Technical Manual – SPAA & DCUSA Theft Tools

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energysavingtrust.org.uk

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About Energy Saving Trust

Energy Saving Trust is the UK's leading impartial organisation helping people save energy, reduce carbon emissions and use water more sustainably. We do this by directly supporting consumers to take action, helping local authorities and communities to save energy, using our expert insight and knowledge, providing quality assurance for goods and services and by working in collaboration with national and international governments and organisations.

This work was carried out by Energy Saving Trust and commissioned by Electralink.

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Version Control

Version	Corresponding tools' version	Date	Authors	Signed Off by	Notes and changes
1.0	2.0	27 April 2020	William Jamieson	Andrew Tod	First creation of technical manual.
1.1	2.1	27th August 2020	William Jamieson	Andrew Tod	Added clamp meter reading calculation details.

Contents

1. Introduction

The SPAA and DCUSA theft tools are used to determine typical gas or electricity usage of domestic and non-domestic properties. This manual should be used in conjunction with the relevant tools, the latest versions of which can be seen in the Version Control section on page 2 of this manual. This manual will present the methods by which the theft is determined for each case, the logic behind these methods and references to the relevant sources of data used. The manual will cover the following types of theft:

- Domestic theft – the method is broadly the same for both electricity and gas and is examined in Section 2. There is some additional complexity for electrical appliances which applies only the electricity tool.
- Baseline theft – the method is the same for both tools and will be explained together in Section 3.
- Non-domestic theft – the two methods are sufficiently different to require separate consideration in this manual. The space heating, hot water and ventilation heating requirements use the same base calculations which will be explained once and referenced in the other. These are discussed in Sections 4 and 5.
- Cannabis, Clamp Meter Readings & Industry calculations apply only to the electricity tool and will be described in Sections 6 and 8.

1.1 Caveat

These tools do not calculate the exact energy theft seen in properties. Instead it gives estimated outputs based on typical and average assumptions.

1.2 How to use this document

This document details the logic behind the calculations in the corresponding gas and electricity tools. It is intended to be used by those who want a more detailed understanding of the calculations used. Where external data that can be updated is used, a numbered reference is included within the text (e.g. [1]) which link to Table 1 in Section 9. This gives details of the source and recommended period of updates. A separate guidance document is also available which describes how a user should use the excel tools and how to identify the correct inputs.

2. Domestic theft

2.1 Gas theft

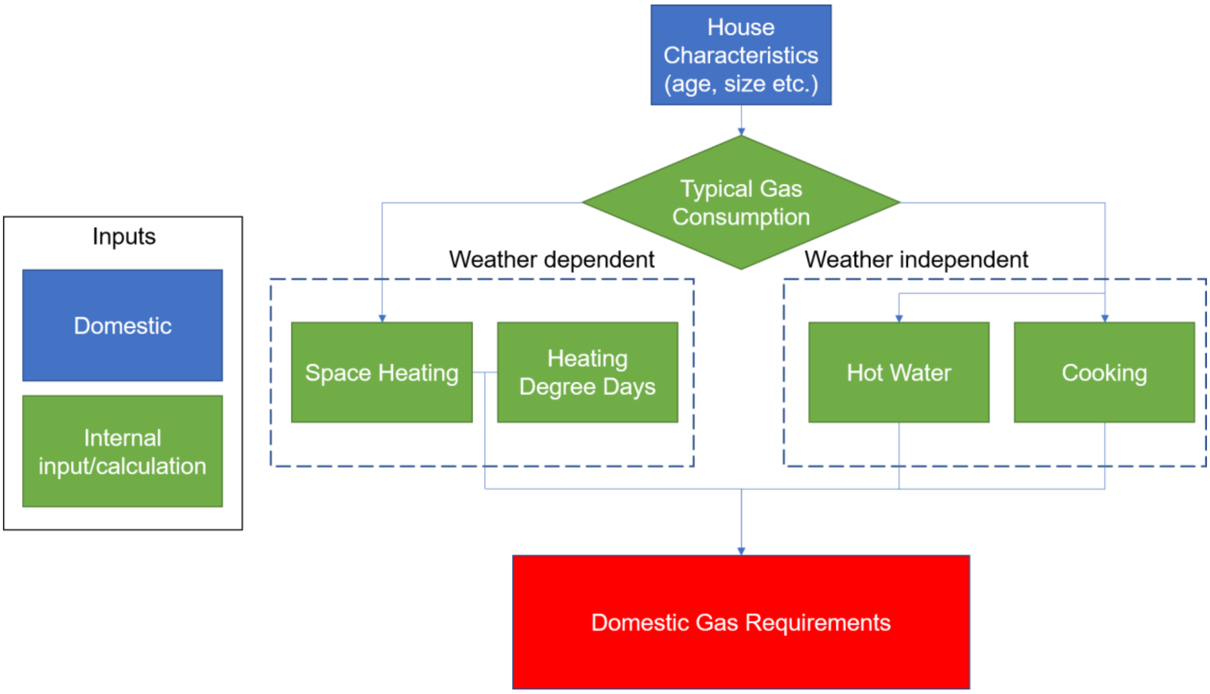

Figure 1: Flow diagram for the domestic gas calculation. The input tabs are shown on the left hand side.

Figure 1 shows the process for calculating the typical gas consumption of a domestic property. Using the region, property type, dwelling age, number of bedrooms and insulation inputs on the 'Domestic' tab, the typical annual gas consumption of that particular property archetype is obtained. This has been calculated from an analysis of the National Energy Efficiency Data-Framework (NEED). [1] Details of this calculation can be found in Section 0.

Using typical housing profiles, the gas consumption of each archetype has been modelled to breakdown the total into typical space heating, hot water and cooking energy consumptions. The effect of the type of boiler and insulation have also been modelled to provide a scaling factor for these variables.

