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Abstract. This paper presents a calculation method for the power consumption of building technology. The methodology notably allows one to quantify power supply losses in a realistic manner. This is achieved by stepping through the entire supply tree, from the field devices up to the grid connection.

1. Introduction
The electricity consumption of building technology systems has rarely been investigated so far. Moreover, no consistent calculation method has been proposed to the best of our knowledge. Such a method, along with the corresponding software tool, will be introduced in this paper. The proposed solution is based on earlier results from a SFOE-funded research project [1]. The existing calculation tool has been improved (user friendliness, default values) and extended to building technology systems other than BACS. The existing tool and related results have been described in several, former publications [1], [2], [3], [4], [5], [6]. The remainder of the paper is organized as follows. In Section 2 the main features of the calculation method are reviewed. In Section 3 additional details about the method are provided. Finally, some conclusions are drawn in Section 4.

2. Features of the calculation method
The proposed calculation method has the following features.

- **Generic method.** The calculation method is generic. It applies to any kind of building technology systems, i.e. heating, cooling, venting, lightning, shading etc. This is needed to ensure wide acceptance by the target audience, namely building technology planners.

- **Proper modelling of power losses.** Power losses in electricity supplies and similar devices at nominal load are usually comprised between 10 to 15%. At low-load regimes, losses may even exceed 50%, as shown by measurements reported in [1] (p. 18). Since the design of electricity supplies for output power is usually generous, losses way above 10-15% are to be expected in practice. It is therefore important to model losses appropriately.

- **Exhaustive consideration of electrical loads and supplies.** All electrical loads in the system are factored in, including loads that are powered by bus systems. Also, it is also possible to define several power inputs for a single device.
• **Lean data provision.** To this end, the following has been ensured: (a) Small number of input quantities; (b) Small number of attributes for each input quantity; (c) Readily available input data (e.g., from datasheets, reference tables).

• **Wide scope.** The calculation method can be applied in early planning phases up to execution.

• **Extensive analyses.** The method allows for various, automated analyses of the data.

### 3. Details

Table 1 summarizes the main features of the proposed method, along with the means used to achieve them. Additional details are discussed in Sections 3.1 and 3.2.

**Table 1.** Features of the proposed calculation method and corresponding means.

| Feature                        | Means                                                                 |
|--------------------------------|----------------------------------------------------------------------|
| Generic method                 | Same device model, irrespective of device (Section 3.1) Method entirely based on internal electricity consumption of devices (Section 3.1.1) |
| Proper modelling of power losses | Depiction of power supply topology (Section 3.2) Power losses approximated as linear function of the output power (Section 3.1.1) |
| Exhaustive consideration of electrical loads | Several electrical inputs allowed per device (Section 3.1.1) |
| Lean data provision            | Small number of input quantities: Each device only needs to be specified once, independently from the number of occurrences in the system\(^a\). Small number of attributes for each input quantity:  
  • Mean value of electrical power (Section 3.1.2)  
  • Two operating states: "active" and "standby" (Section 3.1.1) Readily available input data: The data basis is provided by the number of field devices (quantity structure). This is readily available from building technology planners. |
| Wide scope                     | The data basis may be refined throughout the different planning phases. |
| Extensive analyses             | The input data comprise classification tags (*categories*) that are used for automated analyses. The main categories are:  
  • BACS vs. non-BACS\(^b\)  
  • BACS-level: Field, Automation, Management  
  • Craft: heating, cooling, venting, lightning, shading etc.  
  • Device type: actuator, sensor, power supply, control unit etc. |

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\(^a\)This is true as long as all occurrences of the device under consideration are powered by a device whose occurrences are identical amongst themselves as well.

\(^b\)The system boundary between BACS and non-BACS devices is defined by the user. Therefore, various definitions of this boundary can be accounted for.

### 3.1. Device model

#### 3.1.1. Internal electricity consumption and operating state

The calculation method is based on the internal electricity consumption of building technology devices. Note that the internal electricity consumption is mainly released as heat – usually after several transformation stages.

