PUBLIC DOCUMENT

Service Contract ENER/C3/2017-437/SI2-785.185

SUPPORT THE DISSEMINATION AND ROLL-OUT OF THE SET OF ENERGY PERFORMANCE OF BUILDING STANDARDS DEVELOPED UNDER EC MANDATE M/480

Report on Case Study to EN ISO 52016-1 – Heating and cooling needs and internal temperatures

October 31th, 2021

Prepared by Dick van Dijk with contributions by the Project Team

Project Leader and contact point:

Mr Jaap (J.J.N.M.) Hogeling

Stichting ISSO

Weena 505, NL 3013 AL Rotterdam, The Netherlands

PO Box 577, NL 3000 AN Rotterdam, The Netherlands

T: Mobile: +31 65 31 61 973 |

E: j.hogeling@isso.nl

This document has been produced under contract with the European Commission (service contract ENER/C3/2017-437/S12-785.185).

Contents

Page

Abbreviations and acronyms in this document:

CEN	**European standards organization**
EN	**European standard**
EPBD	**Energy Performance of Buildings Directive**
EPB standard	**Standard for the calculation of energy performance of buildings, that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629 or later updates**
ISO	**International organization for standardization**
MS	**EU Member State(s)**
NA (/ND)	**National Annex or National Datasheet for EPB standards**
NSB	**National Standards Body of CEN and/or ISO**
TRY	**Test Reference Year**
TMY	**Typical Meteorological Year**
TR	**Technical report (of CEN and/or ISO)**

1 Introduction

This document presents the case study on EN ISO 52016-1:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*.

The case study makes use of the spreadsheet tool that has been developed to demonstrate the calculation procedures and to perform example calculations.

One of the aims of the study is to show that the choice for hourly instead of monthly calculation procedures (both are covered in EN ISO 52016-1 and in the spreadsheet) does not require extra input data. On the contrary: the input and procedures (e.g. on the control of solar blinds, on the impact of undersized systems, on intermittent heating) is much more straightforward and the output is richer: e.g. includes a score on thermal comfort. Variations illustrate the sensitivity.

Also illustrated: the impact of less crucial but still influential details for which at national level one has to decide whether default values would be suitable or not.

Most of the work has been applied in the frame of webinars from the EPB Center, recordings of which are available under [5]. This document gives an overview.

2 Executive summary

The basic cases study calculations were performed for use at the webinar presentations on various subjects related to EN ISO 52016-1 and in particular for the webinars 7-10 with example cases. The final set of case study calculations on this standard could only be started when all required tools and conventions were sufficiently developed, which was in summer 2020.

The calculations have been performed for the single-family house. Also, some calculations were performed on a simple office room, in order to demonstrate the impact of different patterns of use, like optional night or day time temperature set back (residential), office hours and weekend interruption (office). This affects not only the temperature settings, but also the thermal comfort scores (only relevant during presence of occupants), and also the required and assumed ventilation, internal heat gains and operation of movable blinds.

The calculations were performed for the three selected climates, with evidently quite different balance between heating and cooling needs.

One of the assets of EN ISO 52016-1 is that it contains both a monthly and an hourly calculation procedure. The hourly calculation procedure has been tailored to ensure that the number of input data that the user needs to gather is kept the same as for the monthly calculation procedures. In this way, this paves the way for (more) countries to take the decision to move from the monthly to the hourly calculation procedures (which is one of the important choices for the National Annex / National Datasheet).

In the case study this is clearly demonstrated. It is also shown that the methodology is much more straightforward and transparent in case of hourly calculation procedures. Where the monthly calculation procedures require series of tabulated correction factors for the impact of hourly varying phenomena on the monthly energy balance, the hourly calculation procedures simply use directly the hourly variations in the calculation of the energy balance.

This is the case for the control of solar blinds at different orientations, for the impact of thermal (building) mass, for the impact of undersized systems, for intermittent heating and cooling, solar and internal gains, ventilation (e.g. ventilative cooling), etc.

The link to the Use Profile Generator based on EN 16798-1 has been demonstrated. This link is important, because it contributes to the overall consistency and transparency of the calculations.

Also a few calculations have been done to demonstrate the dynamic (hourly) interaction between the calculated energy need for heating and the performance of a heat pump system (acc. To EN 15316-4-2): the performance and capacity of the heat pump system is a function of the energy need, but –in turn- if the capacity is not sufficient, the energy need is not satisfied and the temperature does not reach the required set point. This feature requires further optimization (of calculation run time) to enable practical calculations. However, the purpose was not to replace or mimic a software tool, but to demonstrate that the connections between these EPB standards, exchanging input and output on an hour-by-hour basis, are working and enable to take into account realistic dynamic interactions between building, users, climate and systems.

Special attention has been paid to the demonstration of the control of movable solar shading provisions on windows. With the new feature in the spreadsheet various control scenarios can be easily modelled and tested, with impact on energy and thermal comfort.. This new feature is important, because the solar heat gains through the window(s) without solar shading provision are often quite high and applying a time-average (e.g. monthly) reduction factor does not show the strong advantages of choosing hourly instead of monthly calculation intervals for EN ISO 52016-1. This new feature will also be very useful to test and further develop the new standard prEN ISO/DIS 52016-3 on adaptive building envelope elements that is currently being prepared.

A returning element in the demonstrations is the impact not only on the energy needs, but also on the thermal comfort. This has become more important, knowing that the preferred choice in many countries seem to be the principle of “presence of system" (one of the key choices in EN ISO 52000-1): the energy performance calculation is based on the actual system, also if the system is undersized or even absent. In such a case the (calculated and actual) energy performance benefits from the small or absent system, at the cost of thermal comfort. So, the thermal comfort score is a key indicator complementing the EP score.

The calculations also demonstrate, with a few ‘anecdotic’ examples, the impact of less crucial but still influential details for which at national level one has to decide whether default values would be suitable or not. For instance: for which climates it is relevant to take into account the actual colour (solar absorptivity) of the external construction, instead of a default value.

The spreadsheet tool, updated as part of the Service Contract, is publicly available since Nov. 2019. However, a further updated version with additional functionalities as developed for and used in this and other case studies will be completed and is expected to be published spring 2022.

3 The context of the case study

ISO 52016-1:2017 specifies procedures for the calculation of the sensible and latent energy needs for heating and cooling and the internal temperatures and humidity of a thermal zone in a building.

The heating and cooling needs and internal temperatures involves some complex physical phenomena. This is reflected in the calculation procedures in EN ISO 52016-1. And consequently the spreadsheet tool also contains many details that make it more difficult to use than most other spreadsheets in the series.

Note that it is not the intention of this case study to explain the calculation procedure of the standard in full detail. This is extensively done in the technical report that accompanies the standard: CEN ISO/TR 52016-2.

4 Coverage of the scope

4.1 Introduction

4.1.1 Scope of the standard

The EPB standard EN ISO 52016-1 specifies calculation methods for the assessment of:

a) the (sensible) energy need for heating and cooling, based on hourly or monthly calculations;

b) the latent energy need for (de-)humidification, based on hourly or monthly calculations;

c) the internal temperature, based on hourly calculations;

d) the sensible heating and cooling load, based on hourly calculations;

e) the moisture and latent heat load for (de-)humidification, based on hourly calculations;

f) the design sensible heating or cooling load and design latent heat load using an hourly calculation interval;

g) the conditions of the supply air to provide the necessary humidification and dehumidification.

The calculation methods can be used for residential or non-residential buildings, or a part of it, referred to as “the building” or the "assessed object".

This document also contains specifications for the assessment of thermal zones in the building or in the part of a building. The calculations are performed per thermal zone. In the calculations, the thermal zones can be assumed to be thermally coupled or not.

The calculation methods have been developed for the calculation of the basic energy loads and needs, without interaction with specific technical building systems, and for the calculation of the system specific energy loads and needs, including the interaction with specific systems. The hourly calculation procedures can also be used as basis for calculations with more extensive system control options.

This document is applicable to buildings at the design stage, to new buildings after construction and to existing buildings in the use phase.

4.1.2 Scope of this case study

The calculation of **moisture and latent heat loads and needs** is covered in the spreadsheet, but is not specifically investigated in this case study. Of course, it has been subject to testing during the preparation of the standard and as part of the development of the spreadsheet.

Thermal zoning is not included in the spreadsheet: the spreadsheet calculates the hourly or monthly energy balance for a single zone. Results from different spreadsheet calculations can be combined to provide the result for a multi-zone building, if it is assumed (which is a choice that can be made at national level) that the zones are not thermally coupled. This is however not included in this case study.

The case studies on the whole building calculation include multi-zone calculations, calculated with an appropriate software tool.

The standard contains both a **monthly and an hourly calculation procedure**. The hourly calculation procedure has been tailored to ensure that the number of input data that the user needs to gather is kept the same as for the monthly calculation procedures. In this way, this paves the way for (more) countries to take the decision to move from the monthly to the hourly calculation procedures (which is one of the important national choices to make. This is also clearly demonstrated in the spreadsheet, in which both the monthly and the hourly calculation procedures are included.

This case study is focused on the **hourly calculation procedures**.

The hourly calculation procedures can be used to generate or validate correlation factors for the monthly calculation procedures, as illustrated in Figure 1.

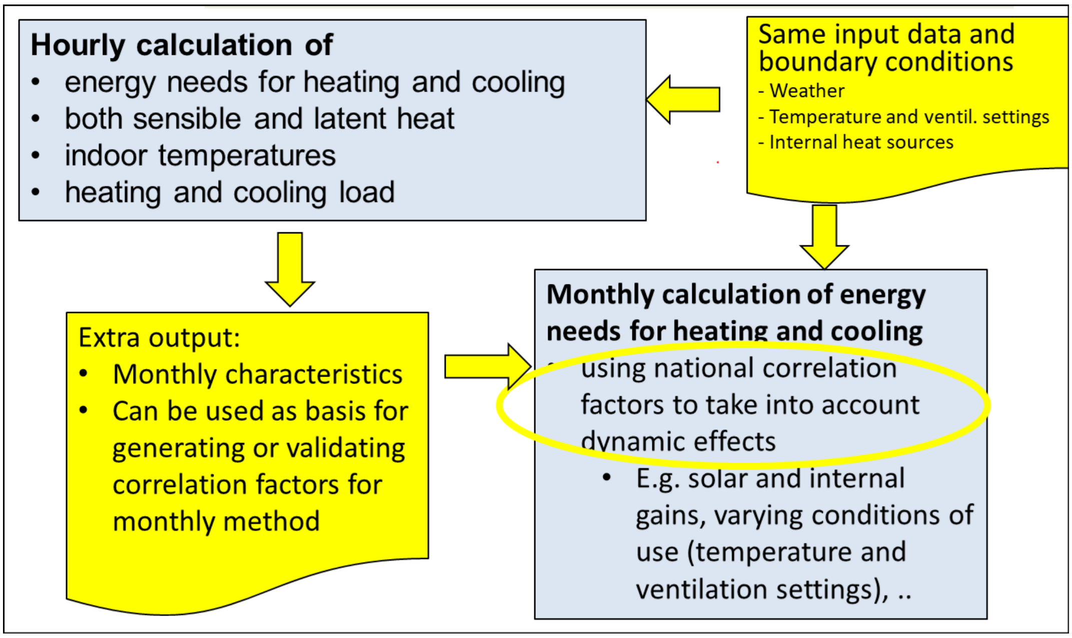


Figure 1 - Illustration of the link between hourly and monthly calculation procedures in EN ISO 52016-1

More background information on the monthly calculation method, relevant for the understanding of the scope of this study, is given below (4.1.3).

One of the bottle necks for choosing an hourly calculation procedure could be the absence of **hourly climatic datasets** for a specific location. The case study on climatic data (EN ISO 52010-1, [7]) shows that this is no longer a problem, thanks to the TMY weather data generator developed and published by JRC.

Some couplings with other spreadsheets in the series are included, to demonstrate the calculation of the **system specific energy loads and needs**, including the interaction with specific systems, which is within the scope of the standard, as shown above (4.1.1).

The **spreadsheet** developed to demonstrate EN ISO 52016-1 is primarily intended to validate and demonstrate the standard in a **transparent** way. In the spreadsheet, each step in the calculation can be followed.

As a result, the spreadsheet is not suited (but also not intended) for use in daily practice.

In any case, for use in the daily practice of EPB assessment, **a software tool** will be needed, with user-friendly interface and connecting the different modules for the overall EPB calculation. The spreadsheet is very suitable for software developers to check the calculation algorithms in their programs.

4.1.3 Monthly calculation procedures

The monthly calculation procedures contain various correlation factors, as a rule derived from series of runs with an hourly calculation method, to account for the dynamic hourly variations and interactions that cannot be taken into account in a direct way (cf Figure 1). So the accuracy of the monthly calculation procedures depends on the validity of the correlation factors for a given case (climate, building type, use, ..).

Moreover, for several aspects, the monthly calculation procedures are more complex and less transparent than the hourly. For instance: on the temperature settings (including weekend interruption for an office building, or night time temperature setback for a dwelling), for the assumed control of movable solar shading at different orientation and different season. With the hourly calculation procedures, the input and impact can be assessed directly for each hour. The monthly calculation procedures also fall short when it comes to the assessment of thermal comfort problems in case of absent or undersized systems.

More information:

Webinar 4, May 26, 2020, *Energy need and indoor temperatures calculation: hourly or monthly?*, Dick van Dijk (see [5])

4.2 Coupling and complementing

4.2.1 Introduction

To facilitate the use of the spreadsheet and to test specific links with other EPB standards, links have been created with the most relevant other spreadsheets in the series.

Some links are straightforward, **one-directional input-output relations**. These are introduced in 4.2.2.

Other couplings are a little **bit more complex**, because they involve hourly interactions. In some cases the hourly interactions can be dealt with by adding the relevant equations from another module into the spreadsheet tool for EN ISO 52016-1. See 4.2.3

If there are hourly interactions with other modules that are **more complex**, then two spreadsheets need to be run as a couple, exchanging input and output on an hourly basis. See 4.2.4. Spreadsheets are not the most appropriate type of tools for such dynamic coupling, in particular in case of hourly calculations covering a full year.

One should keep in mind, though, that such couplings **do not intend to replace a software tool**. The sole intention is to illustrate and demonstrate the calculation procedures and to lay a basis for reference calculation cases e.g. to validate software tools.

4.2.2 Straightforward input-output links

Simple, one-directional links have been created with the spreadsheet that generates **climatic datasets** (see case study on EN ISO 52010-1 [7]) and the spreadsheet that generates a full year of **hourly operation schedules and conditions of use** (see case study on EN 16798-1 [9]).

Both links are important, because they contribute to the overall consistency and transparency of the EP calculations.

See Figure 2. As Figure 2 shows, there is a direct and an indirect link with the climatic data. The indirect link is via the dedicated spreadsheet to calculate the solar shading reduction factor for external obstacles, according to EN ISO 52016-1, Annex F. The latter is covered in a separate case study [8].

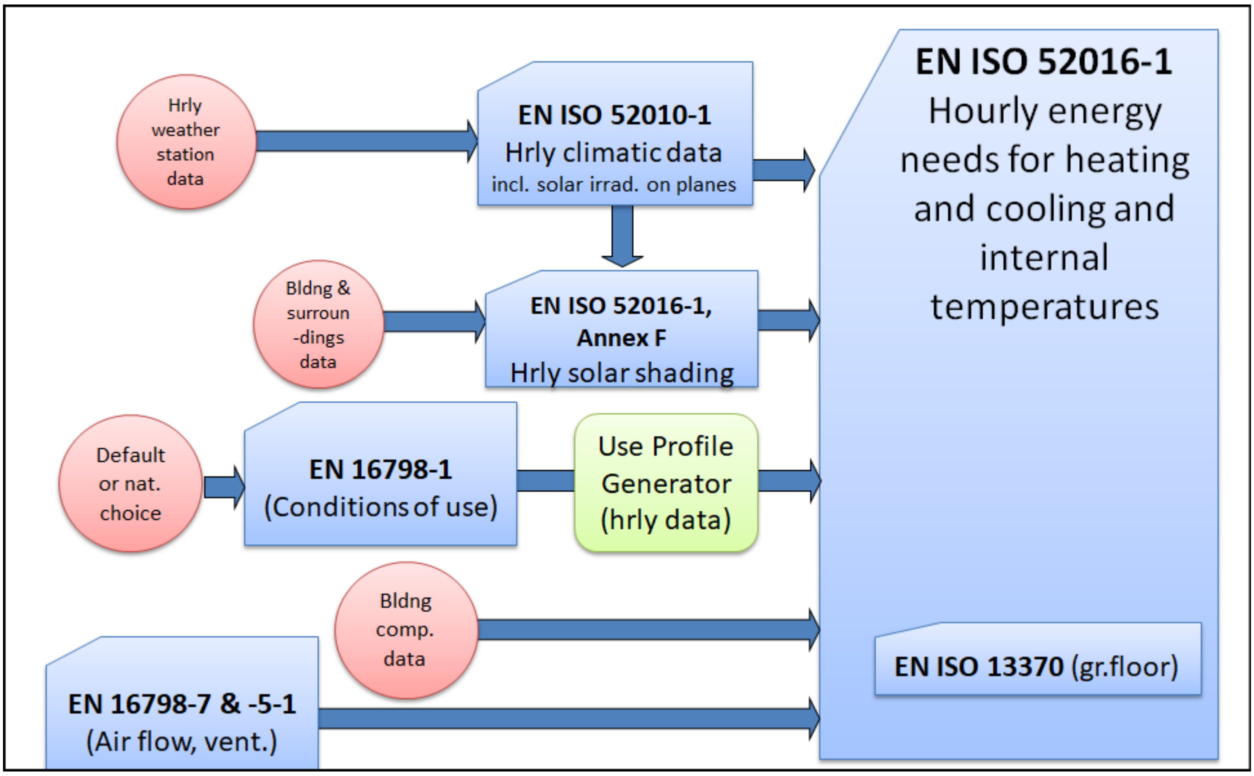


Figure 2 - The climatic datasets based on EN ISO 52010-1 and the use profiles based on EN 16798-1 as input for EN ISO 52016-1

4.2.3 Add on calculations

One example of an "add on" calculation is the calculation of the **heat transmission through a ground floor**. EN ISO 13370:2017 provides the calculation procedures for this, for monthly and for hourly calculations. However, there are links, on an hourly basis, with the calculation of the energy balance according to EN ISO 52016-1. Therefore, the calculation according to EN ISO 13370 has been fully incorporated in the spreadsheet of EN ISO 52016-1 as shown in Figure 2 above, already since its first version.