The broken-down values are separated into weather-independent and weather-dependent portions. The weather-independent values scale linearly with the length of the theft period, while the weather-dependent portion is scaled by comparing region-specific heating degree days for the theft period with average values to account for annual and seasonal variation. [2] The adjusted values are combined to give the overall gas consumption of the property in kWh.

2.2 Electricity Theft

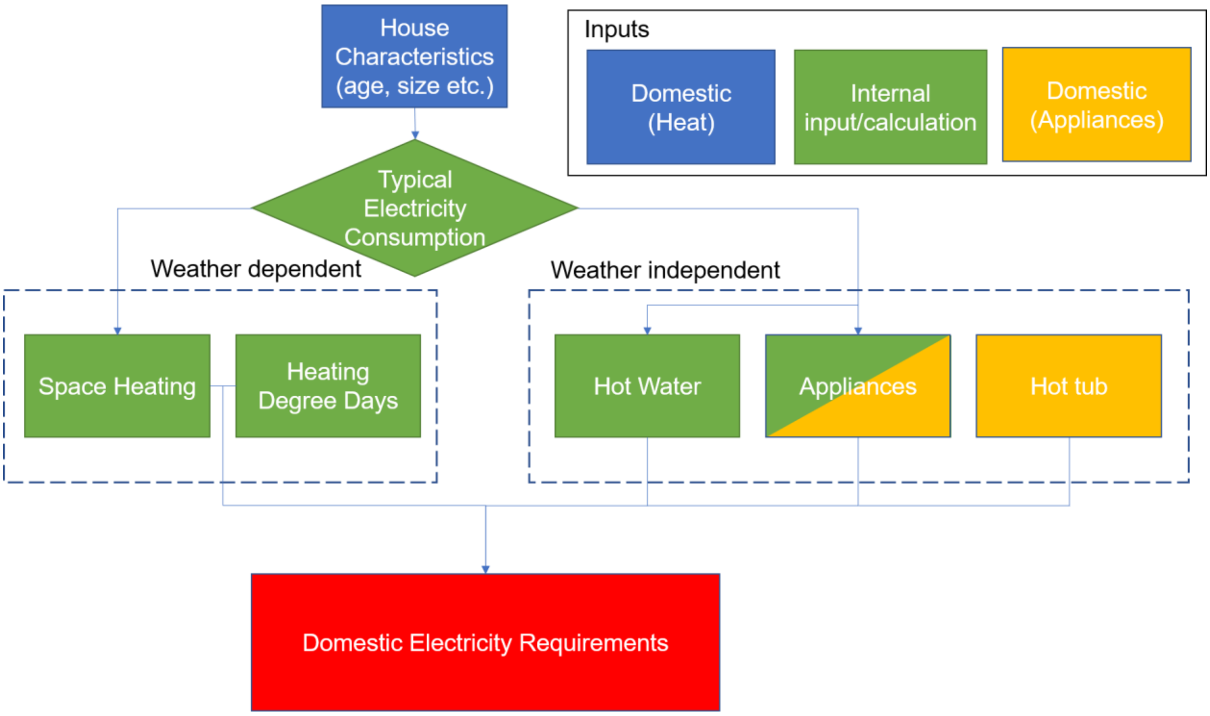

Figure 2: Flow diagram for the domestic electricity calculation. The input tabs are shown in the top right of the figure.

Figure 2 shows the process for calculating the typical electricity consumption of a domestic property. The calculation is very similar to the one for gas, with some additional complexity within the appliances. As per the gas tool, the typical annual electricity consumption is determined using an analysis of the NEED dataset as detailed in Section 0. [1]

Using typical housing profiles, each archetype has been modelled to breakdown the overall consumption into typical space heating, hot water and appliance energy values. The user can also input the exact appliances present using the 'Domestic (Appliances)' tab. From further analysis of the NEED dataset, the spread of appliance usage for each archetype is determined. The energy usage of the specific appliances selected are compared to an average home and scaled to the specific archetype based on the spread in the NEED dataset.

Hot tub usage can be estimated from a separate calculation, using typical values based on the inputs specified. This is calculated using a first principles calculation which determines the energy required to heat up and maintain the temperature of the hot tub.[a] This is combined with typical usage and ratings for the different sizes to give an annual energy consumption.

As with the gas tool, the weather-independent values scale linearly with the duration of the theft period, while the weather-dependent portion is scaled by comparing region-specific heating degree days for the theft period with average values, to account for annual and seasonal variation. [2] The adjusted values are combined to give the overall electricity consumption of the property.

[a] Heat up energy is determined using the volume and required temperature differential of the water. The maintenance energy is calculated using a typical heat loss profile through the walls and top insulation to estimate the energy to keep the temperature constant. This is combined with the energy required by the water pump to keep the water circulating.

2.3 NEED analysis

An average for electricity and gas consumption was calculated for each combination of variables within the NEED dataset (i.e. for each property archetype). These variables correspond to the inputs of the tool. Each archetype had to have a statistically significant number of data points to be considered valid for use in the tool to minimise any heavy weightings from outlier values. Therefore, where insufficient data was available for a particular archetype, an average was used with the region variable removed (giving national figures). Where the national average was also not statistically significant, the average was recalculated with the property type variable removed. It should be noted that due to the nature of the data, the user may encounter some confusing results. For example, some property types in certain regions may have a lower consumption for a higher number of bedrooms. This is simply due to the nature of the dataset and should not be considered an issue.

