * pi() * (month number – 1.78) / 12)]

2.3 Cooking

Where electric cooking is used the cooking energy requirement is estimated in BREDEM as follows:

Cooking energy (kWh/yr) = 472+94*N

A figure for a typical household is therefore about 700 kWh/yr.

For gas cooking the formula is:

Cooking energy (GJ/yr) = 828+167*N

A figure for a typical household is therefore about 1230 kWh/yr.

(Note that for the calculation of internal gains, it is assumed that some of the energy is lost through the additional ventilation associated with cooking, so a utilisation factor is applied. The reduction is higher for gas cooking due to the additional moisture produced.)

SAP doesn't consider the cooking fuel type explicitly, instead taking a figure half way between the gas and electric cooking values for the purposes of working out the internal gains.

The BREDEM equations that form the basis of what's in SAP were developed some years ago (the early 1990s), based on data collected in the 1980s. Although there is very little information to show how cooking energy use may have changed since then, it is conceivable that the figure could now be lower. In the early 1980s microwaves were rare, now the vast majority of homes have one. There also seems to have been a trend towards convenience foods and ready made meals (in some cases only made possible by the use of microwaves).

There are a few sources of cooking energy use figures worth considering, albeit from small and not necessarily representative samples, which only reinforce this perception:

- The equation for cooking energy in Passive House Planning Package (PHPP) [10] gives far lower figures. For a typical household the figure is 264 kWh/yr for electric cooking – less than half the figure from BREDEM.
- Mid-1990's data from the Electricity Association also indicates a lower figure -about 500 kWh/yr.
- A late-1990s study by Cranfield University [11] indicates a figure of 385 kWh/yr.
- DECADE estimates lower cooking energy consumption than BREDEM. Interestingly it also shows cooking energy falling significantly over time. This is probably based on very little real data, but it is a further informed opinion suggesting cooking energy use could have fallen since the existing BREDEM method was devised.

Perhaps the most robust estimate is that in the Domestic Energy Fact File, which indicates an average consumption for cooking of 576 kWh/yr per household (averaged over all cooking fuels). This is lower than the existing formulae predict and closer to the levels shown in the other studies. It is possible to derive new formulae from this for gas and electric cooking as follows:

- Average dwelling size of 90 m² gives average occupancy of 2.62.

- Putting this in the form a + b*N with (per existing equations)

b/a = 0.2

gas/electric = 1.75

- Assuming 50% gas and 50% electric cooking (consistent with DECADE/MTP ownership data) results in:

electricity	275 + 55.0 N (kWh/yr)
gas	481 + 96.3 N (kWh/year)

To get the gains needed for SAP, the existing utilisation factors of 0.9 (electric) and 0.75 (gas) are applied and the units are converted to Watts, yielding:

electricity	28.26 + 5.65 N (W)
gas	41.12 + 8.25 N (W)

The average figure which is required for SAP (where the fuel is unknown), again assuming a 50:50 split is therefore:

Cooking gains (W) = 35 + 7N

2.4 Water heating

The calculation of the energy required for water heating and the associated internal heat gains are discussed in detail in a separate document in this series entitled, “STP09/DHW01. Analysis of the EST’s domestic hot water trials and their implications for amendments to BREDEM and SAP”.

2.5 Pumps and fans

No significant changes have been made to the existing entries in tables 4f, 4g and 5a in SAP, which deal with the energy consumption of and gains from pumps and fans. Some additions and clarifications have been made to deal more precisely with mechanical ventilation systems.

2.6 Internal heat losses

This is a new category which relates to the loss of internal heat to the warming of incoming cold water and to the evaporation of water within homes (e.g. drying towels, moisture from plants) which is then lost when the moist air is ventilated and replaced with dryer air. In the past SAP has assumed this was a negligible loss, but evidence gathered for the Passive House Planning Package indicates it may be significantly large. For this reason, despite having very limited evidence it is important to include this in SAP 2009. According to PHPP a figure of around 100W is appropriate for a typical home. Since all these losses are all associated with occupancy in some way it is suggested that losses should vary as a function of the number of occupants at a rate of 40W per person (giving for a typical home a figure of about 100W). Since the new occupancy formula in SAP 2009 limits the number of occupants to quite a small range (between 1 and about 3.5), this will always lead to a figure of between 40 and 140W. This will reduce the total gains figure by 10-20% in a typical case.