Another example is the calculation of **ventilative cooling**. A special sheet has been added to the spreadsheet of EN ISO 52016-1 with rules, as function of the outdoor conditions and e.g. the calculated operative temperature and cooling load, that can overrule the assumed air flow rate in case the conditions are favourable for applying ventilative cooling. In this special sheet such rules can be specified and modified easily, for testing and demonstration.

This simple 'add on' sheet is possible with the simplifying assumption that the air flow rates are known, with different values as function of the time of the day or assumed occupation and some known higher value for ventilative cooling.

For assessing the actual air flow rates, a coupling with the spreadsheet with EN 16798-7 (air flow rates) is needed, in which case we are on the next level: see 4.2.4

A third important application of an 'add on' sheet is for **movable shading devices** or similar **adaptive building envelope elements**. A new EPB standard is in preparation (EN ISO 52016-3) that deals specifically with the integration of adaptive building envelope elements in the calculation of EN ISO 52016-1, including reference control scenario's. In this add on sheet these control scenarios can be specified and tested. The (hourly) output is a change of state of the adaptive element, so a change in thermal and solar properties, that overrules the fixed input values that are otherwise used.

More explanation and illustration is given in 6.1 (Calculation tools).

4.2.4 Dynamic coupling between two spreadsheets

This concerns two spreadsheets that need to be run as a couple, exchanging input and output each hour during the calculation.

The spreadsheet on EN ISO 52016-1 has been pre-prepared to enable such couplings in a generic way. However, depending on the data that are exchanged some ad hoc adaptations are needed as a rule to make such a coupling operational.

First exercises applying such dynamic links are presented in this case study, for the coupling with heat pump systems (EN 15316-4-2).

But this and similar ways of coupling with the calculation of EN ISO 52016-1 was investigated, tested and reported in the case study on natural ventilation [10] and in the case study on heat pump systems [11].

More explanation and illustration is given in 6.1 (Calculation tools).

5 Definition of the cases

5.1 Rationale of the selection of cases

The cases have been selected to demonstrate various effects. It is obvious that for a calculation in which so many parameters are involved, the focus needs to be on the most important factors, from the point of view of the criteria: completeness, functionality, sensitivity and usability.

Therefore the following factors are considered:

- Space type (residential, office)
- Climate (cold, moderate, warm)
- Operation and use profile (e.g. temperature settings, occupancy)
- Unlimited system versus undersized or absent system (impact on energy needs and on thermal comfort)
- Operation of movable blinds (large effect, dynamics involved)
- Ventilative cooling (special dynamics involved)
- Dynamic (hourly) coupling to heat pump system calculation
- Selected other variations (just to show that apparently minor details may also have a significant effect)

There are no separate cases specified to demonstrate the differences between the hourly and monthly calculation procedures, but for many of the test cases the advantages of the hourly method are explained and shown.

5.2 Sources of input data

5.2.1 Building types

- single-family house (SFH)
- simple office room (SOR)

similar as for the other case studies (see [6]); because of the difference in building type and pattern of use. Most calculations have been done with SFH.

5.2.2 Climates

- Oslo
- Strasbourg
- Athens

similar as for the other case studies (see [6] and [7]).; because of the evidently quite different balance between heating and cooling needs; the difference in solar radiation intensity and solar angle is also an interesting parameter in itself.

5.2.3 Operation and use profile

- Night or day time temperature set back (residential)
- Office hours and weekend interruption (office).

The pattern of use affects not only the temperature settings, but also the thermal comfort scores (only relevant during presence of occupants), and also the required and assumed ventilation, internal heat gains and operation of movable blinds.

A fully operational version of the use profile generator based on EN 16798-1 (see case study on EN 16798-1, [9]) was only available at the end of the project. The ue profile generator can produce output for various types of spaces. One of the sheets with output data is tailored to be fit as input for EN ISO 52016-1. It can be simply copied and pasted into the input data sheet of the EN ISO 52016-1 spreadsheet.

The link to the Use Profile Generator based on EN 16798-1 is important, because it contributes to the overall consistency and transparency of the calculations. Before, the operation and use profile was a tabulated.

5.2.4 System presence and size

- Unlimited heating or cooling system size
- Undersized heating or cooling system
- Absent heating or cooling system

This has an impact not only on the energy needs, but also on the thermal comfort.

This has become more important, knowing that the preferred choice in many countries seem to be the principle of “presence of system" (one of the key choices in EN ISO 52000-1): the energy performance calculation is based on the actual system, also if the system is undersized or even absent. In such a case the (calculated and actual) energy performance benefits from the small or absent system, at the cost of thermal comfort. So, the thermal comfort score is a key indicator complementing the EP score.

EN ISO 52016-1 has the option to perform the calculation in a so-called specific system mode: taking into account for instance (fixed or hourly varying) system size and the heat gain from (hourly) system losses.

5.2.5 Control of movable blinds

- Solar shading provision absent
- Solar shading provision in fixed position
- Movable solar shading provision, with different control scenarios

Special attention has been paid to the demonstration of the control of movable solar shading provisions on windows.

With a new feature in the spreadsheet various control scenarios can be easily modelled and tested, with impact on energy and thermal comfort. This new feature is important, because the solar heat gains through the window(s) without solar shading provision are often quite high and applying a time-average (e.g. monthly) reduction factor does not show the strong advantages of choosing hourly instead of monthly calculation intervals for EN ISO 52016-1. This new feature will also be very useful to test and further develop the new standard prEN ISO/DIS 52016-3 on adaptive building envelope elements that is currently being prepared.

5.2.6 Ventilative cooling

Another example is the calculation of **ventilative cooling**. A special sheet has been added to the spreadsheet of EN ISO 52016-1 with rules, as function of the outdoor conditions and e.g. the calculated operative temperature and cooling load, that can overrule the assumed air flow rate in case the conditions are favourable for applying ventilative cooling. In this special sheet such rules can be specified and modified easily, for testing and demonstration.

With the simple 'add on' sheet introduced in 4.2.3, it is possible to demonstrate the impact of ventilative cooling (with some simplifying assumptions as explained in 4.2.3.

5.2.7 Dynamic coupling to heat pump systems

The performance and capacity of the heat pump system is a function of the energy need, but –in turn- if the capacity is not sufficient, the energy need is not satisfied and the temperature does not reach the required set point. An ad hoc dynamic coupling is made to the spreadsheet on EN 15316-4-2 on heat pump systems.

This feature requires further optimization (of calculation run time) to enable practical calculations. However, the purpose was not to replace or mimic a software tool, but to demonstrate that the connections between these EPB standards, exchanging input and output on an hour-by-hour basis, are working and enable to take into account realistic dynamic interactions between building, users, climate and systems. See 6.1.2 for details.

5.2.8 Selected other variations

- Solar absorptivity of external surfaces: default value
- Solar absorptivity of external surfaces: different colours

This calculation aims to demonstrate, with an 'anecdotic' example, the impact of less crucial but still influential details for which at national level one has to decide whether default values would be suitable or not. For instance: for which climates it is relevant to take into account the actual colour (solar absorptivity) of the external construction, instead of a default value.

5.3 List of selected cases and variants

The following cases have been specified, each with specific variants that are explained with the results (6.2.2).

1. Base variations: climate (cold, moderate, warm), insulation level, space type (residential, office) (also varied in the other cases below), operation and use profile (e.g. temperature settings, occupancy)
2. Unlimited system versus undersized or absent system (impact on energy needs and on thermal comfort)
3. Operation of movable blinds (large effect, dynamics involved)
4. Ventilative cooling (special dynamics involved)
5. Dynamic (hourly) coupling to heat pump system calculation
6. Selected other variations (just to show that apparently minor details may also have a significant effect)

6 Calculation details

6.1 Calculation tools

6.1.1 EN ISO 52016-1 spreadsheet

6.1.1.1 Introduction

The latest version of the spreadsheet about EN ISO 52016-1 was prepared under the Service Contract with DG ENERGY and published in November 2019.

Link: https://epb.center/support/documents/demo-en-iso-52016-1/

However, for the cases studies the spreadsheet has again been significantly updated. The updating requires some final checking and cleaning before it can be published. The publication (at the EPB Center website) is expected spring 2022.

6.1.1.2 Explanation and demonstration

6.1.1.2.1 General

The very extensive spreadsheet on EN ISO 52016-1 has been updated under the Service Contract and published in Nov. 2019.

This spreadsheet tool covers an important ’core’ calculation of the whole EP calculation, requiring many input data on building components, conditions of use and climatic conditions. It had been found very problematic that all these input data are integrated in (different sections of) the Excel file: each time that the Excel (calculation) file is updated, the input data of each case have to be successively copied to the new file.

In the version of Nov. 2019 the input data can be read from a separate file, which enables now an easy exchange and archiving of cases.

Main features:

This spreadsheet comprises a full annual calculation of the heating and cooling needs.

With both the hourly and the monthly calculation method given in ISO 52016-1:2017

Most input data for both methods are identical or similar, as demonstrated in the sheet "Method_input"

The side-by-side calculation using both methods enables comparison of both methods.

The hourly method can also be used to develop or validate the correlation factors for the monthly method.

For that purpose the hourly method produces key monthly parameter values

Ground floor:

The calculation of the thermal transmission through the ground floor according to ISO 13370:2017

has been fully integrated in this spreadsheet (both for the hourly and monthly method).

Otherwise, a manual transfer of monthly output from the ISO 13370 spreadheet would have been required.

Time intervals and period:

This hourly (and monthly) calculation covers a full year of hourly and monthly calculations, in parallel

Main limitations:

- Only single thermal zone
- Work in progress: create separate spreadsheet for solar shading calculation and make link to this spreadsheet
- No adjacent thermally unconditioned zones (incl. sunspaces) foreseen

Protection:

The macro and formulae have been protected against editing.

The main reason is to prevent uncontrolled use and to keep technical support manageable

Why a macro?

The hourly calculation of the thermal balance in the building (zone) is a matrix calculation involving each individual building elements with each element divided in layers (see ISO 52016-1).

This part of the hourly calculation (including the calculation of heating and coolings needs) is done via a macro.

The communication between macro and sheets is time consuming, for a calculation covering a full year. Therefore, the dynamic interactions (e.g. interventions based on calculated temperature and or energy need) are kept to a minimum.

Besides, this would require interaction with other EPB standards (e.g.: night time ventilation as free cooling). With such interactions, the differences between the hourly and monthly method will be more emphasized

More information:

CEN ISO/TR 52016-2, Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 2: Explanation and justification of ISO 52016-1 and ISO 52017-1. Published June 2017

https://epb.center/support/documents/iso-52016-1/

includes also links to published articles and more

Links: https://epb.center/support/documents/isotr-52016-2/

New update in preparation:

New features in this -again- significantly updated version (planned to be published spring 2022):

- Application with an integration of a simplified integration of **ventilative cooling** has been developed for the purpose of the demonstration of the value of an hourly calculation (referred to in some of the webinars, see Task 3.2 in section 6.1).

- The facility for the **coupling with other EPB standards** (such as EN 15316-4-2 for the hourly calculation of heat pumps systems and EN 16798-7 for the hourly calculation of natural and mechanical ventilation has been introduced and also used in several case studies, demonstrated in webinars and reports. This feature requires further optimization (of calculation run time) to enable practical calculations. However, the purpose was not to replace or mimic a software tool, but to demonstrate that the connections between these EPB standards, exchanging input and output on an hour-by-hour basis, are working and enable to take into account realistic dynamic interactions between building, users, climate and systems.
- For this kind of dynamic (hourly) coupling with systems, a **variable (hourly) maximum system capacity** has been added to the features of the spreadsheet.
- The adoption of the **output of the Use Profile Generator** that replaces the input in the form of hourly user schedules based on a weekly schedule.
  Where applicable, also the monthly method is based on these use patterns (by using the annual mean values).
  This link to EN 16798-1 is important, because it contributes to the overall consistency and transparency of the calculations. Moreover, the Use Profile Generator is very versatile.
- Integration of a **special sheet with control scenarios for movable solar shading provisions** on windows. Also this new feature is important, because the solar heat gains through the window(s) without solar shading provision are often quite high and applying a time-average (e.g. monthly) reduction factor does not show the strong advantages of choosing hourly instead of monthly calculation intervals for EN ISO 52016-1. This new feature will also be very useful to test and further develop the new standard prEN ISO/DIS 52016-3 on adaptive building envelope elements that is currently being prepared.
- **Thermal comfort score** in the output of the calculation, based on -for hours during occupation when thermal comfort is required- the number of hours that specific indoor operative temperatures are exceeded. This has become more important, knowing that the preferred choice in many countries seem to be the principle of "presence of system" (one of the key choices in EN ISO 52000-1): the energy performance calculation is based on the actual system, also if the system is undersized or even absent. In such a case the (calculated and actual) energy performance benefits from the small or absent system, at the cost of thermal comfort. So the thermal comfort score is a key indicator complementing the EP score.
- In preparation is also the option to choose **a dynamic thermal comfort requirement**, adapted to the outdoor air temperature (as described in EN 16798-1). For buildings with natural cooling this is an important option to create a level playing field with mechanical cooling, in terms of energy and thermal comfort.

Brief overview of all sheets in this spreadsheet:

This overview gives an impression of the types of input, calculations, intermediate results and output of the spreadsheet

Sheet	Description
INFO	Common info for all EPB spreadsheets, including DISCLAIMER
Explanation	Explanation on this spreadsheet on ISO 52016-1
Method_input	Tabulated overview of all input data, according to common template for all EPB spreadsheets
Input_GrFl	Extra, integrated: Tabulated overview of all input data for ISO 13370 (ground floor th transmission), according to common template for all EPB spreadsheets
Calc_GrFl	Extra, integrated: Step-by-step calculation acc to ISO 13370 (ground floor th transmission), according to common template for all EPB spreadsheets
Method_calculation	Step-by-step calculation, according to common template for all EPB spreadsheets. But partly executed via a macro, see above
Method_output	Tabulated overview of all output data, according to common template for all EPB spreadsheets
Input_0	Input to control the calculation parameters, to fill the data for the building elements; plus processing to prepare the equations
Input_p	Input of hourly varying input data for conditions of use, copied from Use Profile Generator (based on EN 16798-1)
Input_t	Input of hourly varying input data: actually no direct input, but data processed on the basis of the input data. But for some quantities, this sheet enables to introduce hourly varying input data, e.g. responding to the situation (dynamic). However: this may require modification of the macro used to solve the matrix and may slow down the calculation significantly, due to the data traffic between macro and sheets
Calc_H_m	Monthly method: calculation of heating need, including results
Calc_C_m	Monthly method: calculation of cooling need, including results
Graphs	Graphical output
Clipboard	Sheet to store e.g. Screendumps of graphs, for comparison
Output_m	Monthly and weekly calculation results derived from the hourly calculation, plus some post-processing, including key parameters comparison monthly method
Output_t	Hourly calculation and results, some output data are calculated via the macro to solve the matrix
ClimDat_m	Monthly climatic data (in this spreadsheet derived from the hourly data)
Climat_t	Hourly climatic input data

CalcShad	Solar shading by obstacles and overhangs
AdaptW	Special sheet: Windows with hourly adaptive thermal and solar properties (draft prEN ISO/DIS 52016-3)
EN_16798-7	Special sheet: dynamic link to XLS on EN_16798-1
DynamVent	Special sheet: dynamic calc ventilative cooling
EN_15316-4-2	Special sheet: dynamic link to XLS on EN_15316-4-2

6.1.1.2.2 Input data

An important feature of the spreadsheet (since Nov. 2019) is that the input data, with one 'push button' can be imported from a separate Excel file. At the same time the spreadsheet can still be used as stand-alone file to make minor variations in the input manually.

Figure 2 in 4.2 already showed which types of input data are needed.