3. Baseline theft

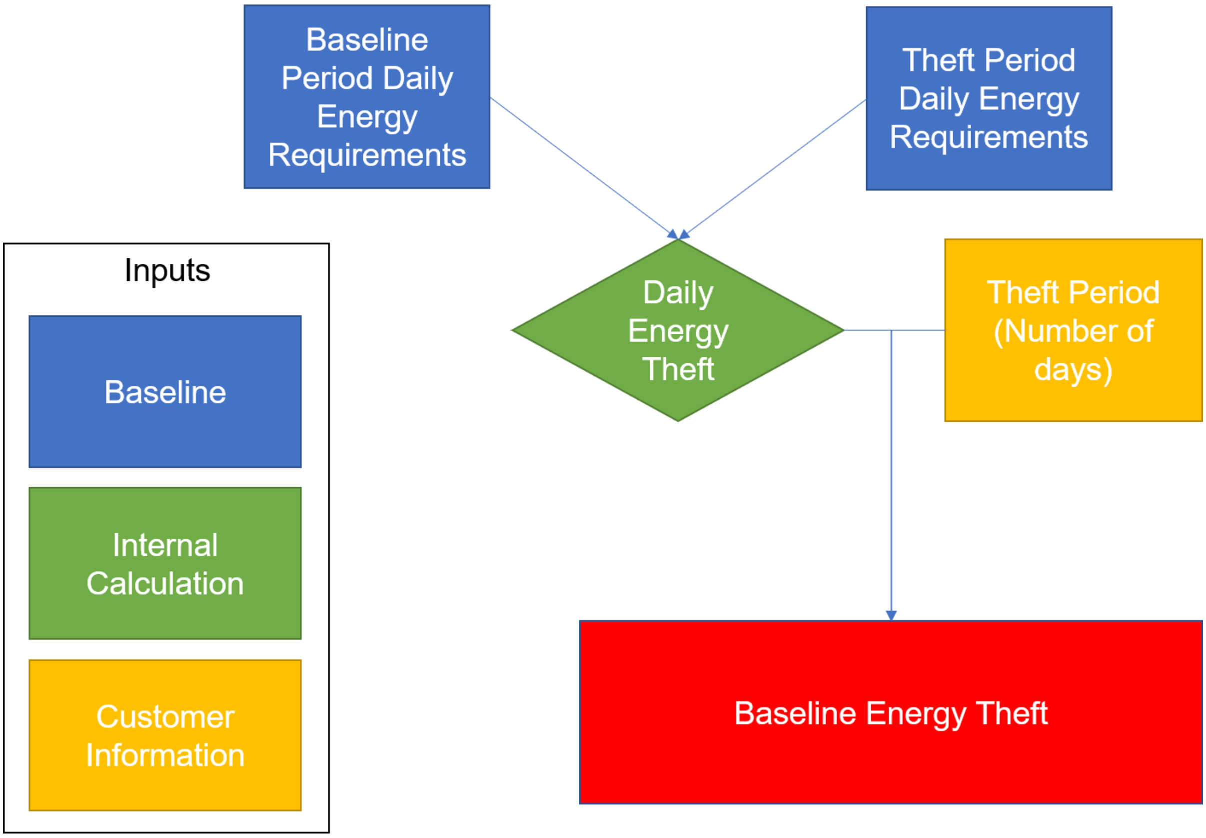

Figure 3: Flow diagram for baseline calculations. The daily energy requirements during baseline and theft periods are determined and the difference multiplied by the length of the theft period to determine the total amount of energy stolen. The tabs where the relevent information is entered are shown in the inputs box.

Figure 3 shows the calculation process for the baseline calculation. The amount of energy stolen is determined by taking meter readings of a known period of typical energy usage and comparing this to meter readings during the theft period of interest. For both tools, values can be input using meter readings (kWh for electricity, m^3 or 100s of ft^3 for gas) or total consumption (kWh) over the known period. A meter correction factor can be applied in the gas tool to account for variations in the energy capacity of the gas. The dates must always be entered in order to calculate a daily rate. The energy theft is then calculated using Equation 1.

$$E_{theft} = t_{days} \times \left(E_{d,baseline} - E_{d,theft}\right) \qquad (1)$$

Where t_{days} is the length of the theft period in days as defined on the ‘Customer Information’ tab. $E_{d,baseline}$ and $E_{d,theft}$ are determine from meter readings or known energy usage as defined in the user inputs on the ‘Baseline’ tab. It should be noted that the theft meter reading dates do not necessarily correspond to the full theft period as defined in the ‘Customer Information’ tab.

4. Non-domestic Gas Theft

This portion of the tool determines typical gas usage using a first principles calculation. This is split into four areas:

- Space heating requirements
- Ventilation requirements
- Hot water requirements
- Appliance requirements

Figure 4 shows the overall process by which the typical gas usage can be estimated. The four parts are separated into weather-independent and weather -dependent portions, with more detailed explanation of each in Sections 4.1 to 4.4. The weather-independent parts scale linearly with theft period, while the weather-dependent parts will vary based on the specific heating degree days for the theft period.