3 Use of lower levels of internal gains for regulatory purposes

Since the true level of internal gains varies greatly in practice depending on occupant behaviours and choices, it may be sensible to base decisions at the design stage on a conservative gains assessment. If a below average figure is used, the dwelling's design, particularly in terms of the energy efficiency of the fabric, should be to a sufficiently high standard to cater adequately for the majority of occupants over its lifetime. There is also the possibility that internal heat gains in an increasingly carbon constrained future might reduce, so using a lower figure may help in terms of 'future-proofing' them.

For this reason alternative formulae have been derived and are put forward for consultation, which give a lower, but still realistic, internal heat gains figure. It is only anticipated that these be used in the calculation of the DER, not the SAP or other ratings[1]. A precedent for this already exists because certain assumptions (e.g. secondary heating assumptions, proportion of low energy lights) already differ for the DER calculation in SAP 2005.

The proposed alternatives are described below.

3.1 Metabolic

A reduction from 60W per occupant to 50W per occupant is proposed. This difference would be equivalent to a family tending to spend more hours of the day away from their home than was assumed in the original calculation.

3.2 Lights and appliances

By performing detailed calculations for some example homes with low energy lights and appliances, rather than average ones, energy use was found to decrease by around a third. Hence it would be reasonable to reduce by a third the result obtained by the formulae for typical homes given earlier to get a low, but still realistic level.

3.3 Cooking

Induction hobs and A-rated ovens have predicted energy savings of around a third compared to typical versions, according to a Market Transformation Programme report. A reduction factor of a third could be applied to the result from the standard cooking formula.

3.4 Water heating

Gains from water heating are largely determined by user inputs specific to the dwelling, so these should be left at the same levels for the DER calculation.

3.5 Pumps and fans

The energy use for pumps and fans are largely determined by user inputs, so these too should be left unchanged.

[1] Nor should the lower level of gains be used when assessing cooling needs.

3.6 Internal heat losses

Since the calculation of internal heat losses is based on very little data, we have no mechanism for modifying it, or even predicting in what circumstance it might be expect to be higher or lower. Until further evidence is available, we really have no feel for what low, but still realistic level should be. For the time being the low level should be the same as the typical level, therefore.

4 Summary of recommendations

- The calculation of metabolic gains should remain unchanged
- The calculation of the energy needed for the lights and appliances and the associated gains should be updated to use the equations given in this report
- Cooking energy use and associated internal gains has probably declined since the present SAP equations were developed but we don’t have any robust evidence with which to update it at this stage
- SAP’s water heating procedure should be updated in line with the separate note on the subject
- No significant change to the pumps and fans table is proposed
- Internal heat losses associated with the warming of incoming cold water and heat lost via evaporation should be taken into account using the equation proposed in this document
- Consideration should be given to the use of alternative lower levels of internal heat gains for the assessment of the DER

5 References

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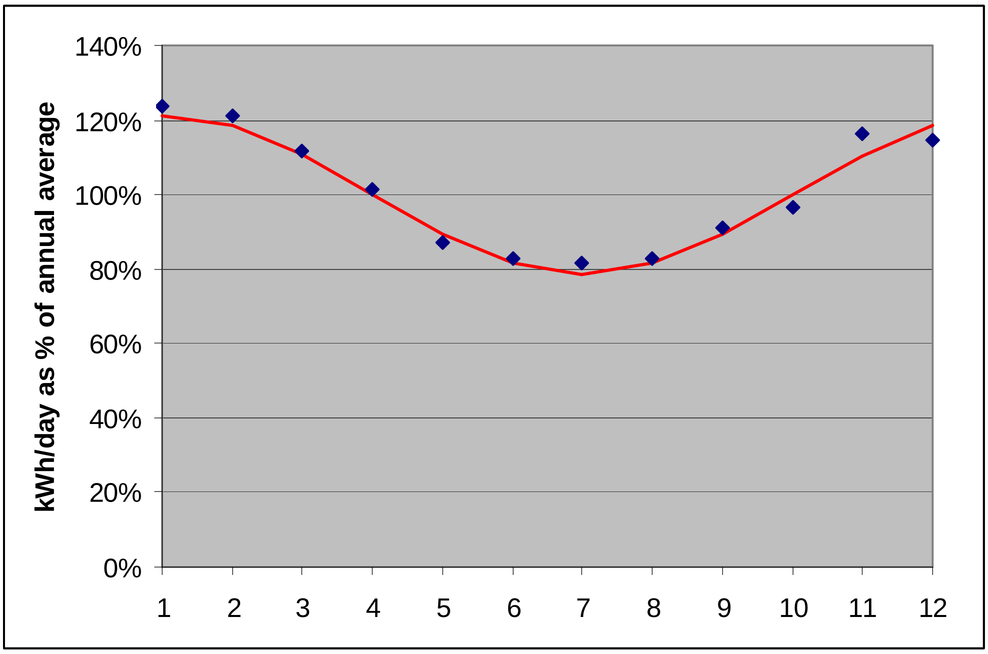
Appendix – Seasonal variation of energy use for lights and appliances