Building component data:

For hourly calculation no more input data needed than for monthly calculation

- Each opaque construction:
  - Area
  - Orientation&tilt
  - *R*-value (**EN ISO 13789**)
  - Solar absorptance external surface
  - Type of construction (heavy, light; homogeneous, sandwich, ..)
- Ground floor:
  - Same, but few extra data (e.g. ground properties), depending on floor type (**EN ISO 13370**): *also for hourly calculation (ground inertia!!)* *=> **Integrated** in EN ISO 52016-1 spread-sheet tool*
- Each window:
  - Area
  - Orientation&tilt
  - *U*-value (thermal transmittance; **EN ISO 10077-1**)
  - *g*-value (total solar energy transmittance; **EN ISO 52022-3**)

So primarily: ***R*-value, *U*-value, *g*-value:**

- Very conventional types of information,
- usually provided by component or building element suppliers

In short: the usual input data, similar as for simplified methods

Illustration of the sheet with input for each construction element:

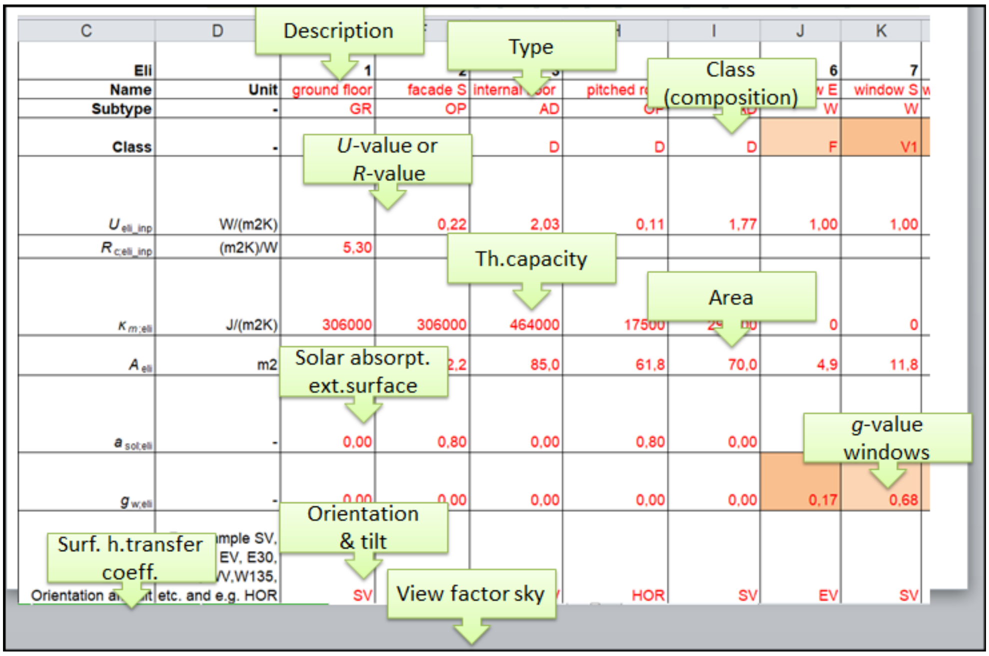


Fig 3

Other 'static' input data:

- Area
- Volume
- Thermal capacity
- Temperature setpoints
- Humidity setpoints
- Internal heat gains
- Air flow rates *(if not input from ventilation standards)*
- Correlation factors for monthly method
- ...

In short: again, the usual input data

Air infiltration and ventilation:

- Air flow rate provided by EN 16798-7
- (Mechanical) ventilation system data provided by EN 16798-5-1
  - Ventilation pattern
  - Supply air temperature and humidity (if other than outside)

See other case study [10], including dynamic links with EN ISO 52016-1..

But: it's possible to start calculation of energy needs with simplified assumptions of air flow rate pattern.

Indoor conditions:

- In the context of EPB regulations, to be specified by the public authorities:
  - Occupant schedules
  - Temperature and humidity set points
  - Internal heat and moisture loads
- These can be set for each hour and each day
  - E.g. a standard office schedule
  - E.g. a standard residential building schedule
  - ...
- Default schedules provided in EN 16798-1

Examples:

Heating set point, 3 levels

2	°C	22	2: high comfort required
1	°C	19	1: moderate comfort required
0	°C	15	0: low comfort required

Cooling set point, 3 levels

2	°C	26
1		32
0	°C	99

Internal heat gains, 3 levels

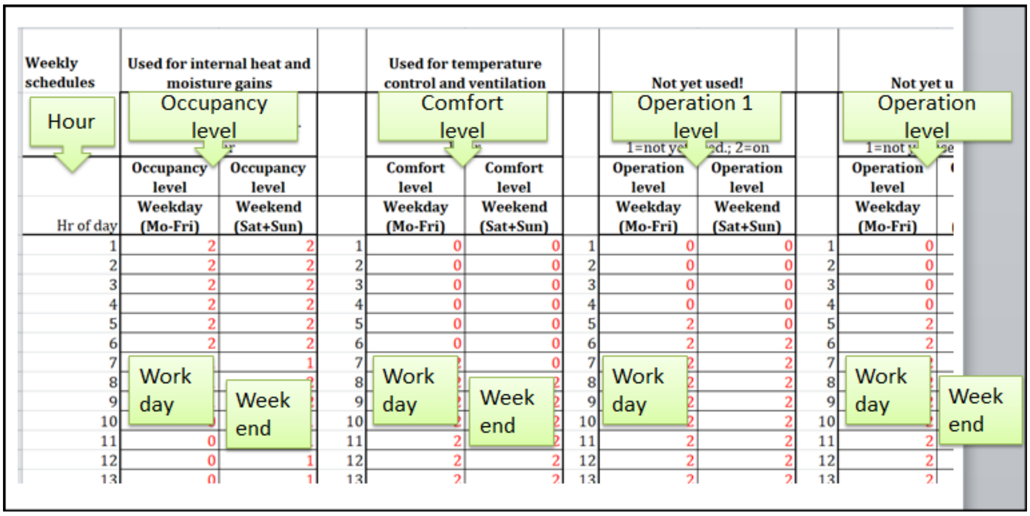
Constant internal heat flow rate during all hrs	$q_{int;tot;24}$
Extra internal heat flow rate during moderate comfort hrs	$q_{int;tot;con}$
Extra internal heat flow rate during high comfort hrs	$q_{int;tot;con}$

Humidity set points

$\varphi_{int;set;HU;ztc;t}$	%	25
$\varphi_{int;set;DHU;ztc;t}$	%	60

Assumed moisture production inside thermal zone

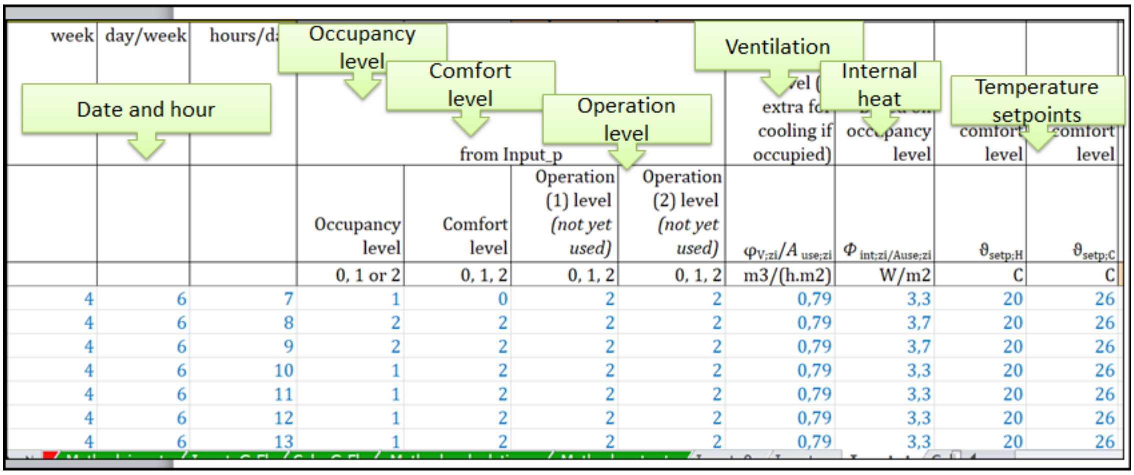
Moisture production during all hrs	$G_{int;24x7}/A_{use}$	kg/(
Extra moisture production during moderately occupied hrs	$G_{int;occ1}/A_{use}$	kg/(
Extra moisture production during highly occupied hrs	$G_{int;occ2}/A_{use}$	kg/(



Weekly schedules	Used for internal heat and moisture gains			Used for temperature control and ventilation			Not yet used!			Not yet u
Hr of day	Occupancy level Weekday (Mo-Fri)	Occupancy level Weekend (Sat+Sun)		Comfort level Weekday (Mo-Fri)	Comfort level Weekend (Sat+Sun)		Operation level Weekday (Mo-Fri)	Operation level Weekend (Sat+Sun)		Operation level Weekday (Mo-Fri)
1	2	2	1	0	0	1	0	0	1	0
2	2	2	2	0	0	2	0	0	2	0
3	2	2	3	0	0	3	0	0	3	0
4	2	2	4	0	0	4	0	0	4	0
5	2	2	5	0	0	5	2	0	5	2
6	2	2	6	0	0	6	2	2	6	2
7	[illegible]	1	7	[illegible]	0	7	[illegible]	2	7	[illegible]
8	[illegible]	[illegible]	8	[illegible]	[illegible]	8	[illegible]	2	8	[illegible]
9	[illegible]	[illegible]	9	[illegible]	[illegible]	9	[illegible]	2	9	[illegible]
10	[illegible]	[illegible]	10	[illegible]	[illegible]	10	[illegible]	2	10	[illegible]
11	0	[illegible]	11	2	[illegible]	11	2	2	11	2
12	0	1	12	2	2	12	2	2	12	2
13	0	1	13	2	2	13	2	2	13	2

New: **Use Profile Generator spreadsheet tool** available (see Case study [9]):

Profiles from EN 16798-1 and national: converted to a “calendar”: full year of hourly input for EN ISO 52016-1 spreadsheet and other EPB standards.



week	day/week	hours/d	Occupancy level	Comfort level	Operation (1) level *(not yet used)*	Operation (2) level *(not yet used)*	extra for cooling if occupied) $\varphi_{V;zi}/A_{use;zi}$	occupancy level $\Phi_{int;zi/Ause;zi}$	comfort level $\vartheta_{setp;H}$	comfort level $\vartheta_{setp;C}$
			0, 1 or 2	0, 1, 2	0, 1, 2	0, 1, 2	m3/(h.m2)	W/m2	C	C
4	6	7	1	0	2	2	0,79	3,3	20	26
4	6	8	2	2	2	2	0,79	3,7	20	26
4	6	9	2	2	2	2	0,79	3,7	20	26
4	6	10	1	2	2	2	0,79	3,3	20	26
4	6	11	1	2	2	2	0,79	3,3	20	26
4	6	12	1	2	2	2	0,79	3,3	20	26
4	6	13	1	2	2	2	0,79	3,3	20	26

This is a new sheet, with full year of hourly data, that replace the weekly schedules shown in the previous illustration.

One of the output sheets from the 16798-1 spreadsheet can be readily copy-pasted into the EN ISO 52016-1 input data sheet.

Illustration of th

e use profile generator:

1) Select which profile, from database with hourly profiles based on EN 16798-1 plus customized data sets

USER PROFILE:		
Residential: detached house		10
Source data sheet	RES_Det_house	
Zone area	m²	50
BASE PARAMETERS	**Value**	**Unit**
Hour at day, START	0	hour
Hour at day, END	24	hour
Breaks, inside range	0	hours
Days/week	7	days
hours/day	24	hours
hours/year	8760	hours
Occupants	45,2	m²/pers
Occupants [Total]	2,8	W/m²
Occupants [Dry]	1,9	W/m²
Appliances	2,4	W/m²
Lighting	0	

CO_2 production	0,44	g/m²h
Min T,op in unoccupied hours	16	°C
Max T,op in unoccupied hours	32	°C
Min T,op	20	°C
Max Top	26	°C
Ventilation rate [min]	0,5	l/sm²
Ventilation rate for CO2 emission	0,16	l/sm²
Max CO2 concentration [above outdoor]	500	ppm
Min. relative humidity	25	%
Max. relative humidity	60	%
Lighting. illuminance in working areas	0	lux

Domestic hot water		Calculated average year	
Tapping profile selection		ERP - XL	
Reference data for dhw needs	Cold water temperature	15	°(
Results for dhw	Yearly needs	2.847	k\
Daylight saving time	Starts at hour	1995	ends at hour

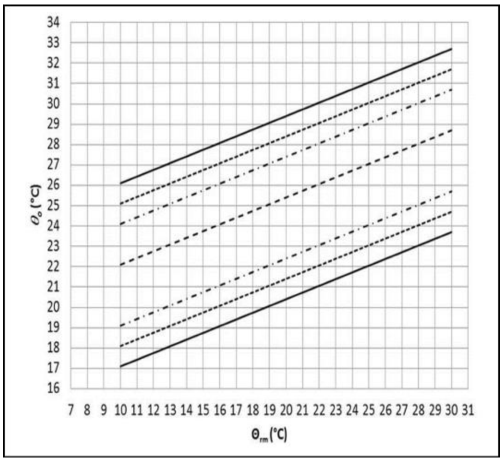
2) Generate output sheet with hourly data for a full year:

TOTAL DATA												
	Appliances gain		Persons gains		Vapou	CO2		Temperature setpoints			DHW needs (volume)	DHW needs (energy)
p	W	W	W	W	g/h	g/h	°C	°C	°C	°C	l @ θ_{draw}	kWh
0,88	60	13	112	76	56	18	20	20	26	26	3	0,086
0,88	60	50	112	76	56	18	20	20	26	26	3	0,086
0,88	84	50	112	76	56	18	20	20	26	26	2	0,047
0,88	84	50	112	76	56	18	20	20	26	26	5	0,133
0,88	96	50	112	76	56	18	20	20	26	26	2	0,047
0,88	96	50	112	76	56	18	20	20	26	26	73	2,106
0,88	96	50	112	76	56	18	20	20	26	26	63	1,833
1,11	72	38	140	95	71	22	20	20	26	26	0	0,000
1,11	72	38	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000
1,11	60	0	140	95	71	22	20	20	26	26	0	0,000

In a specific output sheet for EN ISO 52016-1 the relevant data are selected and where needed combined to make the data fit as hourly input for specific EPB standard such as for spreadsheet on EN ISO 52016-1.

Still in preparation: for spreadsheet on EN ISO 52016-1: hourly **adaptive temperature setpoint** (based on EN 16798-1, or customized)
For residential .buildings and offices with operable windows and without mechanical cooling)

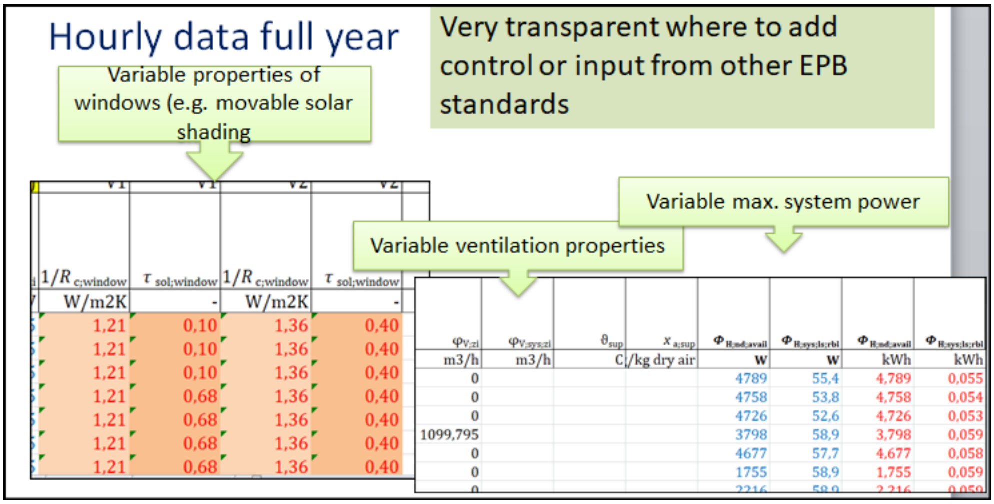
as illustrated in the following Figure:



Note: all hourly input data are combined:

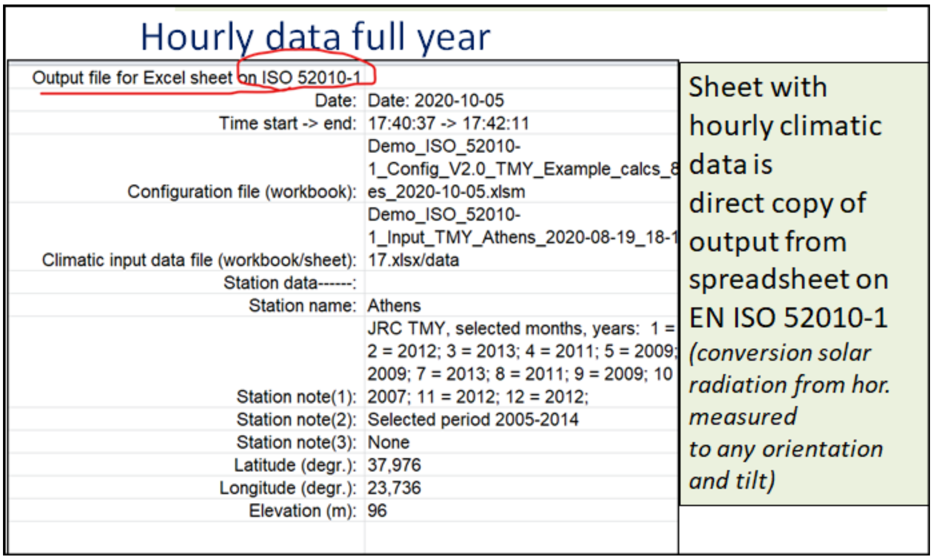
All input data with (potential) hourly variation are presented in the Input_t sheet, with hourly values for the full year (and including an initialization period).

This makes the spreadsheet very transparent e.g. on where to add control or input from other EPB standards. Illustration:



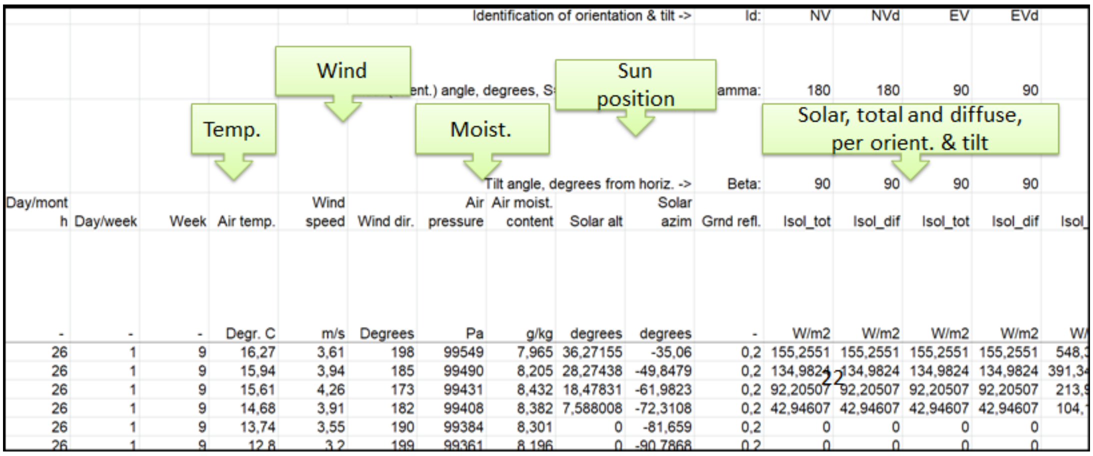
Climatic input data:

The hourly climatic data are in a separate sheet.