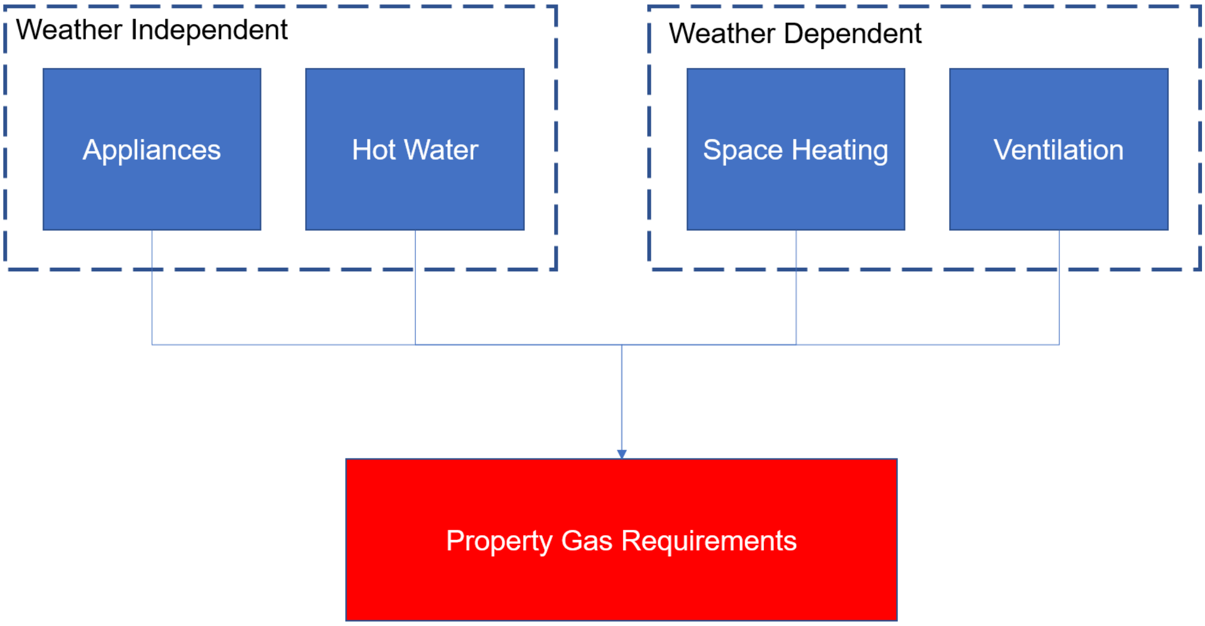

Figure 4: Non-domestic Gas Theft Methodology.

4.1 Space heating

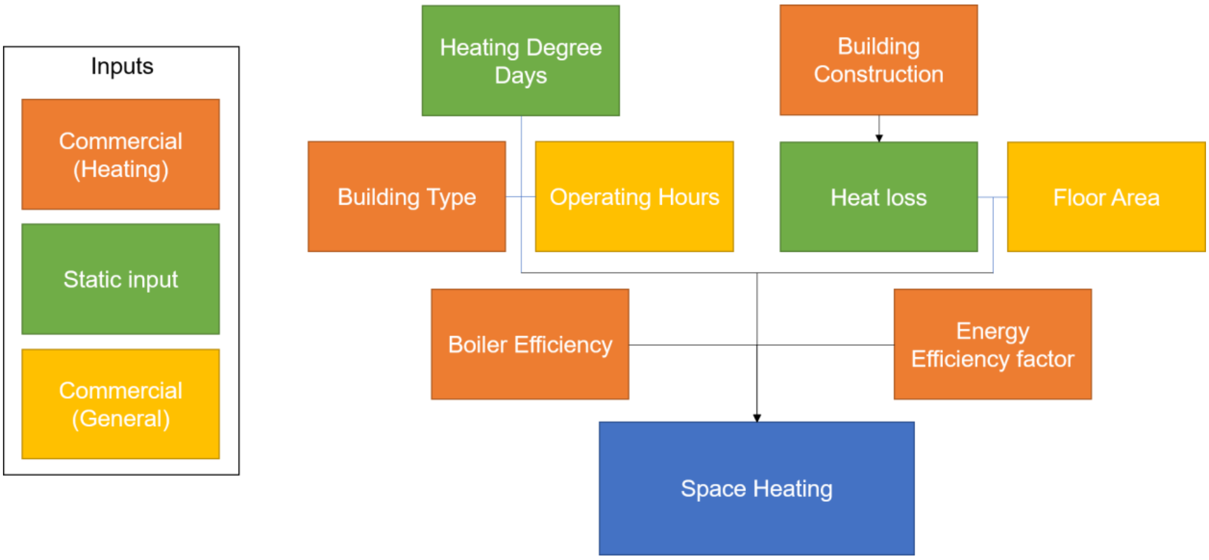

Figure 5: Flow diagram for the space heating portion of the calculation. The input tabs are shown in different colours on the left-hand side of the diagram.

Figure 5 shows the flow diagram for the space heating portion of the calculator. This will determine the requirements to maintain the building at the desired temperature during operational hours. Heating degree days are obtained for the specific period and scaled depending on the building type and operating hours of the business. [2, 3]

An additional preheating time is included on top of the operational hours to ensure the property is at the desired temperature for the times they are open. The specific heat loss of the building is calculated from the building construction type and floor area inputs. [4]

The heating degree days, operating hours and property heat loss are combined to give the space heating requirements. This value is scaled by the boiler efficiency and an energy efficiency improvement factor to give the final output. Typical energy efficiency improvements would include insulation or other measures to reduce heat loss.