Monthly electricity consumption data for 52 homes monitored during the 1980s was obtained. 22 of these were collected as part of the Milton Keynes monitoring work in 1988-89. 28 were collected as part of the Collyhurst monitoring work in 1984-86. The final 2 were based on my own home and my parents' home for which detailed electricity consumption figures were available for a number of years.

For each month the average energy consumption over all the cases available was averaged, as was the annual total. These figures were converted to daily averages for each month by dividing by the number of days in the month. The daily average for the month as a percentage of the annual total was calculated. These values, along with the best sinusoidal fit to them are plotted in the following graph.

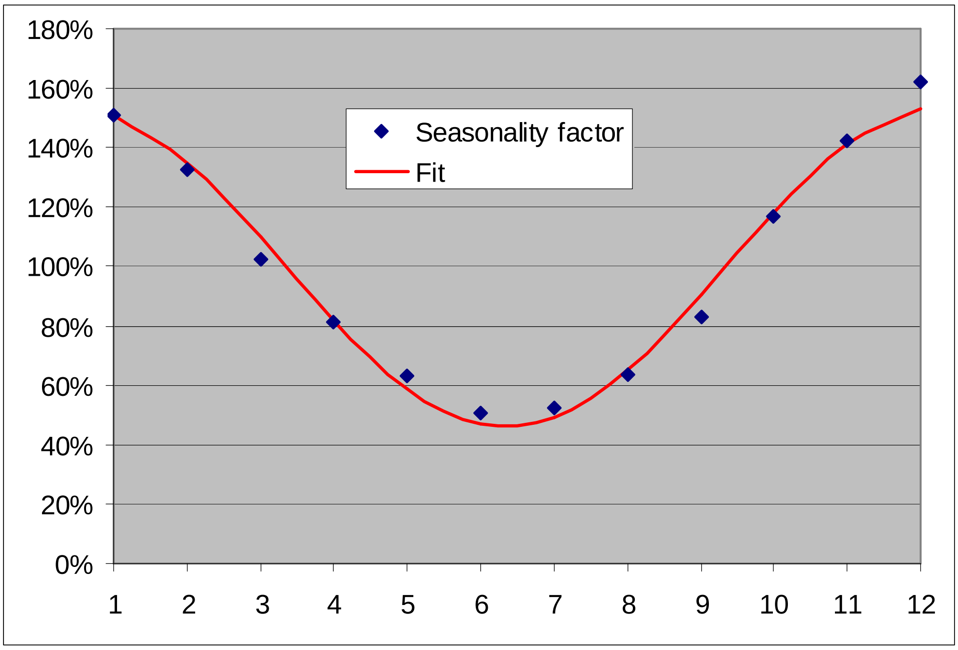


The coefficients of the fit imply a seasonal swing of ±21%, symmetrical around mid-July:

Month factor (L&A together) = 1 + 21.0% * [cos (2 * pi() * (month number - 1.06) / 12)]

However, this only gives the variation in the total energy use for lights and appliances. For SAP, it is necessary to have separate equations to deal with lights and appliances individually.

Separate data collected by the Electricity Association in the 1990s was available which could be used to consider lighting energy alone. Data was available giving half-hourly lighting energy consumption values for a whole year averaged over approximately 100 homes. This was summed to give monthly totals. These were divided by the number of days in each month to give the value for an average day in each month. These were divided by the lighting consumption of the average day for the whole year to produce the monthly seasonality factors needed. These are plotted in the following graph.



The variation over the months of the year is found to be about ±50%. Thus the equation recommended for SAP is:

Month factor (lighting only) = 1 + 50% * [cos (2 * Pi() * (month number – 0.2) / 12)]

Now it is possible to return to the L&A seasonal variation equation derived earlier and subtract the lighting only equation from it, to leave the seasonal variation only for appliances. By assuming lighting makes up 21% of the total we get:

Month factor (appliances only) = 1 + 15.7% * [cos (2 * pi() * (month number – 1.78) / 12)]