Output file for Excel sheet on ISO 52010-1	
Date:	Date: 2020-10-05
Time start -> end:	17:40:37 -> 17:42:11
Configuration file (workbook):	Demo_ISO_52010-1_Config_V2.0_TMY_Example_calcs_8es_2020-10-05.xlsm
Climatic input data file (workbook/sheet):	Demo_ISO_52010-1_Input_TMY_Athens_2020-08-19_18-117.xlsx/data
Station data------:	
Station name:	Athens
Station note(1):	JRC TMY, selected months, years: 1 = 2 = 2012; 3 = 2013; 4 = 2011; 5 = 2009; 2009; 7 = 2013; 8 = 2011; 9 = 2009; 10 2007; 11 = 2012; 12 = 2012;
Station note(2):	Selected period 2005-2014
Station note(3):	None
Latitude (degr.):	37,976
Longitude (degr.):	23,736
Elevation (m):	96

Illustration of hourly data, full year:

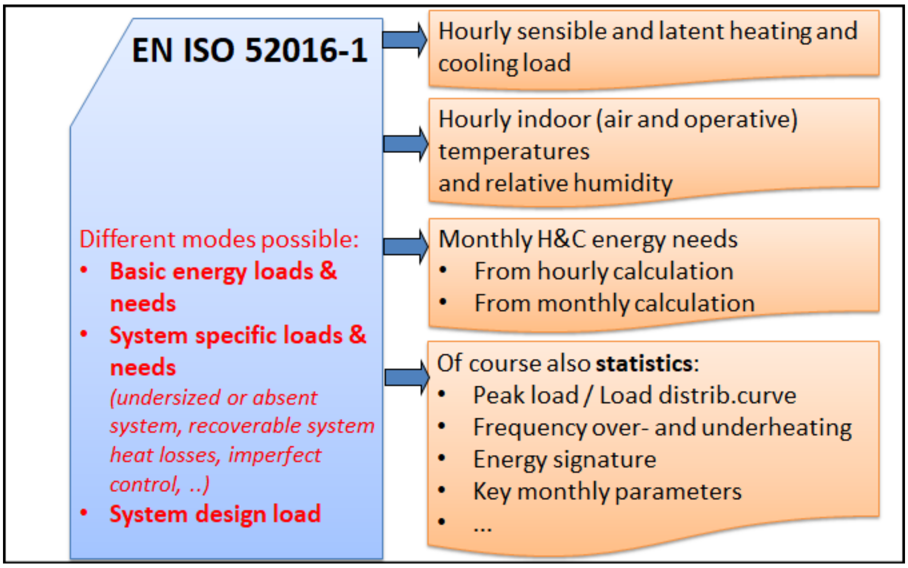


									Identification of orientation & tilt ->	Id:	NV	NVd	EV	EVd	
							ent.) angle, degrees, S			amma:	180	180	90	90	
							Tilt angle, degrees from horiz. ->			Beta:	90	90	90	90	
Day/month	Day/week	Week	Air temp.	Wind speed	Wind dir.	Air pressure	Air moist. content	Solar alt	Solar azim	Grnd refl.	Isol_tot	Isol_dif	Isol_tot	Isol_dif	Isol_
-	-	-	Degr. C	m/s	Degrees	Pa	g/kg	degrees	degrees	-	W/m2	W/m2	W/m2	W/m2	W/
26	1	9	16,27	3,61	198	99549	7,965	36,27155	-35,06	0,2	155,2551	155,2551	155,2551	155,2551	548,
26	1	9	15,94	3,94	185	99490	8,205	28,27438	-49,8479	0,2	134,9824	134,9824	134,9824	134,9824	391,3
26	1	9	15,61	4,26	173	99431	8,432	18,47831	-61,9823	0,2	92,20507	92,20507	92,20507	92,20507	213,
26	1	9	14,68	3,91	182	99408	8,382	7,588008	-72,3108	0,2	42,94607	42,94607	42,94607	42,94607	104,
26	1	9	13,74	3,55	190	99384	8,301	0	-81,659	0,2	0	0	0	0	
26	1	9	12,8	3,2	199	99361	8,196	0	-90,7868	0,2	0	0	0	0	

In the updated version under preparation, also the climatic data file can be imported with one 'push button' and the operation and use profile data.

6.1.1.2.3 Output data

Illustration of the output from the standard:



Illustrative examples:

Time dependent interim output

Internal gains / Incident solar radiation on each construction element

<simplified to only 1 H_ve>		$I_{sol;eli}$	Incident solar radiation, per element eli, per m2 (W/m2)							
H_{ve}	$\Phi_{int;zi}$	1	2	3	4	5	6	7	8	
W/K	W	W/m2	W/m2	W/m2	W/m2	W/m2	W/m2	W/m2	W/m2	W/
39,86945667	555	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,
39,86945667	555	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,
39,86945667	555	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,
39,86945667	555	30,14	30,14	87,89	70,04	30,14	285,92	30,14	30,14	30,
39,86945667	495	76,53	76,53	114,32	276,76	76,53	625,47	76,53	76,53	76,
39,86945667	495	168,02	168,02	106,79	490,80	168,02	754,22	168,02	106,79	106,

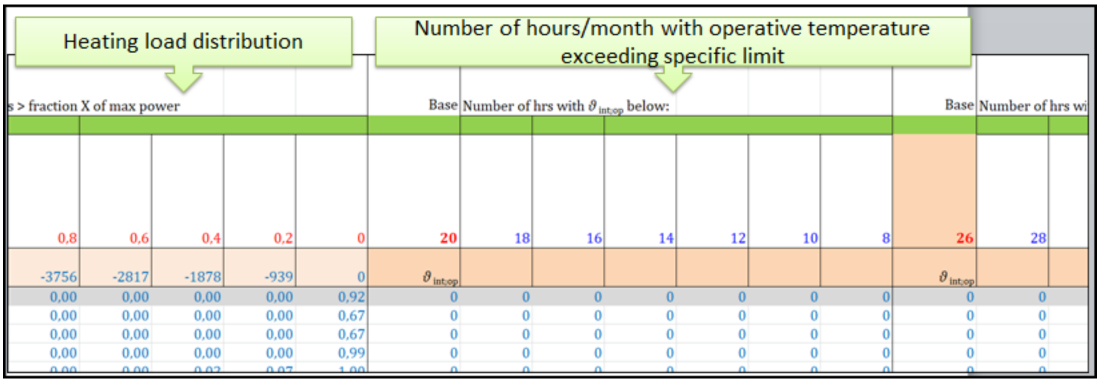
Needs / Indoor temperature

$\Phi_{HC;nd}$	$\vartheta_{int;op}$	$\vartheta_{int;a}$	$\vartheta_{int;rm}$
W	C	C	C
-1012,15	26,00	25,95	26,05
-1415,35	26,00	25,92	26,08
-2043,02	26,00	25,87	26,13
-2995,82	26,00	25,79	26,21
-1895,59	26,00	25,83	26,17
-1980,10	26,00	25,83	26,17

Moisture

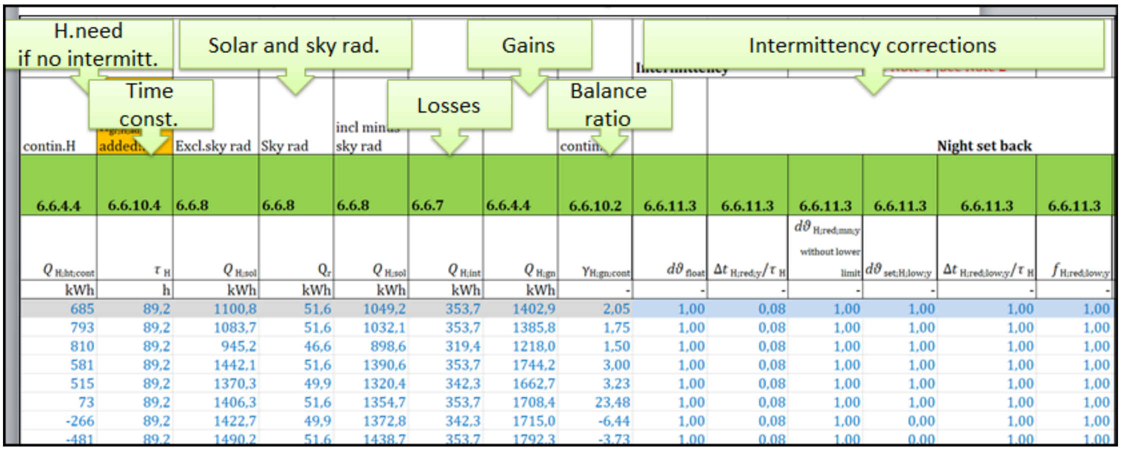
Saturization pressure	(actually only relevant during hours at moderate or high comfort level; so see $G_{HU;ld}$)	(actually only relevant during hours at moderate or high comfort level; so see $G_{DHU;ld}$)	*Copied from input to quickly compare*	Humidi-fication moisture load to maintain min. setpoint	Dehumidi-fication moisture load to maintain max. setpoint
$p_{sat;int}$	$x_{set;min}$	$x_{set;max}$	$x_{e;air}$	$G_{HU;ld}$	$G_{DHU;ld}$
Pa	g/kg dry air	g/kg dry air	g/kg dry air	kg/s	kg/s
3343,94	0,00517	0,01257	0,01499	0,00000	0,00000
3337,18	0,00516	0,01254	0,01484	0,00000	0,00064
3327,09	0,00515	0,01250	0,01449	0,00000	0,00062
3311,08	0,00512	0,01244	0,01407	0,00000	0,00059
3319,37	0,00514	0,01247	0,01356	0,00000	0,00054

Sheet with **monthly** output from **hourly** calculation:



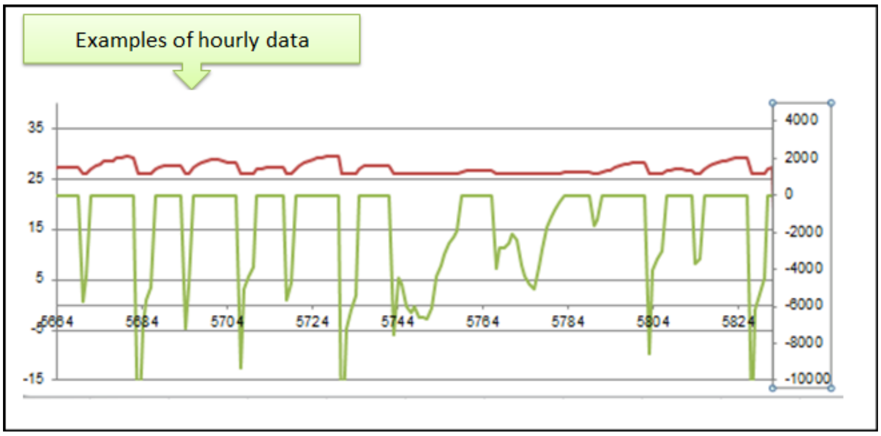
s > fraction X of max power					Base	Number of hrs with ϑ int;op below:						Base	Number of hrs wi
0,8	0,6	0,4	0,2	0	20	18	16	14	12	10	8	26	28
-3756	-2817	-1878	-939	0	ϑ int;op							ϑ int;op	
0,00	0,00	0,00	0,00	0,92	0	0	0	0	0	0	0	0	0
0,00	0,00	0,00	0,00	0,67	0	0	0	0	0	0	0	0	0
0,00	0,00	0,00	0,00	0,67	0	0	0	0	0	0	0	0	0
0,00	0,00	0,00	0,00	0,99	0	0	0	0	0	0	0	0	0

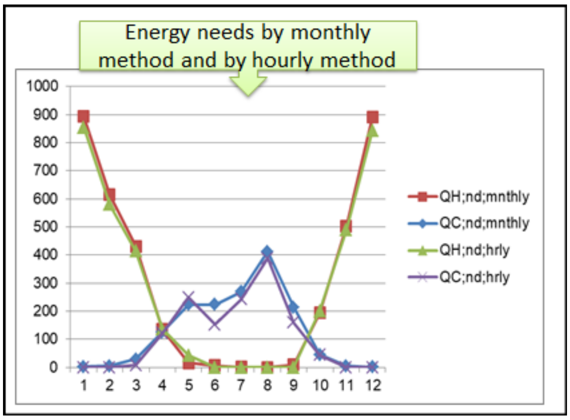
Sheet with **monthly** output from **monthly** calculation:

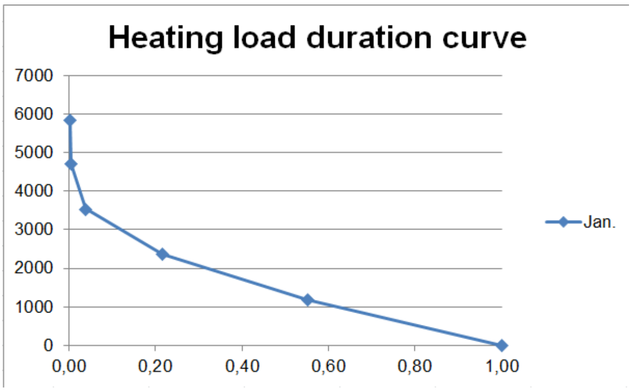


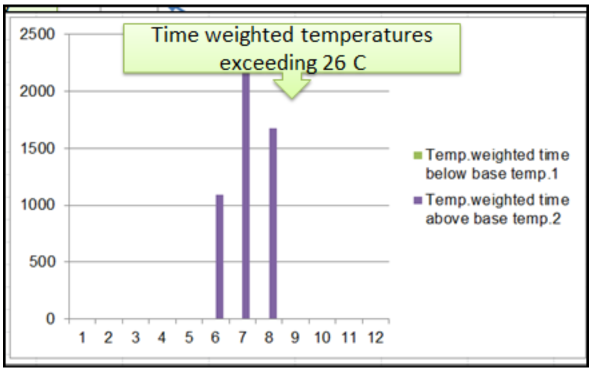
contin.H	added	Excl.sky rad	Sky rad	incl min sky rad			contin.						
6.6.4.4	6.6.10.4	6.6.8	6.6.8	6.6.8	6.6.7	6.6.4.4	6.6.10.2	6.6.11.3	6.6.11.3	6.6.11.3	6.6.11.3	6.6.11.3	6.6.11.3
$Q_{H;ht;cont}$	τ_H	$Q_{H;sol}$	Q_r	$Q_{H;sol}$	$Q_{H;int}$	$Q_{H;gn}$	$\gamma_{H;gn;cont}$	$d\vartheta_{float}$	$\Delta t_{H;red;y}/\tau_H$	$d\vartheta_{H;red;mn;y}$ without lower limit	$d\vartheta_{set;H;low;y}$	$\Delta t_{H;red;low;y}/\tau_H$	$f_{H;red;low;y}$
kWh	h	kWh	kWh	kWh	kWh	kWh	-	-	-	-	-	-	-
685	89,2	1100,8	51,6	1049,2	353,7	1402,9	2,05	1,00	0,08	1,00	1,00	1,00	1,00
793	89,2	1083,7	51,6	1032,1	353,7	1385,8	1,75	1,00	0,08	1,00	1,00	1,00	1,00
810	89,2	945,2	46,6	898,6	319,4	1218,0	1,50	1,00	0,08	1,00	1,00	1,00	1,00
581	89,2	1442,1	51,6	1390,6	353,7	1744,2	3,00	1,00	0,08	1,00	1,00	1,00	1,00
515	89,2	1370,3	49,9	1320,4	342,3	1662,7	3,23	1,00	0,08	1,00	1,00	1,00	1,00
73	89,2	1406,3	51,6	1354,7	353,7	1708,4	23,48	1,00	0,08	1,00	1,00	1,00	1,00
-266	89,2	1422,7	49,9	1372,8	342,3	1715,0	-6,44	1,00	0,08	1,00	0,00	1,00	1,00
-481	89,2	1490,2	51,6	1438,7	353,7	1792,3	-3,73	1,00	0,08	1,00	0,00	1,00	1,00

Sheet with graphical output, for example:









6.1.2 Coupling

6.1.2.1 Add-on sheets

As explained in 4.2.3, some couplings can be done by an add-on sheet in the overall spreadsheet.

Adaptive building envelope elements:

For instance for movable solar shading provisions or other adaptive building envelope elements.