4.2 Ventilation

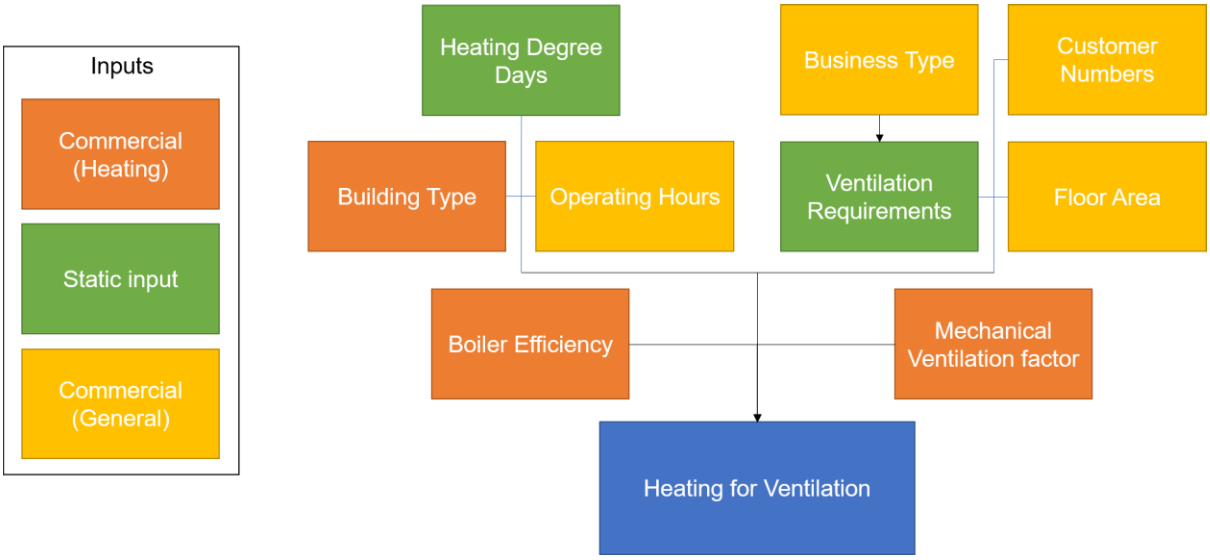

Figure 6: Flow diagram for the ventilation portion of the calculation. The input tabs are shown in different colours on the left-hand side of the diagram.

Figure 6 shows the process for calculating the additional heating requirement for ventilation. This is the additional energy required to heat fresh air required by customers within the property. As with the space heating portion of the calculator, heating degree days for the specific period are scaled depending on the building type and operating hours. [2, 4] The ventilation requirements (in m^3) are determined from the business type, customer numbers and floor area of the property. [3] The heating requirements for the additional ventilation are calculated from the heating degree days and the ventilation requirements. This value is scaled by the boiler efficiency and a factor for the ventilation type (natural or mechanical).

4.3 Hot water

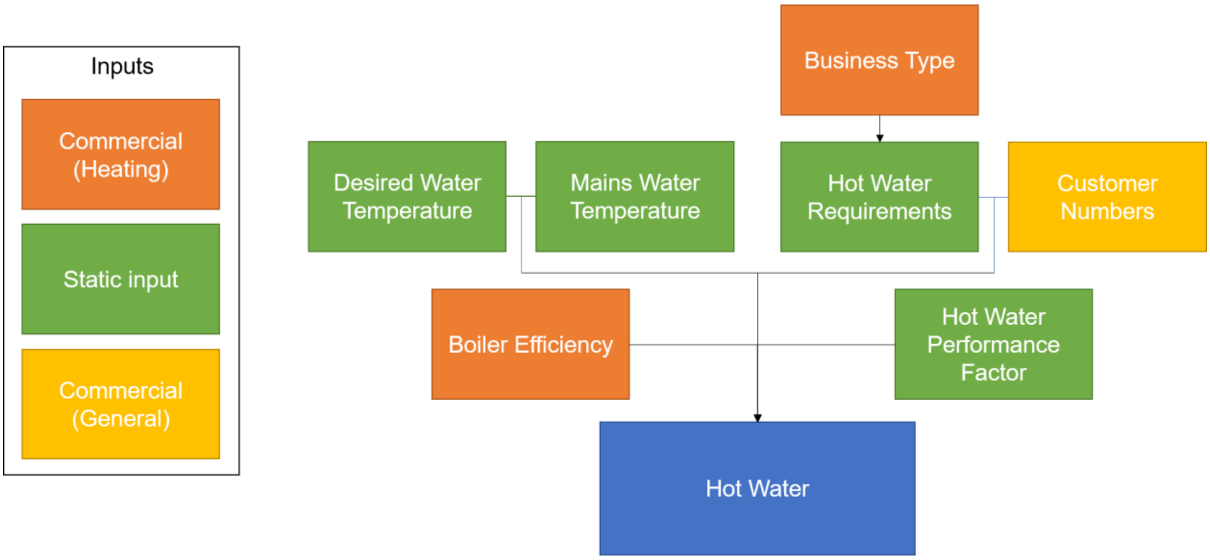

Figure 7: Flow diagram for the hot water portion of the calculation. The input tabs are shown in different colours on the left-hand side of the diagram.

Figure 7 shows the process for determining the hot water energy requirements of the property. The daily hot water needs are determined from the business type selection and the customer numbers. [3] The overall water heating energy is calculated using these requirements and the desired water temperature. This is scaled by the boiler efficiency and a performance factor for hot water to account for any losses in the pipework.

4.4 Appliances

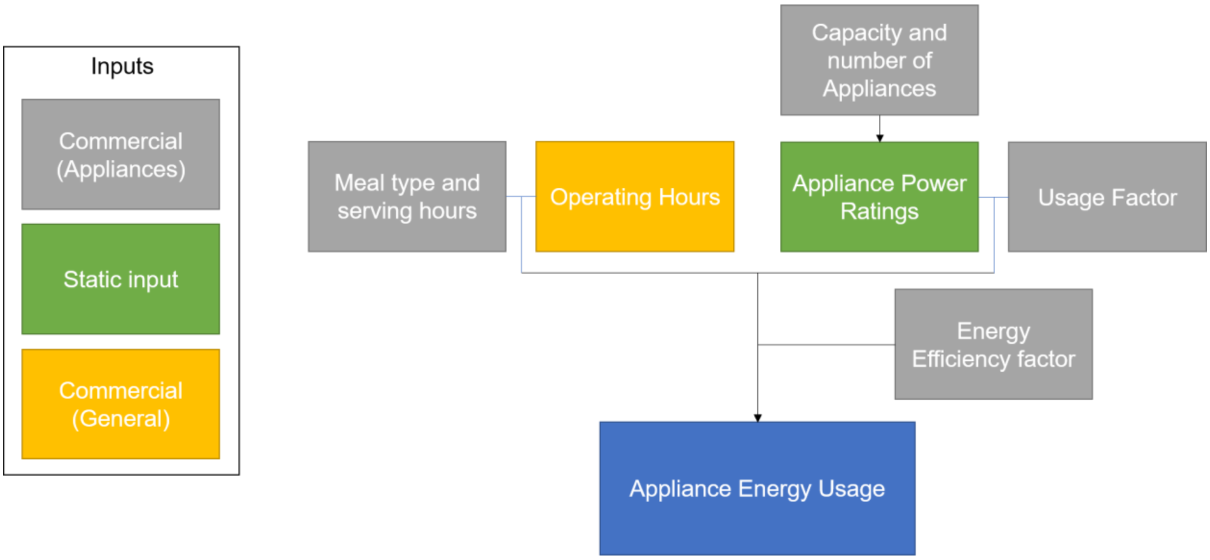

Figure 8: Flow diagram for the appliance portion of the calculation. The input tabs are shown in different colours on the left-hand side of the diagram. The appliances vary depending on their specific operation and this is therefore a general process diagram for an individual appliance.