In the proposed solution, devices with power inputs as well as outputs (Figure 1 and Figure 2) are characterized by two consumption models: (1) Fixed internal consumption; (2) Internal consumption depends linearly on the output power. Either of these models as well as their combined use ((1) & (2)) is applicable. In case of the combined model, the nominal power output of the device must be indicated.
When the linear model is used, the efficiency factor $\eta$ of the device must be specified. For power supply units, the combined model is typically used. Each device may further have as many supply inputs as needed. Two types of power supply are available (Figure 2):

- **Main input.** The power from the main supply may be transferred partially or completely to further devices via the output, possibly after some transformation (e.g. voltage, AC/DC or via bus-connections). Only one main supply is allowed for each device in order to limit the total number of input quantities. Without this restriction, one would have to specify the power ratio from different main inputs in the resulting output power.

- **Secondary input.** The power from secondary inputs is fully consumed by the connected device.

In additions to the above types of input, two operating states are defined: **active** and **standby**. The active state is for instance the state of a drive whose motor is moving. For each input, the fraction of time spent in the active state must be defined. The sum of time spent in active state plus time spent in standby state corresponds to the total timespan under consideration (for instance one year). The consumption model parameters that are available are summarized in Figure 3.

3.1.2. **Mean power**

All power values (input, output and internal power consumption in Figure 1 and Figure 2) are indicated by their mean value rather than actual time series. Mean values are easier to determine whilst being adequate for our purposes.

The input power is (a) equal to the user given internal power consumption (weighted by the time ratio spent in both operating states, active and standby) for devices without output (field devices) and (b) a computed value for devices with an output (supplies). The output power is always a computed value. It is equal to the sum of all subsequent inputs, weighted by the time ratio spent in both operating states.

3.2. **Power supply topology and calculation method**

3.2.1. **Power supply topology**

The losses of a power supply unit (and other devices with similar purpose) are notably dependent on its output power. Therefore, the output power of each device needs to be accounted for by the calculation method. This means in turn that the method must know the power supply topology (supply tree) of the system under consideration.

In practice, several supply methods are possible:

- Direct supply by the power grid (possibly through relays, triacs…)
- Supply by an external power supply (direct or through relays, triacs…)
- Supply by a communication bus, exclusively or in addition to the above supply methods.
To model the above supply methods, two types of power input are available as mentioned in Section 3.1.1, namely main input and secondary input. The main input must be indicated for every device, while secondary inputs are optional. A sample topology is depicted in Figure 4. This represents the power supply tree of a building technology system. Note that both types of power input have been used here.

Figure 4. Power supply topology of a building technology system. Each box depicts one device. The number of occurrences of each device is indicated by \( n \).

The power supply topology can further be visualized in the calculation tool (Section 3.3). This allows one to easily check the topology and to visualize input quantities and results at their respective locations.

### 3.2.2. Calculation method

The calculation starts at the bottom of the tree, where devices without any output are located (field devices). For those devices, the total power consumption is equal to the internal power consumption, as indicated by the current operating state. The total average power consumption is then given by the time-weighted sum of the consumption at both operating states.

The so-computed consumption is then passed on to the devices located one level above the initial device within the supply tree. For these devices, the average power is again computed according to Section 3.1.2. This process is repeated recursively until the top of the supply tree has been reached.

### 3.3. Excel-Implementation

The proposed calculation method has been implanted using Microsoft Excel. The actual calculation operations have thereby been specified in Visual Basic. The tool acquires all input quantities, displays the power supply topology, and it automatically performs and visualizes various analyses. Two examples are shown below: In Figure 5, for BACS the yearly power consumption per square meter is displayed for different crafts (at left) and sorted by device type (at right). Note that similar figures can be generated for non-BACS.
Figure 5. Yearly power consumption (BACS) sorted by building technology craft (at left) and sorted by device type (at right).

4. Discussion and outlook
A calculation method and corresponding software tool have been proposed for the calculation of the electricity consumption of building technology systems. The solution exhibits various, desirable features which make it powerful and consistent whilst easy to use in practice. The main challenge for users lies in gathering all the necessary product data. Often, consumption values and efficiency factors are inexactly specified or missing entirely. One should seek for a unified representation of such data. In the future, the method and tool described in this paper shall be adapted to the needs of and made available to building technology planners.

In view of the trend Internet of Things (IoT), in buildings the number of electrical devices is expected to be growing – many of these operate continuously in the active state or at least in standby. Thus, in the planning phase the usage of such calculation tool becomes increasingly important.

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