Illustration of input data:

Name	Symbol	Unit	value lightest state	value intermediate state	value darkest state	Validity interval[a]	Origin[b]	Va
Windows(group): Wadapt1								
Thermal transmittance	$U_{w;Wadapti;sti}$	W/(m²·K)	1,00	future option	1,00	0 to 10	M2-5	
U-value minus surface resistances	$1/R_{c;w;Wadapti;sti}$	(m²·K)/W	1,21		1,21			
Total solar energy transmittance	$g_{w;Wadapti;sti}$	-	0,77	future option	0,30	0 to 1	M2-8	
Visual transmittance	$\tau_{vis;w;Wadapti;sti}$	-	0,70	future option	0,25	0 to 1	M2-8	
Adaptive element type	--	-	1					
Control scenario type	--	-	2					
Windows(group): Wadapt1								

Output_m / Output_t / ClimDat_m / ClimDat_t / CalcShad / AdaptW / EN_16798-7 / DynamVent / EN_15316-4-2

Illustration of the rules that can be programmed in this ‘add-on’ sheet:

					For orientation and tilt: find a bldng element in the group:						
					First element in group Wadapt1	First element in group Wadapt2					
					7	8					
ata (columns)	12										
? (0 = don't!!)	0	0	0	0	0	0	0	0	0	0	0
		Not used (yet?)	Copied from Input_t	Occupancy	Irradiance	Irradiance	State? (Light =1; dark=0)		Wadapt1	Wadapt1	Wada
	C	C	0 or 1		Wadapt1	Wadapt2	Wadapt1	Wadapt2	$1/R_{c;window}$	$\tau_{sol;window}$	$1/R_{c;wi}$
ten by macro)	$\vartheta_{e;air}$	$\vartheta_{int;op}$	Comfort level		W/m2	W/m2			W/m2K	-	W/r
1	16,44	20,00	1	to be completed	0,00	0,00	0	0	1,00	0,30	
2	16,38	20,00	1		0,00	0,00	0	0	1,00	0,30	
3	16,32	20,00	1		0,00	0,00	0	0	1,00	0,30	
4	16,26	20,00	1		0,00	0,00	0	0	1,00	0,30	
5	16,2	20,00	1		0,00	0,00	0	0	1,00	0,30	
6	16,14	20,00	1		0,00	0,00	0	0	1,00	0,30	
7	16,08	20,00	1		0,00	0,00	0	0	1,00	0,30	
8	16,02	20,00	1		128,35	30,42	0	0	1,00	0,30	
9	15,97	20,00	1		57,36	47,55	0	0	1,00	0,30	

AdaptW / EN 16798-7 / DynamVent / EN 15316-4-2

For simple control scenarios this has been successfully tested. For more complex scenarios this is will be done in the context of the preparation of EN ISO 52016-1, as explained in 4.2.3,

The output (properties in a specific state) then overrules, on an hour by hour basis, the fixed properties for the adaptive building element.

Ventilative cooling:

See discussion in 4.2.3 on the **limitations** of this ‘add-on’ compared to a coupling with EN 16798-7 as shown in case study 10].

Illustration of how the criteria can be set and modified:

Criteria:		
Start increased (*) vent. if temp.diff. is higher than:	3	K
And if outdoor temp. is higher than:	12	C
And if the indoor temp. has exceeded: (cooling set point - xx), with xx =	2	K
Extra ventilation factor if in low, moderate resp. high comfort level:	5	
Extra means: times the ventilation rate normally applied during high comfort period		

Illustration of some hourly data where the criteria are tested:

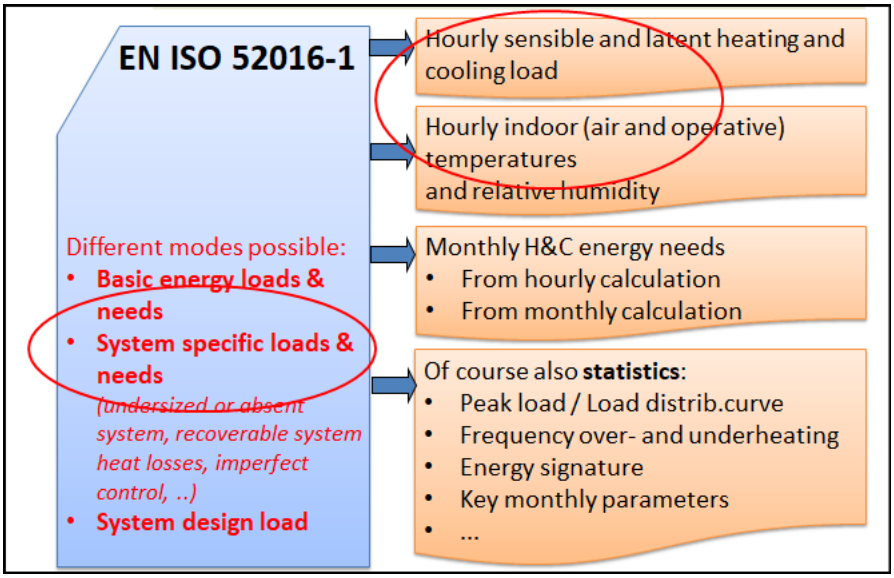
	(only used in next timestep)	(only used in next timestep)	Copied from Input_t			Extra vent.
	C	C	2, 1 or 0	1 or 0		m3/(h.m^2)
	$\vartheta_{e;air}$	$\vartheta_{int;op}$	Comfort level	Criteria met?	VCS-factor	$\Delta\varphi_{V;zi}/A_{use;zi}$
5798	26,3	27,00	2	0	0,0	0,00
5799	26,6	27,00	2	0	0,0	0,00
5800	26,4	27,00	2	0	0,0	0,00
5801	26,4	27,00	2	0	0,0	0,00
5802	25,8	27,00	2	0	0,0	0,00
5803	23,7	27,82	0	0	0,0	0,00
5804	22,5	26,53	0	1	5,0	22,50
5805	21,7	25,91	0	1	5,0	22,50
5806	21,2	25,48	0	1	5,0	22,50
5807	20,5	25,02	0	1	5,0	22,50
5808	20	24,61	0	1	5,0	22,50
5809	19,2	25,62	0	0	0,0	0,00
5810	18,4	23,97	0	1	5,0	22,50
5811	17,6	24,96	0	0	0,0	0,00
5812	17,2	25,13	0	0	0,0	0,00
5813	17,7	23,30	0	1	5,0	22,50

This output then overrules, on an hour by hour basis, the pre-set hourly input data for the air flow rate.

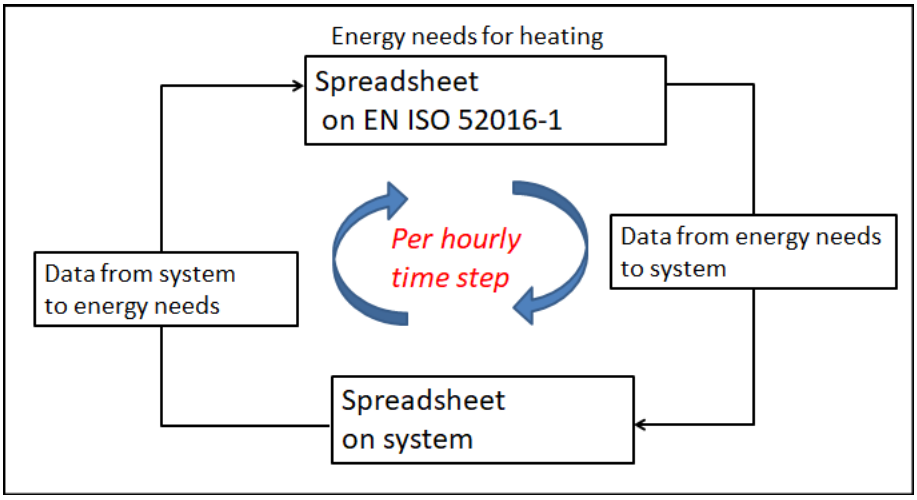
6.1.2.2 Dynamic coupling between two spreadsheets

See introduction in 4.2.4.

In case of system specific calculation: input of system performance that has an impact on the hourly heating or cooling load and internal temperatures; and vice versa!



Generic illustration:



The special sheets created for such a dynamic (hourly) coupling have a generic table that dictates which input data (for each hour) have to be read from the other spreadsheet and written where on this spreadsheet (sheet name and column number) and vice versa , as illustrated for the coupling with EN 15316-4-2 (heat pump systems):

Parameters for macro:

WB_slave filename: CEN-CE Excel sheet EN 15316-4-2Rev 20101018b_Strbg_01b_HP02JAN27a1_test40.xlsm

	Read from this WB on ISO_52016-1...				.. And write in WB_slave Input_series		
	Number of data		4				
No	Description (just as info)	Sheet	Column (start from A)	First data row in this sheet	Description (just as info)	Column (start from 1st Data)	Multipl.factor
1	Unlimited energy load	Output_t	54	7	Heat output to the heating distribution subsystem (kWh)	1	0,001
2	HP output temp	EN_15316-4	19	21	Required flow temperature for heating	2	1
3	ϑint;op (C)	Output_t	31	7	Ambient temperature	6	1
4	Outdoor air temp. (C)	ClimDat_t	13	21	Energy source temper	7	1
5							
6							
7							
8							
9							

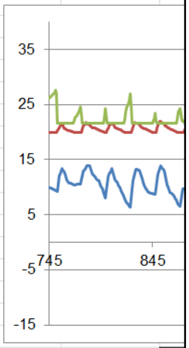
	Read from WB_slave Output_ser		.. And write in this WB on ISO_52016-1	
	Number of data	6		
No	Description (just as info)	Column (start from 1st Data)	Description (just as info)	Sheet
1	Generation input (kWh)	1	Generation input (Wh)	EN_15316-
2	Back-up energy input	2	Back-up energy	EN_15316-
3	Total auxiliary energy	5	Total auxiliary energy	EN_15316-
4	COP system	7	Overall COP HP system	EN_15316-
5	Energy delivered for Heating (kWh)	8	Energy delivered for Heating (Wh)	Output_t
6				
7				
8				
9				

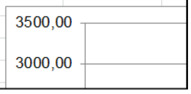
In this way the hourly output from one spreadsheet is used as input (overruling existing input) in the other spreadsheet and vice versa. This reading and writing at each hourly time step of the calculation is handled by the macro (programmed).

In practice, depending on the specific nature of these variables, some extra (maybe ad hoc) adaptations are needed.

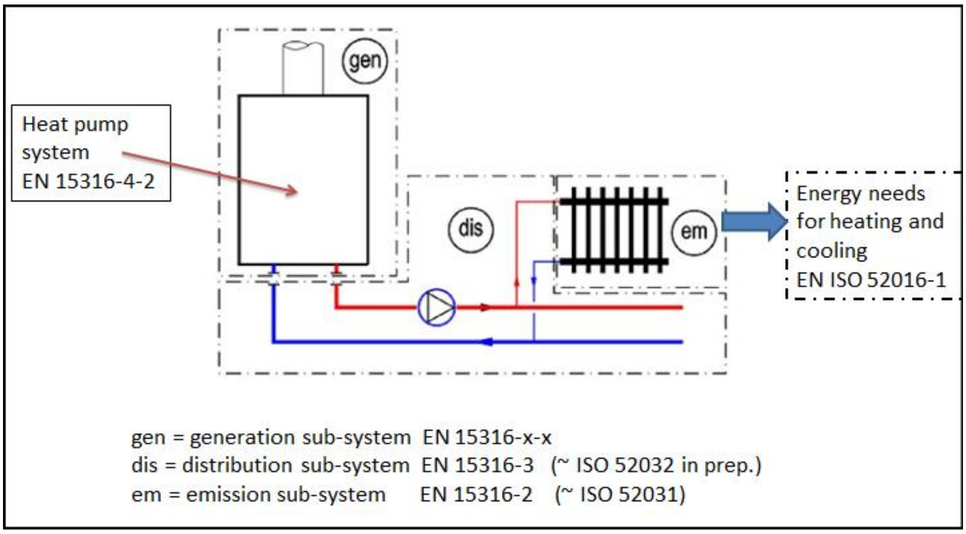
The result may be shown on the same sheet (see illustration below), but can also be traced, of course, on the sheets where it has been written.

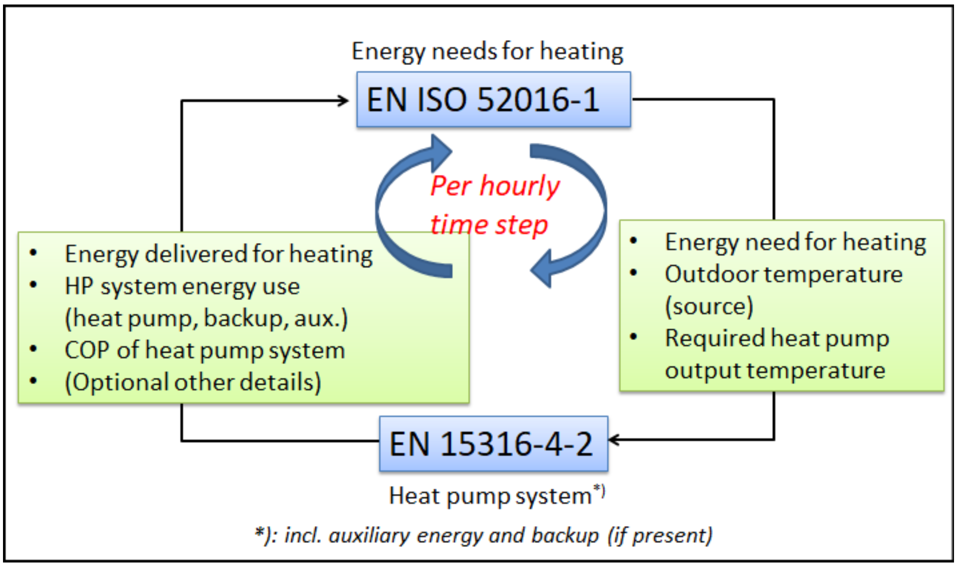
olumns)	10					OUTPUT from HP system					Postprocessing
don't!!)	0	0	0	0	0	1	1	1	1	0	
	Calculated here	Copied from ClimDat_t (by macro)	Copied from Output_t	Copied from Output_t		Generation input	Total auxiliary energy	Back-up energy	Overall COP HP system	Energy delivered for Heating	Check overall COP HP system
	C	C	C	W		W	W	W	-	W	-
number	$\vartheta_{HP;gen;out}$	$\vartheta_{e;air}$	$\vartheta_{int;op}$	$\Phi_{HC;ld;unlim}$	void	$E_{H,gen,in}$	$W_{H,gen,aux}$	$E_{H,gen,bu,in}$	COP_{HPsys}	$Q_{HC;avail}$	COP_{HPsys}
1	31,2	16,44	20,0	585	0	0	0	0	0,00	12000	#DIV/0!
2	31,2	16,38	20,0	568	0	619	200	0	2,90	12000	14,65
3	31,2	16,32	20,0	569	0	634	201	0	2,87	12000	14,37
4	31,2	16,26	20,0	573	0	653	202	0	2,83	12000	14,04
5	31,3	16,20	20,0	579	0	673	204	0	2,79	12000	13,68
6	31,3	16,14	20,0	586	0	694	206	0	2,75	12000	13,34
7	31,3	16,08	20,0	565	0	754	210	0	2,65	12000	12,45
8	31,3	16,02	20,0	168	0	737	209	0	2,66	12000	12,69
9	31,3	15,97	20,0	271	0	757	211	0	2,62	12000	12,41
10	30,5	18,62	20,1	0	0	762	211	0	2,63	12000	12,33
11	30,3	19,00	20,2	0	0	699	206	0	2,76	12000	13,26
12	30,2	19,39	20,2	0	0	633	201	0	2,89	12000	14,40
13	30,1	19,77	20,3	0	0	521	192	0	3,04	12000	16,84
14	30,2	19,42	20,4	0	0	519	191	0	2,98	12000	16,90
15	30,3	19,07	20,5	0	0	559	195	0	2,88	12000	15,91
16	30,4	18,71	20,3	0	0	828	216	0	2,46	12000	11,49
17	30,6	18,12	20,3	0	0	883	221	0	2,36	12000	10,87
18	30,8	17,54	20,2	0	0	892	221	0	2,33	12000	10,78
19	31,0	16,95	20,2	0	0	927	224	0	2,26	12000	10,43
20	31,1	16,77	20,1	0	0	928	224	0	2,25	12000	10,42



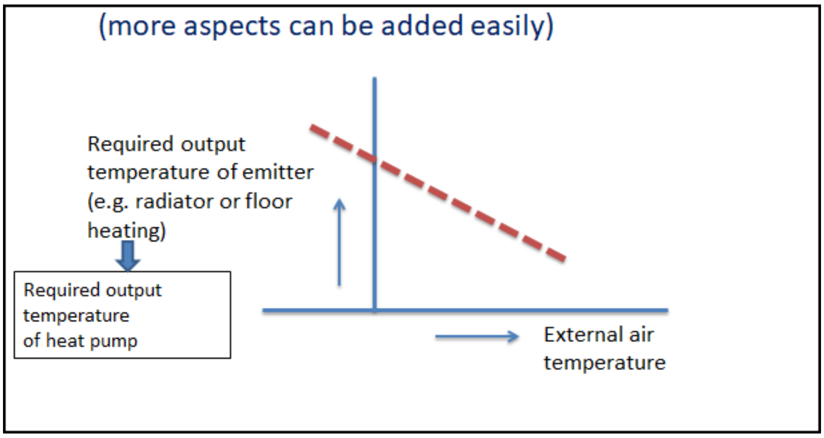


For the heat pump system the links concern a few properties



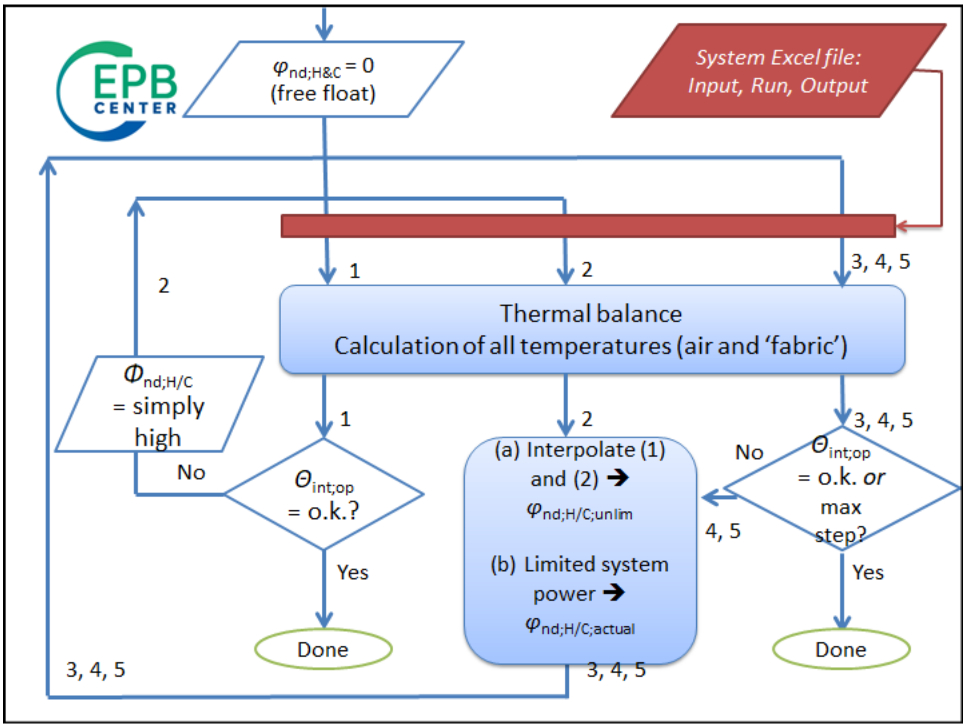


The required output temperature of the heat pump has to be obtained from the EN ISO 52016-1 spreadsheet, because it depends on the heating need during that hour. Therefore a simple curve has been introduced in the special sheet, to provide the required temperature, as function of the outdoor temperature:



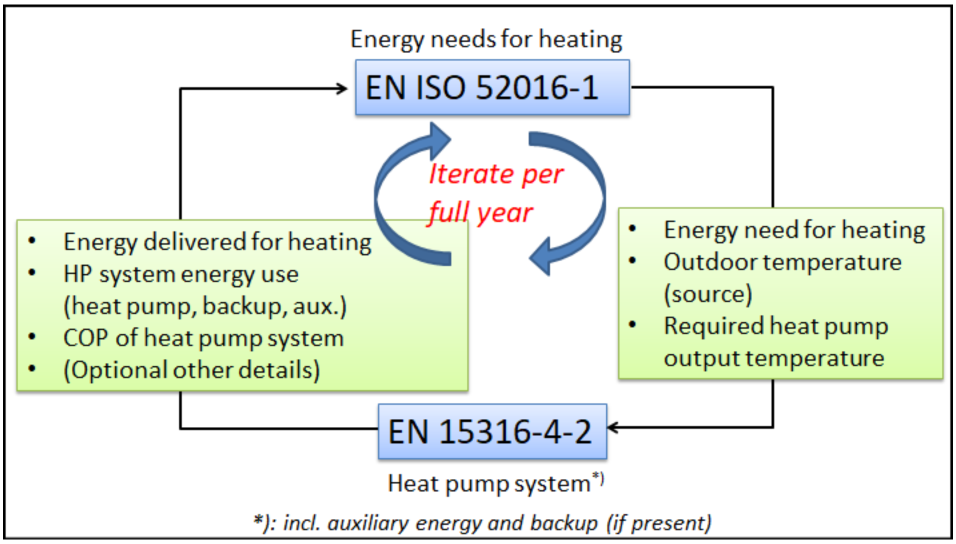
A real complication for the coupling was that the calculation of the heating or cooling load for each hour, had to be extended to produce two values: the load required to meet the temperature setting and the load that the system (in casu the heat pump system) can provide, which differs per hour if there is no back up heating.

This led to the implementation of the following calculation schedule:



The coupling appeared to work well, but very slow, despite precautions taken to avoid that the unnecessary screen refresh and recalculations are avoided. An hourly calculation for a full year (incl. initialization > 10 000 time steps) of the spreadsheet on EN ISO 52016-1 normally takes only a few minutes. With the coupling it takes many hours.

An **alternative approach** of coupling could be a blunt iteration for the full year. It is expected that a few iterations would already be enough (see also Case study [10]). Illustration of such approach:



6.1.3 Supporting calculations

No special supporting calculations needed, other than explained above

6.2 Results

6.2.1 Introduction

The calculations have been performed in preparation of the presentations at the webinars. The spreadsheet and related tools were further developed according to the needs. A clean set of final calculation runs will be made available as soon as the updated spreadsheet has been finalized.

Overview of most relevant webinars:

	Cases	**Presented in webinar(s)** *(see overview of webinars below)*
1	Base variations: climate (cold, moderate, warm), insulation level, space type (residential, office) *(also varied in the other cases below)*, operation and use profile (e.g. temperature settings, occupancy)	Webinar 5 Webinar 9 Webinar 7
2	Unlimited system versus undersized or absent system (impact on energy needs and on thermal comfort)	Webinar 5
3	Operation of movable blinds (large effect, dynamics involved)	Webinar 9
4	Ventilative cooling (special dynamics involved)	Webinar 4
5	Dynamic (hourly) coupling to heat pump system calculation	Webinar 8 Webinar 9
6	Selected other variations (just to show that apparently minor details may also have a significant effect)	Webinar 9

Overview of these webinars and the most relevant presentations:

	Date	**Title of webinar**	**Title of presentation**
4	May 26, 2020	EPB standards hourly vs monthly methods	Energy need and indoor temperatures calculation: hourly or monthly? by Dick van Dijk
5	June 16, 2020	EPB standards linked to health and wellbeing	Energy needs calculation (EN ISO 52016-1) and thermal comfort by Dick van Dijk
7	Oct. 6 2020	Example calculations with the set of EPB standards – (1) Introduction and overarching calculation procedures	First series of example calculations, on energy needs (EN-ISO 52016) by Dick van Dijk
8	Oct. 20 2020	Example calculations with the set of EPB standards – (2) Energy needs combined with specific systems	Coupling of the thermal zone (EN-ISO 52016) and heat pump systems (EN 15316-4-2) by Dick van Dijk

9	Dec. 20 2020	Example calculations with the set of EPB standards – (3) Whole building calculations, from components to overall primary energy	Building envelope: how to identify the starting point of an nearly zero-energy building (NZEB) with heating and cooling needs and partial performance indicators by Dick van Dijk
10	Feb 2nd 2021	Example calculations with the set of EPB standards – (4) Focus on non-residential buildings	Specific features of the calculation of energy needs for heating and cooling for non-residential buildings by Dick van Dijk

6.2.2 Calculation results and discussion

6.2.2.1 Base variations

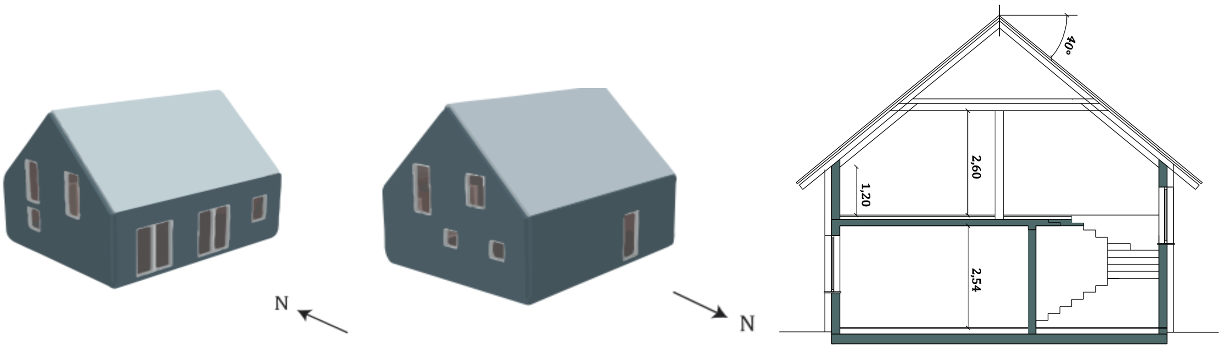
(e.g. temperature settings, occupancy)

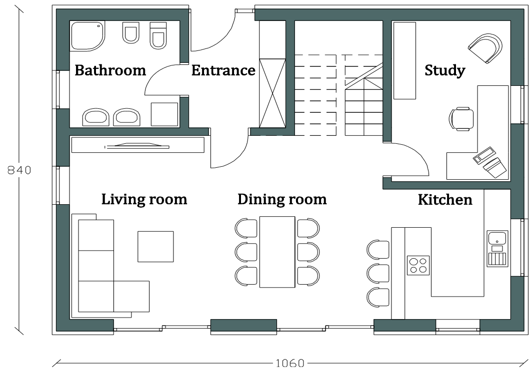
Main variations:

- 3 (European) climates:
  - Oslo, Strasbourg, Athens
- EP levels:
  - Bad energy performance
  - Good energy performance

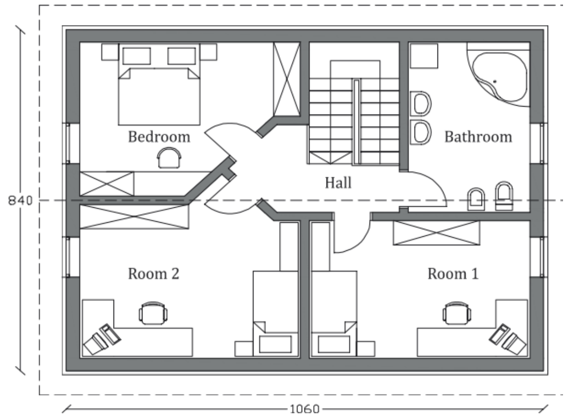
Main selected building:

A detached single family house, described as Example 1 in the Technical Report, CEN ISO/TR 52016-2, accompanying EN ISO 52016-1:



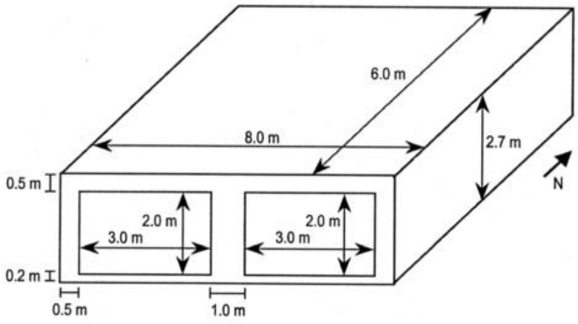


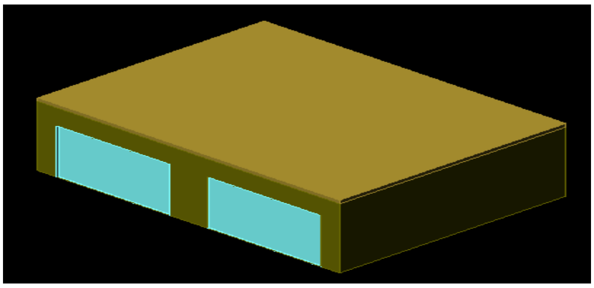
Bathroom
Entrance
Study
Living room
Dining room
Kitchen
840
1060



Bedroom
Bathroom
Hall
Room 2
Room 1
840
1060

Also an office room is used, with geometry based on the BESTEST "shoebox" model:





See description in the Case studies Preparation document [6].

Results:

Athens:

	Uninsulated		Insulated	
Energy needs (kWh)	Heating	Cooling	Heating	Cooling
Continuous	10207	3670	470	4534
Intermittent	9317	3670	441	4534
%	- 9 %		-6 %	

Discussion:

- It is a national technical choice to assume continuous or intermittent heating.
- From uninsulated to insulated = from heating dominated to cooling dominated
- Heating nowadays small; but if no heating available? Good for the energy performance, but also good for thermal comfort? See next case in 6.2.2.2.

Oslo:

	Uninsulated		Insulated	
Energy needs (kWh)	Heating	Cooling	Heating	Cooling
Continuous	46103	3	7992	751
Intermittent	43101	2	7813	749
%	-7 %		-2 %	

Discussion:

- It is a national technical choice to assume continuous or intermittent heating.
- From uninsulated to insulated = from heating dominated to … still heating dominated
- Cooling still small; but if no cooling available? Good for the energy performance, but also good for thermal comfort? See next case in 6.2.2.2.

6.2.2.2 Unlimited system versus undersized or absent system

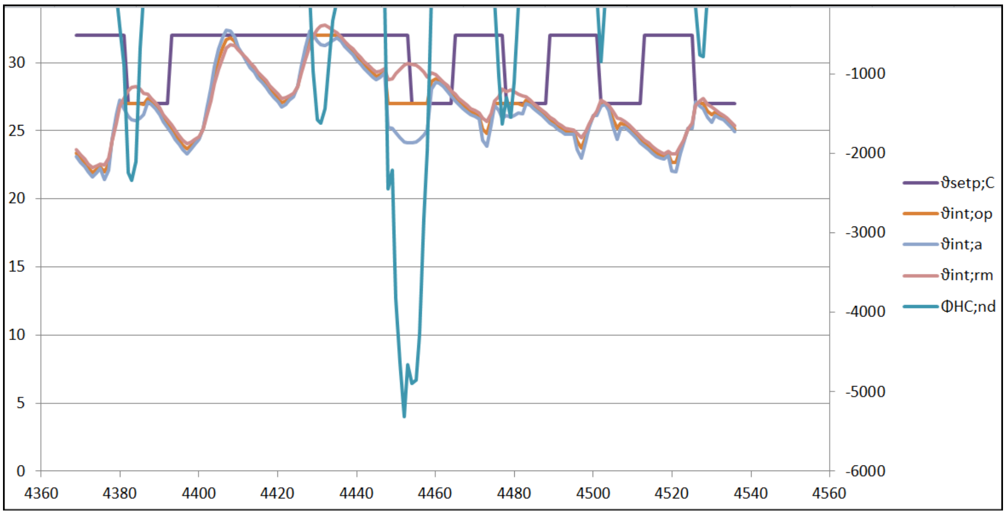
(impact on energy needs and on thermal comfort)

Main variations:

- Heating or cooling system:
  - sufficiently sized
  - Undersized
  - absent

Thermal comfort:

As starting point: just an illustration of a typical hourly calculated internal air and mean radiant and operative temperatures and heating or cooling load:



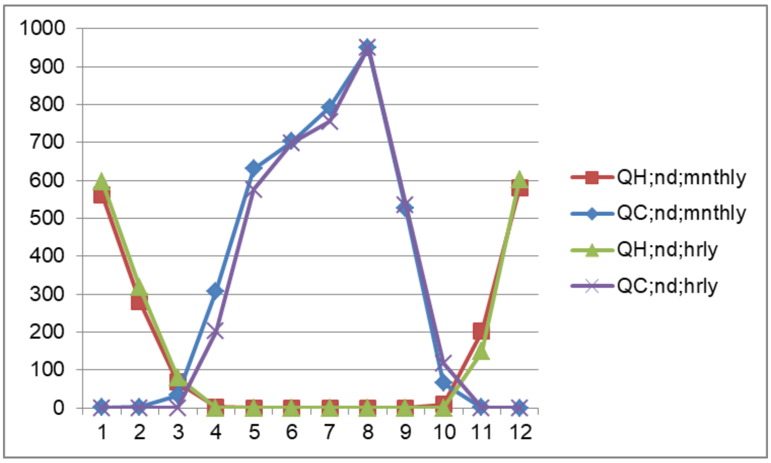
These output data are available from the hourly calculation procedures in EN ISO 52016-1 and can be used to assess the thermal comfort in case of absent or undersized systems.

Part of the post-processing of the hourly results in the spreadsheet is the **statistics on the hourly operative temperature** as basis for a **thermal comfort score**. Of course it is important to make a distinction between hours that the building is assumed to be occupied and unoccupied hours. This is covered in the spreadsheet.

However, the change over from a tabulated pattern of use to results from the new Use Profile Generator (spreadsheet on EN 16798-1 [9]) triggered a discussion between the experts: in residential buildings some countries choose for night time temperature setback, other countries don't. This may be related to culture and/or climate. But if a country opts for night time temperature setback, it assumes that the required temperature level during the night is lower than during the day (in technical terms: in bed the "clo" factor is higher and the metabolism is not much different from the metabolism in the evening).

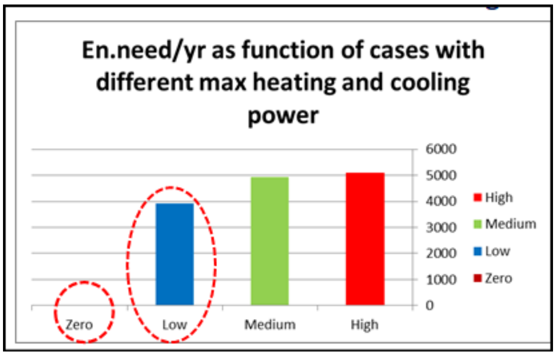
So, in case of **night time temperature setback**, an **additional parameter** needs to be added in the use profile generator, to avoid that a decreased operative temperature is counted as a contribution to a bad **thermal comfort score**.

For a conventional case the agreement between monthly and hourly calculations may be quite good. The EN ISO 52016-1 spreadsheet produces results for both methods in parallel. For example:



However, the monthly method has a difficulty to deal with undersized or absent systems and the associated thermal comfort risks.