Figure 8 shows the general process for determining the energy usage of gas appliances in the tool. Due to the large range of appliances, this process does not directly apply to each appliance. For example, the grill has a large number of inputs which effectively duplicates the appliance power rating portion of Figure 8 (top right 3 boxes) to give the overall appliance output. The operating hours, meal type and serving hour inputs are used to give typical usage hours for each appliance which were determined through research carried out in previous research. [5] The overall appliance energy usage is calculated using the operational hours and the appliance power ratings scaled by an appropriate usage factor for the specific appliance.. An energy efficiency factor is also applied to account for more efficient appliances. This has been calculated based on previous research.

5. Non-domestic Electricity Theft

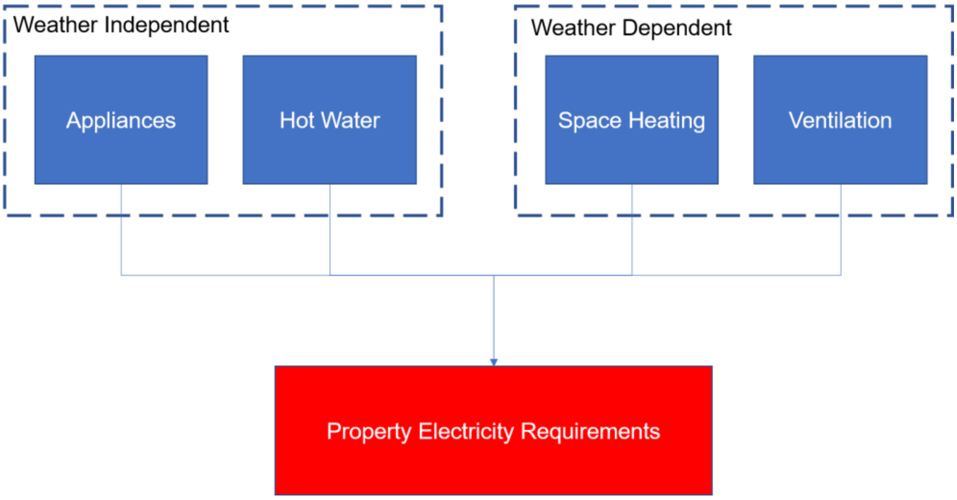

Figure 9: Flow diagram showing how the electricity requirements of a property are calculated. This is split into weather-dependent and weather-independent parts.

Figure 9 shows the process to calculate the electricity requirements for a non-domestic property. The calculations for the space heating, ventilation and hot water are the same as the gas calculations which can be found in Section 4 of this manual. A number of internal static values are different to account for the variations in the two heating methods and an electrical heating efficiency factor is used instead of the boiler efficiency seen in Figures 5-7.

5.1 Appliance energy requirements

In the electricity tool, the appliance energy requirements are calculated based on the floor area and business type of the property. For takeaways and restaurants/pubs there is the additional option to specify the appliances which are present. Each appliance has a factor which scales the appliance energy requirements based on typical usage and power demands. [6] These factors have been determined by research carried out in previous iterations of the tool.

