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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 16798-7 Natural Ventilation

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Abbreviations and acronyms in this document:

AHU	**Air handling unit**
CA-EPBD, CA-5	**Concerted Action EPBD V**
CEN	**European standards organization**
EN	**European standard**
EPBC	**Energy Performance of Buildings Committee (C09300)**
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**
GDPR	**EU General Data Protection Regulation (2018)**
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**
RER	**Renewable energy ratio**
TR	**Technical report (of CEN and/or ISO)**

1 Introduction

This document is intended to present the case study and to discuss the contents of *EN 16798-7 Energy performance of buildings — Ventilation for buildings — Part 7: Calculation methods for the determination of air flow rates in buildings including infiltration (Modules M5-5)* in combination with ISO 52016-1 *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures (ISO 52016-1:2017)*, in order to show the effect of the natural ventilation calculation represented in EN 16798-7 on the energy needs and internal temperature calculation.

This document is focused on the calculation of air flow rates due to natural ventilation through openings, such as openable windows, in an hourly calculation interval, and their dependence from and influence on internal temperatures and on the energy needs for heating and cooling.

This case study concentrates on a small part of EN 16798-7 in the area of the calculations of air flow rates: the *simplified* calculation of the air flow rates through *open windows*, neglecting all other parts, such as advanced calculation methods and other opening types.

The effect of the coupling of the calculations is shown and discussed, including an intermediate control element between both, determining the conditions and the size of the openings.

An explanation and a summary of the results have been presented in the frame of a webinar from the EPB Center, a recording of which is available under [1].

2 Executive summary

This case study demonstrates the calculation of natural ventilation by coupling of the spreadsheets to the standards EN ISO 52016-1 and EN 16798-7. The single family house from CEN ISO/TR 52016-2 is used. An opening pattern of the east and west windows is used for natural ventilation purposes, using the simplified calculation for openable windows of EN 16798-7. Four cases are calculated, with tow variants each:

- A winter period for an average climate showing the difference between continuous and intermittent airing 3 times a day and its influence on the heating needs:
  The heating needs show peaks at every hour when the intermittent airing is active, often reaching the maximum power, while the continuous airing variant shows a more evenly distributed heating power with peaks in the morning at the starting point of the heating operation. The decrease of the indoor operative temperature during night time is weaker for intermittent airing due to the absence of ventilation losses.
- A summer period for an average climate showing the influence with and without ventilative cooling on the zone operative temperature:
  The ventilative cooling operation leads to considerable lower indoor operative temperatures (maxima always below 27°C) than without ventilative cooling (maxima above 30°C).
- A summer period for a warm climate, also showing the influence with and without ventilative cooling on the zone operative temperature:
  While the indoor temperature without ventilative cooling is far too high, it is lower with ventilative cooling, but still not in a comfortable range. This shows the limitation of the ventilative cooling in this climate, mainly due to the high night time temperatures.
- A whole year hourly calculation for a warm climate showing the influence with and without ventilative cooling on the cooling energy needs:
  The annual cooling needs can be reduced by ventilative cooling by 50%, with the reduction varying between 100% (intermediate season) to 14% during the hot summer months.

The case study demonstrates and proofs the functionality of the simplified openable window calculation in interaction with the energy needs for heating and cooling and the temperature calculation for a thermal zone. The results show an expected behaviour of the thermal zone under the influence of the ventilation boundaries, and vice versa. The order of magnitude of the calculated air flow rates is plausible.

3 The context of the case study

Natural ventilation is, in general, a complicated issue. By natural ventilation, the movement of air into and out from a thermal zone without mechanical means is meant. There are also combined natural and mechanical means, often referred to as "hybrid" ventilation. In this case study, a pure natural ventilation is considered. The air flow rates reached with a specific setup of openings (such as size and placement of openable windows) under specific circumstances (outdoor and indoor climatic conditions) depends on these conditions and simultaneously influences at least a part of them (the indoor conditions), thus forming a classical problem involving an iterative solution.

On the other hand, natural ventilation is important for several reasons, such as to provide sufficient indoor air quality without (direct) energy expenditure and consider this requirement and the different ways of its covering (e.g. continuous opening versus short time boost opening) as a boundary condition for the energy needs. Also, with increasing outdoor temperatures in the course of climate change, the calculation of the effect of techniques and possibilities of "ventilative cooling", i.e. the removal of surplus heat from a thermal zone with the help of cool outdoor air, becomes more important as well as the knowledge and the possibility of the determination of their limits.

In EN ISO 52016-1, the air flow rate due to natural ventilation entering a thermal zone is an input, originating from "module M5-5", represented by EN 16798-7 within the set of (CEN and ISO) EPB standards. Often, in calculations of the energy needs for heating and cooling, these data are entered as constant values, sometimes based on some rules of thumb on the required flow rates for a certain purpose. However, no reliable answer can be given whether or not this assumed amount is really reached under specific conditions. The latter is only possible by using the coupled calculation as shown in this case study.

As can be seen from the above explanations, natural ventilation is an effect strongly varying in time. Therefore, longer calculation intervals, such as monthly calculations, always require either the approach of estimated constant values or a statistical analysis of the conditions, which leads to the indirect consideration of short time interval values (such as hourly). Thus, this topic is one of the predestined effects to demonstrate the value of an hourly (or sub-hourly) calculation interval.

In EN 16798-7, the calculation of the air flow rates covers both natural and mechanical ventilation. The scope is the "emission" part of the ventilation service, which means exactly the determination of the air flow rates to a thermal zone. The mechanical part is not considered in this case study, and for the natural ventilation, only a small part of the techniques covered by the standard is included.