Four cases are presented, each with different maximum heating and cooling power:



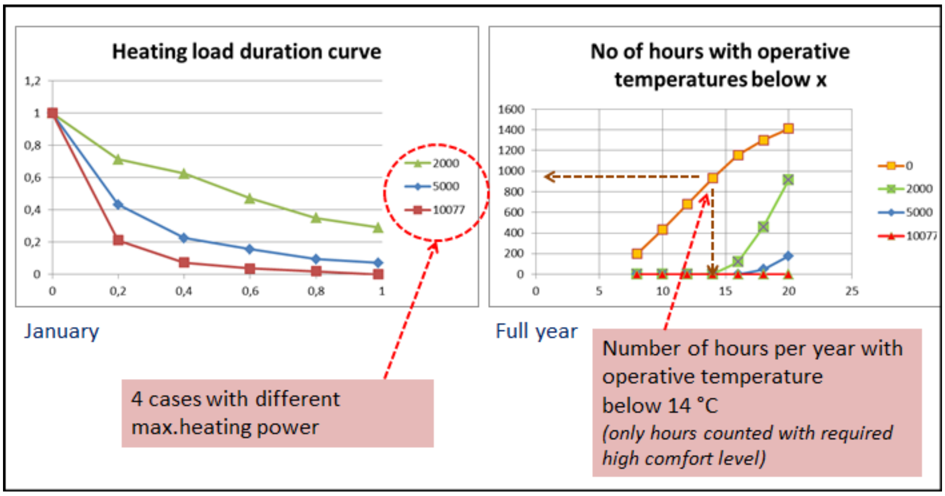
If there is no detection of or compensation for an undersized system: the energy performance of the case with the **lowest system capacity** will have the **best energy performance:**

the defect becomes an advantage.

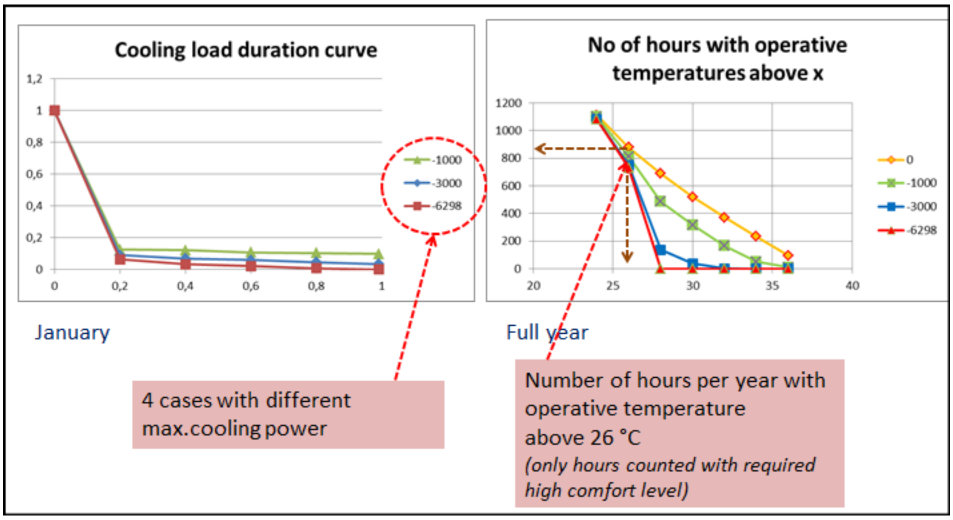
Unless the reference is adjusted, or thermal comfort is taken into account as requirement or penalty.

See for the 4 cases the heating resp. cooling load curve (left) and the statistics on the operative temperature (right):

Heating:



Cooling:



Conclusion:

The hourly calculation method is an adequate method to calculate the impact of undersized or absent systems and to provide the information to take measures to ensure a level playing field.

NOTE This concerns the assessment of the energy performance. For a good **design** of a building more refined information is needed, e.g. on individual room level.

To keep a level playing field between buildings where some or all of the occupied spaces are

– *Not heated or cooled: **low energy use**, possibly bad thermal comfort*
– *Adequately heated and cooled: **higher energy use**, adequate thermal comfort*

different options can be considered for adoption in the national or regional regulations, for example:

a) In case of absent or deficient system: assume in the energy performance calculation a **fictitious system**, with a conservative efficiency. Effect: the energy performance is calculated as if the space is adequately heated and cooled, ergo: level playing field. Disadvantage: a possible thermal discomfort is kept hidden. So this may only work if it may be assumed that in the use phase of the building an adequate system will be added to such space.

b) Fictitious system, but with the impact **weighted** by the degree of thermal comfort problems.

c) Perform the calculation with the real or absent system, but add a **separate thermal comfort** indicator and **minimum thermal comfort requirement**.

d) Set a different **EP requirement** in absence of a system; for instance in heating dominated climates: a more stringent minimum EP requirement in case of absent cooling system.

A more sophisticated solution is a combination of option a) and option c). For instance option a) for the EP label and option c) for information on the EP certificate. In this case **two calculations** need to be done. Actually, this should not be a problem in practice, assuming that the calculations will be automated anyway.

Note that in the latter case it is **not possible to do just one calculation** with the real system and then calculate for each hour how much heating or cooling *would* have to be added to reach the required comfort level. This would give wrong results, because if the missing heating or cooling *would really* be added for that hour in the calculation, the temperature of the building, including the mass of the constructions, would be raised, which has an effect on the heat balance of the next hour, due to the large inertia of the building.

Coming back to the base cases from 6.2.2.1, it is interesting to see what would happen with the energy and thermal comfort if in **a cooling dominated climate** there would be no heating system:

Athens:

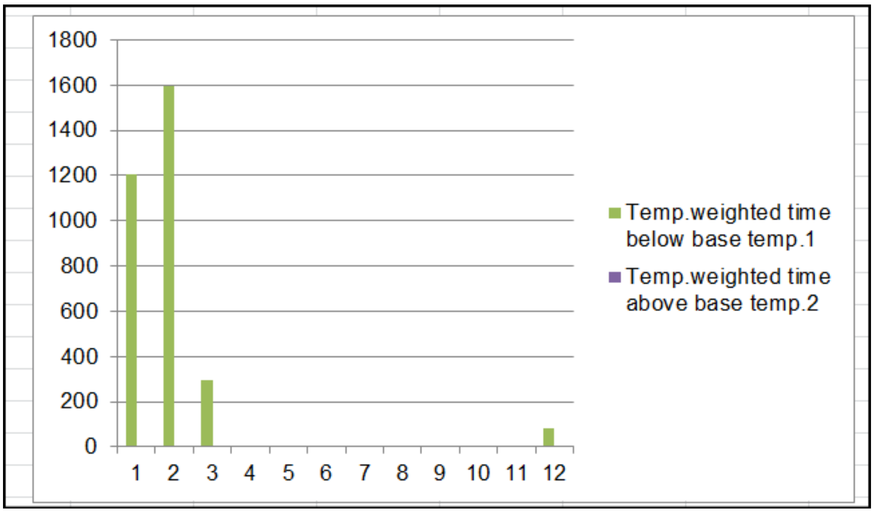
	Insulated		
Energy needs (kWh)	Heating	Cooling	Mean indoor temp. February
Continuous	470	4534	20 °C
No heating system	0	4533	17,6 °C
% of heating+cooling	-9 %		

The average operative temperature In February is a few degrees below the set-point of 20 °C

This could be one simple way to indicate thermal comfort. A more conventional way is to count the temperature weighted hours with indoor temperature below 20 °C (“accumulated temperature difference with base temperature 20 °C”).

EXAMPLE: if, for a specific month, 90 hours are counted with temperature 19 °C and 25 hours with 18 °C and zero hours below 18 °C , the temperature weighted hours with indoor temperature below 20 °C is 90 x 2 + 25 x 18 = 630 for that month.

The following Figure shows the result for each month for the Athens case.



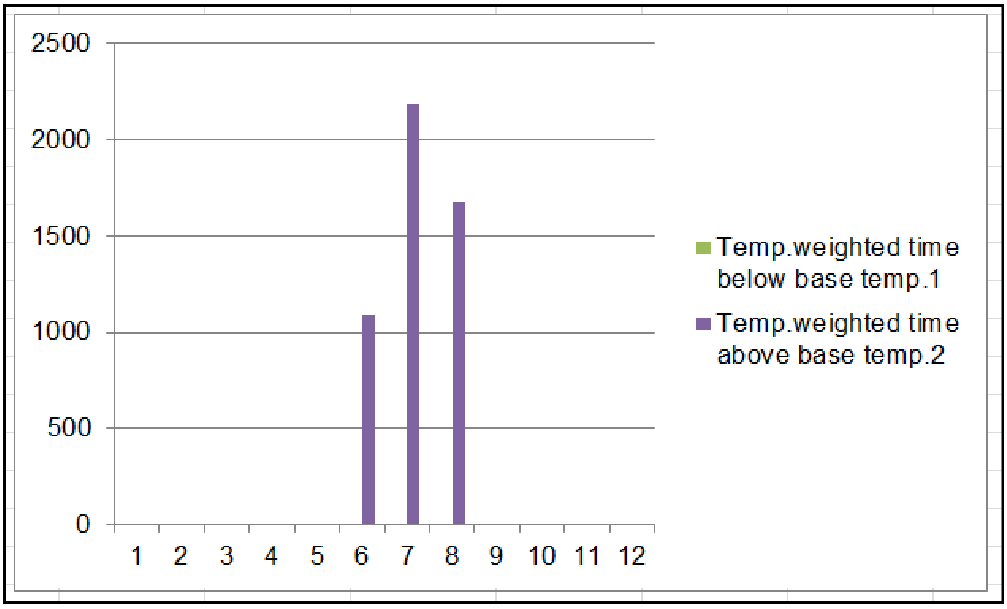
Note: the graph gives the option to compare two base temperatures. Base temp.1 = 20 °C

Similarly, it is interesting to see what would happen with the energy and thermal comfort if in **a heating dominated climate** there would be no cooling system:

Oslo:

	Insulated		
Energy needs (kWh)	Heating	Cooling	Mean indoor temp. July
Continuous	7992	751	25,9 °C
No cooling system	7976	0	28,9 °C *)
% of heating+cooling		-9 %	*): 2,9 K above 26°C

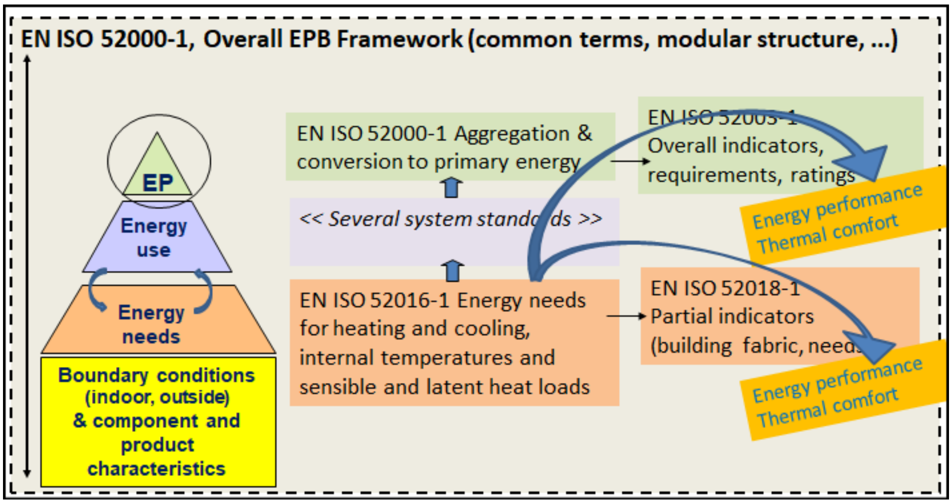
And the temperature weighted hours with indoor temperature above 26 °C:



Note: the graph gives the option to compare two base temperatures. Base temp.2 = 26 °C

Conclusion:

The hourly calculation procedures contain the ingredients needed to provide several types of thermal comfort scores that are needed in case of absent or undersized systems. The choice of thermal comfort indicator is specified in one of the two EPB standards that deal with the post-processing of the calculated overall (EN ISO 52003-1) and partial (EN ISO 52018-1) energy performance:



6.2.2.3 Operation of movable blinds

(large effect, dynamics involved)

The sensitivity of assumed use of solar shading devices is shown for the Athens case in the following table:

	Insulated	
Energy needs (kWh)	Heating	Cooling
Down at solar irrad. > 200 W/m² (default)	470	4534
Down at solar irrad. > 400 W/m²	249	6272
%	-47 %	+38 %

The criterion for closing the blinds at solar irradiance 200 W/m2 is used in the calculations shown above. As can be seen in the table, if the criterion is increased, it has a huge effect on the cooling and heating needs.

For the hourly calculation method such a change in the criterion means only to change the value of the criterion: the calculation will check automatically at each hour for each window at each orientation and tilt angle if the criterion is exceeded in which case the thermos-physical property of the window system (window including the blinds) is adapted. For the monthly calculation method a change in criterion would require a series of hourly calculations to prepare new tabulated values for each orientation and tilt angle….

Moreover, here the criterion is kept very simple, but the criteria can be easily expanded to more complex control scenarios that do more justice to the practice, distinguishing manual control (with delays in response, etc.) and automated control (involving multiple sensors and/or algorithms). These options have recently be added to the spreadsheet, as introduced in 4.2.3 and will be used in the context of the preparation of EN ISO 52016-3 on adaptive building envelope elements.

The details of the add-on sheet have been presented under the description of the calculation tools in 6.1.2.1 (coupling, add-on sheets).

6.2.2.4 Ventilative cooling

(special dynamics involved)

With the simple ‘add on’ sheet introduced in 4.2.3, it is possible to demonstrate the impact of ventilative cooling (with some simplifying assumptions with regard to the assumed air flow rates, as explained in 4.2.3; otherwise a dynamic coupling is needed with the air flow rate calculation, see case study on EN 16798-7, [10]).

The details of the add-on sheet have been presented under the description of the calculation tools in 6.1.2.1 (coupling, add-on sheets).

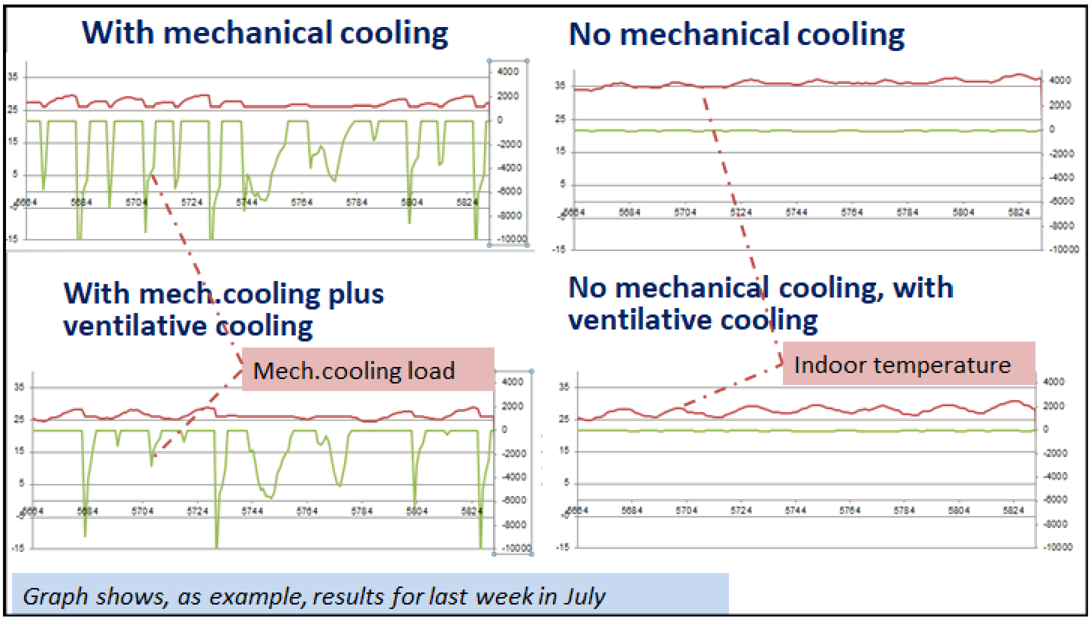
So, an example of **simple and transparent but effective rules** that can be specified in this sheet:

- Increased ventilation if:
  - indoor-outdoor temperature difference > 3 K
  - AND outdoor temperature > 12 C
  - AND indoor temperature exceeds (cooling set-point - 2 K)
- Amount of increased ventilation depends on occupancy
  (cq the required comfort level):
  - Unoccupied or low comfort required: 5 x nominal ventilation
  - Semi-occupied (e.g. daytime residential buildings): 3 x nominal ventilation
  - Fully occupied, high comfort level required: 2 x nominal ventilation

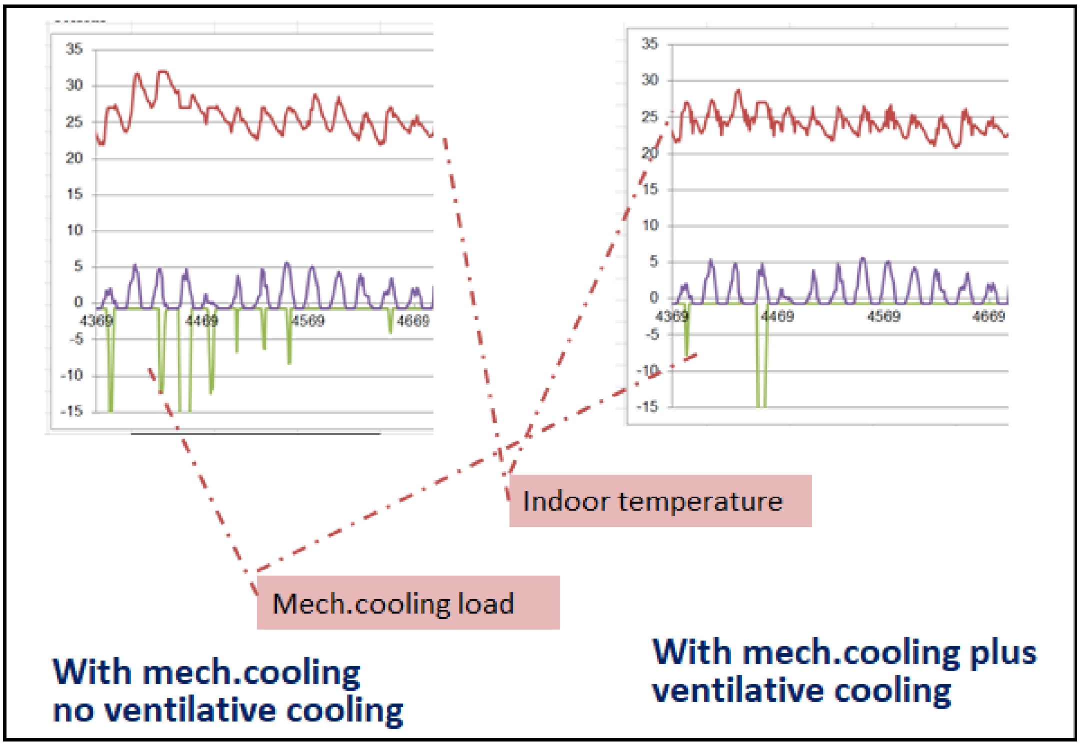
Again, this is only simple and transparent for the hourly calculation method.