6. Clamp Meter Readings

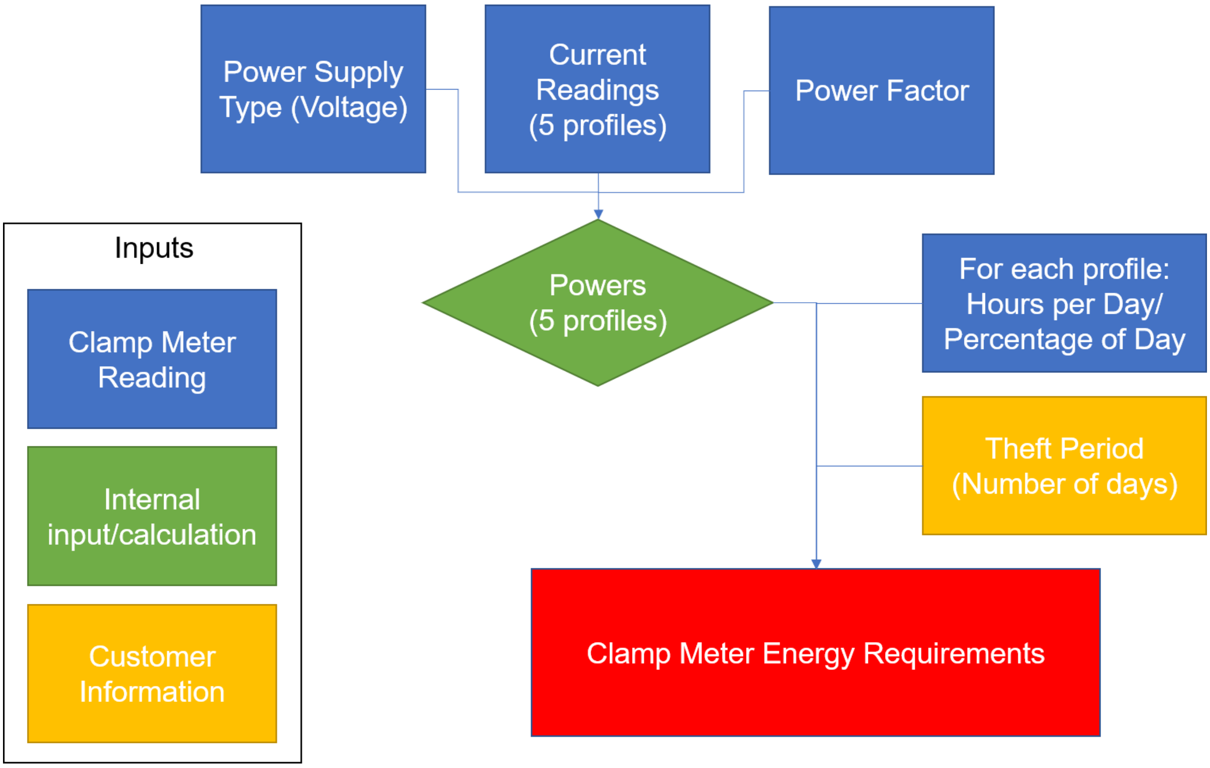

Figure 10: Flow Diagram for Clamp Meter Readings.

Figure 10 shows the process by which the energy requirements of a building are calculated through clamp meter readings. The power supply type and power factor are specified to give the required voltage and power factor. Up to 5 separate profiles can be specified for different operating conditions within the property. For each profile, 5 current readings can be specified, of which an average is taken. Using the voltage, average current and power factor, the power for each profile is determined.

For each profile, the percentage of day or actual hours can be input. The sum of these must add to 100% or 24 hours. The daily energy is determined by the sum of the individual profile energies. These are then scaled to the theft period to give to energy consumed over the period.

The following equation summarises the process described above:

$$E = \begin{cases} d \sum_{i=1}^{n} \sum_{p=1}^{m} t \times PF \times IV & t = time\ in\ hours \\ d \sum_{i=1}^{n} \sum_{p=1}^{m} 24\, t \times PF \times IV & t = time\ as\ \% \end{cases}$$

Where *E* is the energy consumption in Wh (converted to kWh in the tool), *d* is the number of days the theft took place, *n* is the number of current profiles measured, *i* (1 to 5), *m* is the number of phases, *p* (1 or 3), *t* is the time in hours or as a percentage of the total, *PF* is the power factor, *I* is the averaged current in Amps and *V* is the supply voltage in Volts.

7. Cannabis Theft

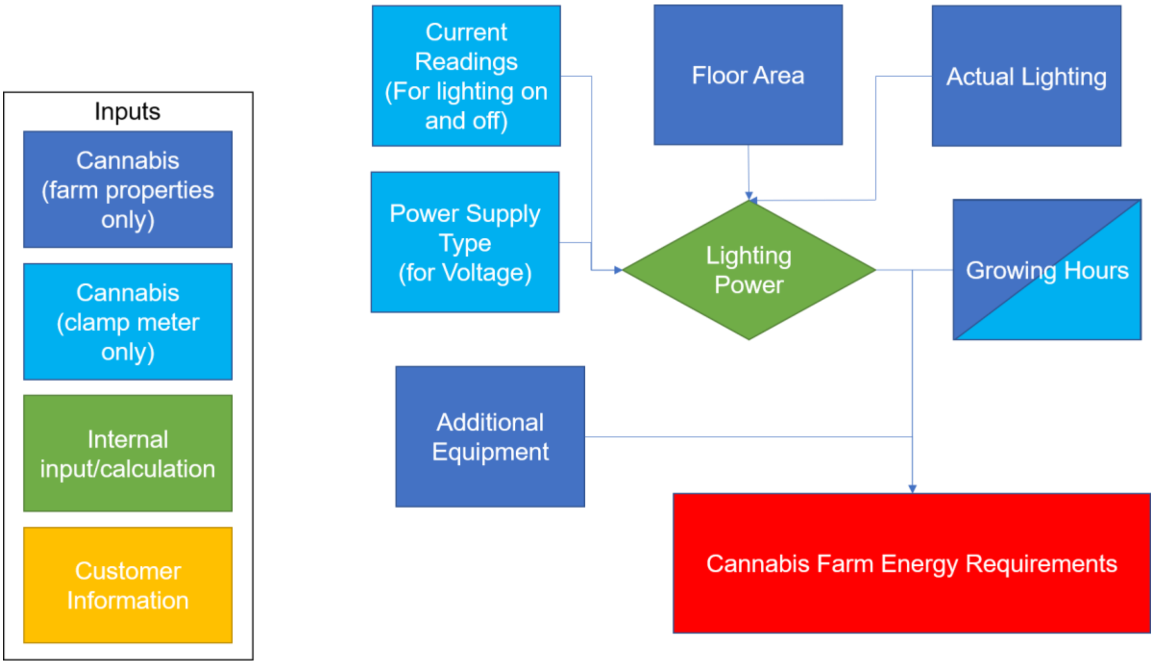

Figure 11: Flow diagram for the calculation of typical energy requirements of a cannabis farm. All the inputs are from the 'Cannabis Farm' input tab. The lighting power can be determined either by specifying the exact lighting present or using a typical value per m^2.

Figure 11 shows the process for the estimation of the energy consumption of a cannabis farm. The lighting power requirements are determined either by specifying the number and power of each bulb type, or by a typical cannabis farm value based on the floor area (currently 430 W/m^2).

The growing hours for the cannabis farm can be specified and are separated into two stages: the vegetative growth and flowering stages. Typical defaults for these can be used if no other information is available.

Additional growing equipment is specified in terms of number and power consumption for each appliance. This is assumed to be on for 24 hours a day in order to regulate heat, humidity and ventilation needs of the farm. These are combined to give the annual energy requirements of the farm which is then scaled to the theft period of interest.

Alternatively, the current recorded during periods when the growing lamps are on and off can be recorded together with the type of supply (single or three phase). Up to 5 clamp meter readings can be taken per phase and an average of them will be used to determine the power using the same method as in Section 6. The weeks and hours for the different growing stages are specified to give the annual energy requirements which are then scaled down to the theft period of interest.

8. Industry Theft

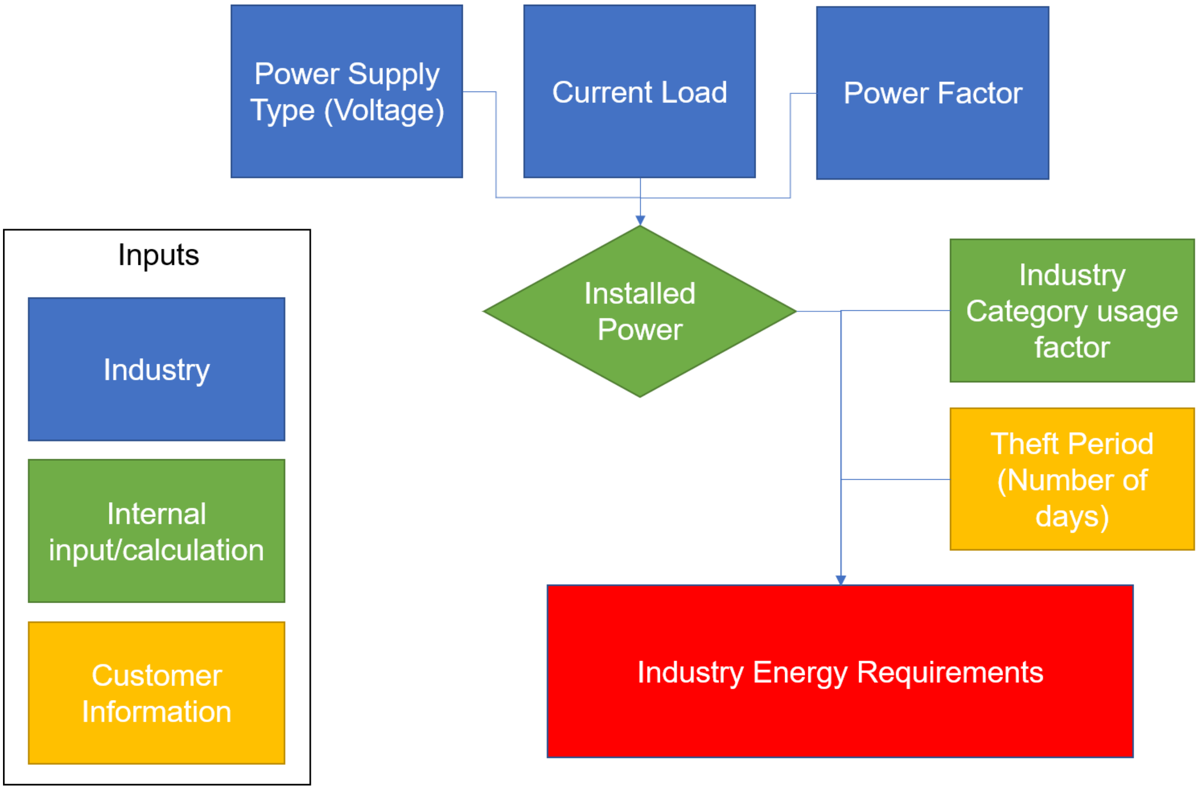

Figure 12: Flow diagram for the calculation of typical industry energy requirements. The input tabs used in the tool are shown in the box on the left-hand side of the Figure. NOTE: for clarity the process for a warehouse is not shown – for these the 'Installed Power' is replaced by a floor area input which is scaled by a usage factor to give the energy requirements.

Figure 12 shows the process by which the typical energy requirements of industrial properties are determined. For the desired industry type, the power supply type, load current and power factor for the property are used to determine installed power. An industry specific usage factor is applied and scaled using the theft period dates to give the typical energy requirements of the property.

It should be noted that warehouses are calculated slightly differently and are not shown in the Figure 12. Their energy requirements are calculated based on the floor area of the premises. A scaling factor for the floor area determines the energy requirements which are then scaled for the period of theft.

9. Typical Update Times

This section details the areas of the calculator which would benefit from periodic updates. Table 1 gives the sources and typical update periods for each area.

Table 1: Typical update periods

Update area	Source	Document Reference Number	Suggested update period	Which calculator
Domestic Gas Consumptions	NEED[b]	[1]	Full dataset published every few years. Will be updated when data becomes available.	Gas
Domestic Electricity Consumptions	NEED[b]	[1]	As above	Electricity
Heating Degree Days	Vesma[c]	[2]	Quarterly to annually	Both
Business Type typical properties	Research carried out by EST & UCL	[3]	Unlikely to change – to be reviewed if/when additional business types are added	Both
Non-domestic building characteristics	Internet research (possible sources include EPC certificates)	[4]	Review figure every 5 years	Both
Gas non-domestic appliance power ratings	Research carried out by EST & UCL	[5]	Review figure every 5 years	Gas
Electricity non-domestic appliance scaling factors	Research carried out by EST & UCL	[6]	Review figure every 5 years	Electricity

[b] https://www.gov.uk/government/statistics/national-energy-efficiency-data-framework-need-report-summary-of-analysis-2019
[c] http://www.vesma.com/ddd/regular.htm

We're here to help people across the UK save energy and reduce fuel bills. It's a big task that we won't solve alone. But by working with partners who share our goals, we believe we can make a real difference.

Underpinned by our independent status and impartial perspective, we offer a depth of energy expertise, but we're not content to stand still. Our goal is to find new and better ways to drive change and reduce UK energy consumption.

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