For the monthly calculation method it would require complex formulae that correlate the monthly mean extra ventilation for ventilative cooling (which in itself is already complex to comprehend) to monthly mean cooling need, outdoor temperature and more.

Examples of the hourly calculations using the add-on sheet with the above mentioned criteria, moderate climate:



Graph shows, as example, results for last week in July

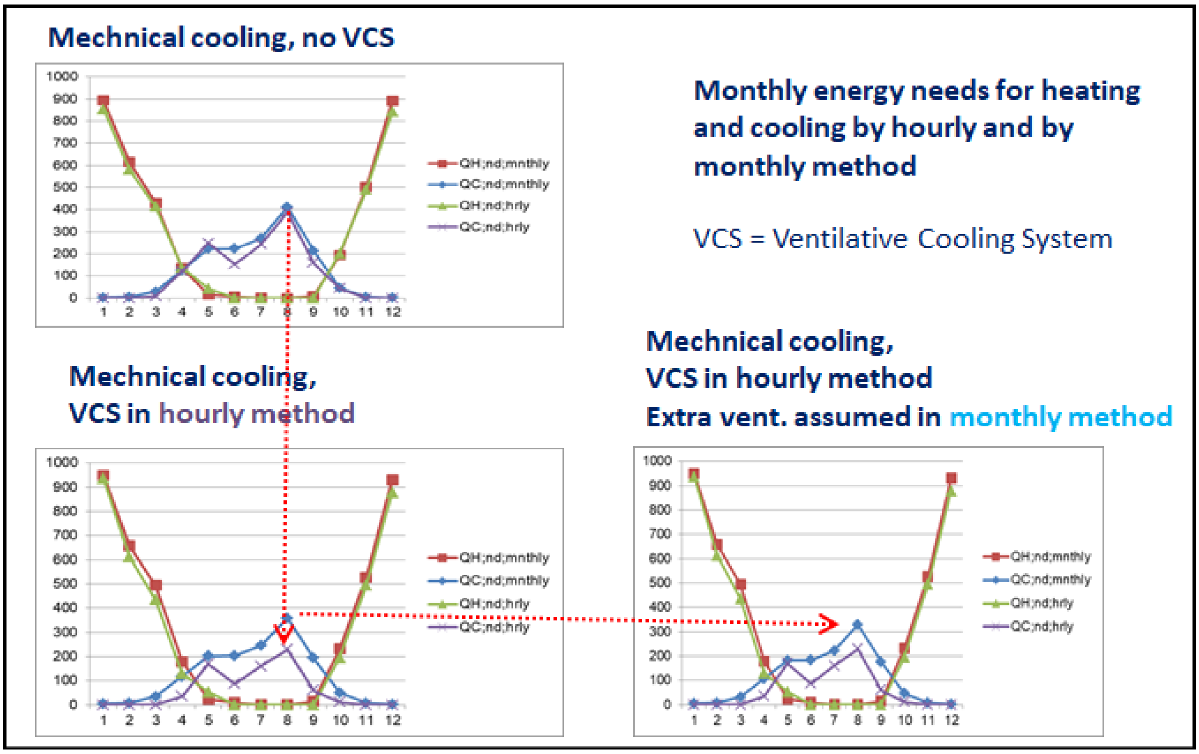


Comparison of results between the hourly method and monthly method:

Without ventilative cooling the results are quite similar.

With ventilative cooling taken into account in the hourly method the results are quite different.

Then a first rough guess was made for the monthly method how much the monthly mean ventilation would have to be increased to take into account the ventilative cooling. Of course this should be different per month, etc. As the graphs show, a better guess would be needed.



6.2.2.5 Dynamic (hourly) coupling to heat pump system calculation

With the dynamic coupling of spreadsheets introduced in 4.2.4, it is possible to demonstrate the impact of a heat pump system on the heating needs and vice versa.

The details of the dynamic coupling have been presented under the description of the calculation tools in 6.1.2.2 (coupling, dynamic coupling).

Note that the case study report on EN 15316-4-2 (heat pump systems) contains a more extensive and systematic set of cases involving heat pumps, also including the coupling with the heating needs[11]).

Variations in the underlying case study:

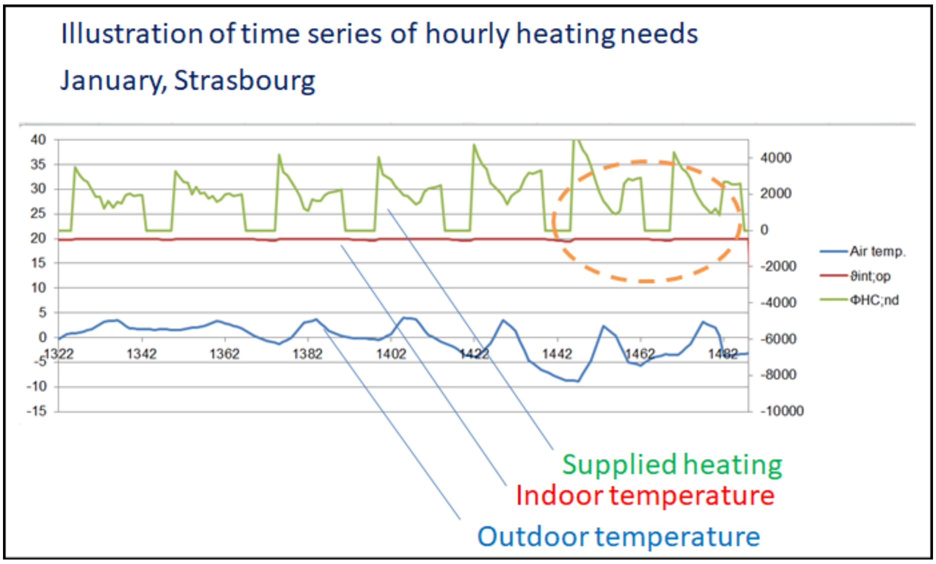
  – 3 climates: Oslo, Strasbourg, (Athens)

- Variation in energy needs
- Heat pump system
  – Air-Water
  – Inverter type
  – Variation in capacity

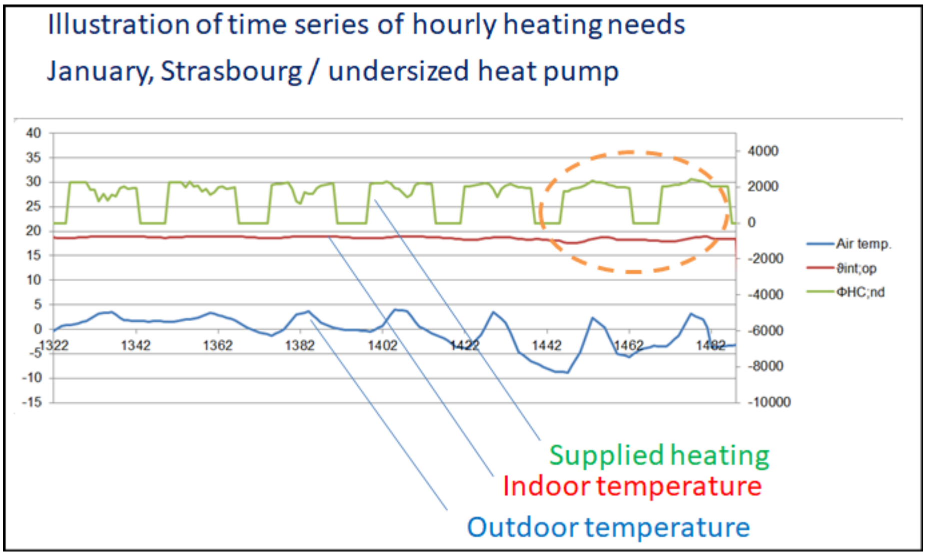
– With/without (electric) backup

Main results of the coupling of the spreadsheets on EN ISO 52016-1 and EN 15316-4-2:

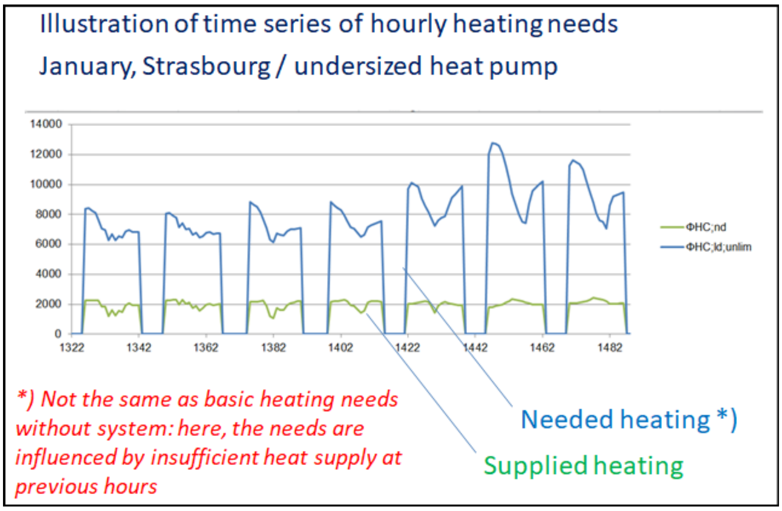
Properly sized heat pump:



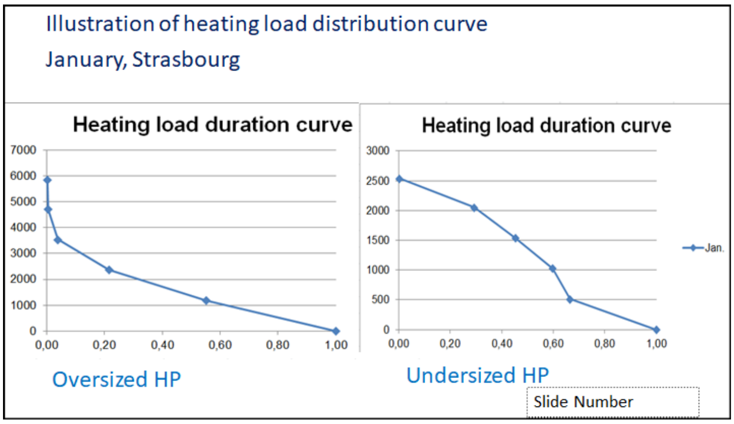
Undersized heat pump, e.g.: **supplied** heating:



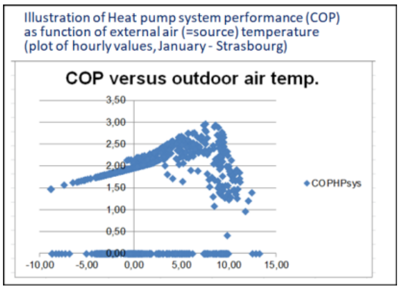
Undersized heat pump, e.g.: **needed** heating versus **supplied** heating:

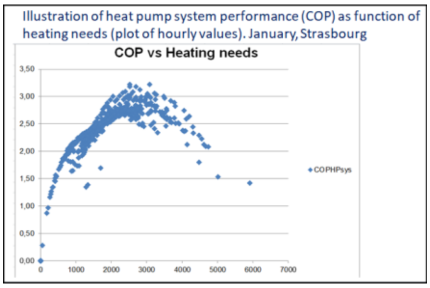


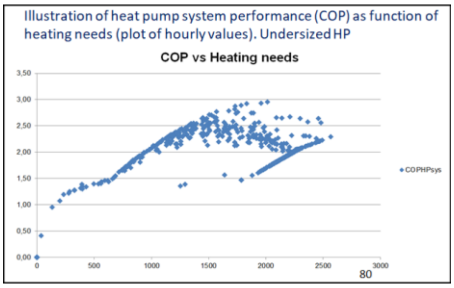
Heating load distribution curve (one of the standard graphs that is provided by the spreadsheet on EN ISO 52016-1):



Coefficient of performance (COP) of the heat pump system, hourly values, as function of outdoor temperature (the source of the heat), hourly heating load if oversized and if undersized. Note that this information is known thanks to the dynamic (hourly) interaction between the two spreadsheets.







Disclaimer: after completion of these calculations, the heat pump system calculation procedures were updated, and so was the spreadsheet on EN 15316-4-2, see [11] for more details.

Conclusion:

The coupling to specific systems has been developed to <u>demonstrate</u> the impact of interaction between hourly energy needs & conditions and the system performance.
Why is this done with spreadsheets?

- Fully transparent step-by-step validation and demonstration
- To show all intermediate results plus references to the formulae in the EPB standard(s)
- Not intended for daily practice
- Results can be used as reference for software tools.

6.2.2.6 Selected other variations

(just to show that apparently minor details may also have a significant effect)

The sensitivity of the colour of external opaque surfaces has been taken as an arbitrary example of the impact of a seemingly minor detail can have on the results.

Athens:

	Insulated	
Energy needs (kWh)	Heating	Cooling
Abs factor=0,8 (default)	470	4534
Abs factor=0,2 (variation)	617	3811
%	+30 %	-16 %

Observations:

Taking into account the colour (solar absorptance) of the external surface has a significant impact on result in a warm and sunny climate.

Because in EN ISO 52016-1 it is a national choice to allow a fixed default value or to ask for the real values, it is relevant to investigate the sensitivity of such parameter.

7 Analysis

7.1 Functionality

The spreadsheet on EN ISO 52016-1 enabled to check many of the functionalities of EN ISO 52016-1 and the links with related EPB standards.

This case study demonstrates that the standard EN ISO 52016-1 provides the necessary information for the other EPB standards, on the basis of available input data.

7.2 Completeness

This case study demonstrates that the hourly calculation procedures in EN ISO 52016-1 provide the data that are needed, in terms of energy needs and thermal comfort.

7.3 Sensitivity

The hourly calculation procedures in the standard and spreadsheet can handle a wide variety of situations and take into account dynamic (hourly) interactions that are important for novel technologies and to bring down the energy needs for heating and cooling to a minimum, while safeguarding thermal comfort.

7.4 Usability

This case study has shown that EN ISO 52016-1 is usable in practice: the input data are conventional and the output is easily understandable.

The spreadsheet is quite complex, because it tries to be as transparent as possible on all steps in the calculation process. Once the focus is on the actually needed input data requested from the user (on a specific building), then it confirms that the input data are conventional.

The use of the spreadsheet is significantly facilitated by the possibility to import climatic data files from EN ISO 52010-1 and hourly operation and use profiles from EN 16798-1.

8 Conclusions and recommendations

The standard covers adequately the scope and produces results that can be readily used in other EPB standards.

The heating and cooling needs and internal temperatures involves some complex physical phenomena. This is reflected in the calculation procedures in EN ISO 52016-1. And consequently the spreadsheet tool also contains many details that make it more difficult to use than most other spreadsheets in the series.

The spreadsheet works well to demonstrate, validate and illustrate the calculation procedure. In particular because nearly each step of the calculation is visible and can be tracked and traced.

The spreadsheet tool is not suited for application in daily practice. It has not been developed for that purpose. For daily use in practice, software tools can be used that have a user-friendly interface and that make the connections to other parts of the calculation. Which connections are needed is clearly shown in the standard as have been illustrated in this document.

The spreadsheet clearly shows all needed input data and that these are available from the specific project (for the hourly calculation method the same as for the monthly calculation method) or from other EPB standards.

It also clearly shows the output data and how these can be used as input for the system related EPB standards (it already handles by itself a 'system specific' calculation) and that, where relevant, hourly interactions can be taken into account.

This underlines that the calculation procedures in EN ISO 52016-1 fulfil the requirements.

The updated version of the spreadsheet, with the major improvements resulting from this case study, will be published spring 2022.

All data and the updated spreadsheet tool will be made publicly available for additional exercises.

Bibliography

[1] (EN) ISO 52016-1:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*

[2] (CEN) ISO 52016-2:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 2: Explanation and justification of ISO 52016-1 and ISO 52017-1*

[3] (EN) ISO 52010-1:2017, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*

[4] (CEN) ISO/TR 52010-2:2017, *Energy performance of buildings — External climatic conditions — Part 2: Explanation and justification of ISO 52010-1*

[5] EPB Center webinars, in particular webinars 4, 5, 7, 8, 9, 10, https://epb.center/support/webinars/

[6] ENERC32017-437-SI2-785.185, Case studies preparatory work, October 31, 2021

[7] ENERC32017-437-SI2-785.185, Case study on EN ISO 52010-1, Climatic data October 31, 2021

[8] ENERC32017-437-SI2-785.185, Case study on EN ISO 52016-1, Annex F, Solar shading reduction factors October 31, 2021

[9] ENERC32017-437-SI2-785.185, Case study on EN 16798-1, Conditions of use October 31, 2021

[10] ENERC32017-437-SI2-785.185, Case study on EN 16798-7, Natural ventilation October 31, 2021

[11] ENERC32017-437-SI2-785.185, Case study on EN 15316-4-2, Heat pumps October 31, 2021

[12] ANSI/ASHRAE standard 140, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*, 2014

Please check the EPB Center website for the overview and most recent versions of the other case study reports.

Link: EPB Center support documents

NOTE References to the applied tools and supporting data are provided in the relevant paragraphs of this document.

This document has been produced under contract with the European Commission (service contract ENER/C3/2017-437/S12-785.185).