The methods for calculation of air flow rates given in EN 16798-7 include

- Flow rates entering and leaving through
    - open windows
    - vents
    - leakages
    - passive and hybrid ducts
- Boundary conditions (driving forces):
    - Temperature difference (causing a stack effect)
    - Wind speed
- Different levels of models:

  - Simplified (single formula for an element)
  - Detailed (iteration to resolve for balance)
- The definition of openings as an input, e.g.
  - What size of window(s)?
  - What percentage of area can be opened?
  - Single sided or cross ventilation
  - Height and placement of window(s)
  - Similar for other elements

For this case study, the option of the *simplified calculation* for *openable windows* is chosen, including *cross ventilation*.

The coupling of the two spreadsheets of the above-mentioned standards demonstrates that the calculations, their interactions and the data exchange are working as intended.

As will be shown below (Figure 1), the coupling needs the assumption of the operation (control) of the natural ventilation. Although natural ventilation can be automatized, it is in practise often done through hand operation by the occupants. In these cases it is therefore highly user behaviour dependent. In the calculations dealt with in the EPB standards, the modelling of the user behaviour is not possible in detail. As a proxy, some control assumptions, depending on certain criteria, have to be made, which have more the nature of the specification of an automized control. They can be considered as an "ideal" user behaviour. A more realistic user behaviour might be considered by non-ideal criteria in the control assumptions.

4 Coverage of the scope

4.1 Introduction

The criteria to evaluate the intended scope of EN 16798-7 are straightforward:

Since the scope of the standard is the calculation of the air flow rates, these can be directly taken as criterion.

However, the criteria to evaluate the performance of the coupling of EN 16798-7 and EN ISO 52016-1 is, besides the flow rates, the effect of these on

- the energy needs for heating or cooling,
- the indoor air temperatures

on an hourly basis, both standard results from the EN ISO 52016-1 calculation.

4.2 Coupling and complementing

The coupling of the calculation procedures is explained in more detail in section 6.1. The principle of the coupling and the involved data exchange is shown in Figure 1.

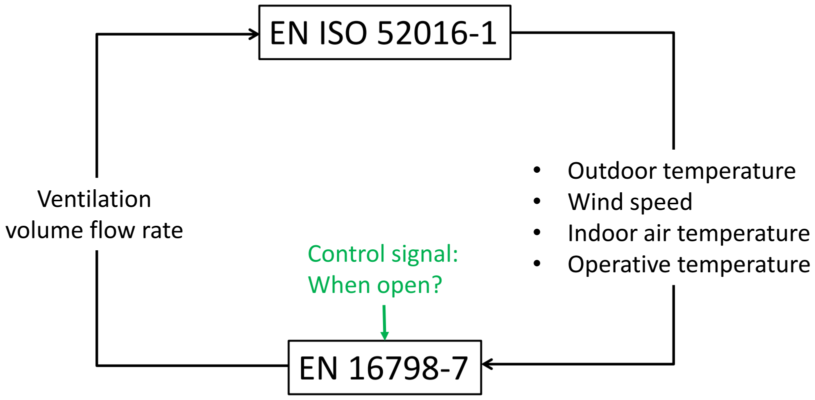

Figure 1 Principle of the coupling of the calculation modules

This principle clearly shows the iterative nature of the coupling:

- A result from the EN ISO 52016-1 calculation – the indoor operative temperature – is transferred to the EN 16798-7 module in order to perform the air flow rate calculation;
- The result from the EN 16798-7 calculation – the resulting air flow rate – is transferred back to the EN ISO 52016-1, in order to repeat the calculation with the new flow rates.

More data transfers from EN ISO 52016-1 to EN 16798-7 are shown in Figure 1. These data – the climatic conditions – are actually common input data to both calculations. They are transferred to make sure that both calculations use the same climatic conditions. The transfer is not mandatory, it can be assured by feeding both calculations with the same data in the beginning. So, there is actually one variable to be transferred each way.

The iterative nature of the coupling is an issue that occurs in different places of the overall calculation by coupling the different modules. No specific technique is given in the standards for this. However, an implementation of the coupled modules in a software will require such technique to be implemented. There are available in the literature, and software developers are familiar with them.

In this case study, which is intended to demonstrate the nature of the coupling, these iterations are avoided by simplifications (see section 6 below).

There is actually a third module involved in the loop shown in Figure 1: the control strategy for the opening of the windows. In EN 16798-7, this is an input variable, but no actual strategy is given. Such strategy needs to be defined case by case, and it involves actually, depending on the intended operation of the openings, a BAC (building automation and control) function. The respective module in the EPB standards gives a classification of such functions, but does not prescribe specific strategies.

In order to make the coupled calculations work, this gap needs to be filled by an assumed control strategy. This is described in section 5.

5 Definition of the cases

5.1 Rationale of the selection of cases

For the demonstration of the intended effects, a simple case of a small building is sufficient. The effects are portable to any other cases of more complex buildings and other types of natural ventilation openings. The technique remains the same, some of the parameters may differ.

The addition of complexity would rather hinder the understanding of the mechanism, therefore the case was kept as simple as possible.

5.2 Types of buildings

The building considered is a the single family house, which is used as one of the examples in the accompanying technical report to the standard EN SO 52016-1 [2]. It is a detached house with ground floor and heated attics. The house is without cellar. It has 150 m² net heated area, 345 m³ net heated volume and 483 m³ gross volume. The area of envelope circumcising heated volume is 386 m² and it consists of floor on the ground, facade, windows, doors, pitched roof and horizontal ceiling towards unheated roof space. The floor plans are shown in Figure 2 and the 3D views in Figure 3.

The properties of the constructions etc. can be taken from [2].

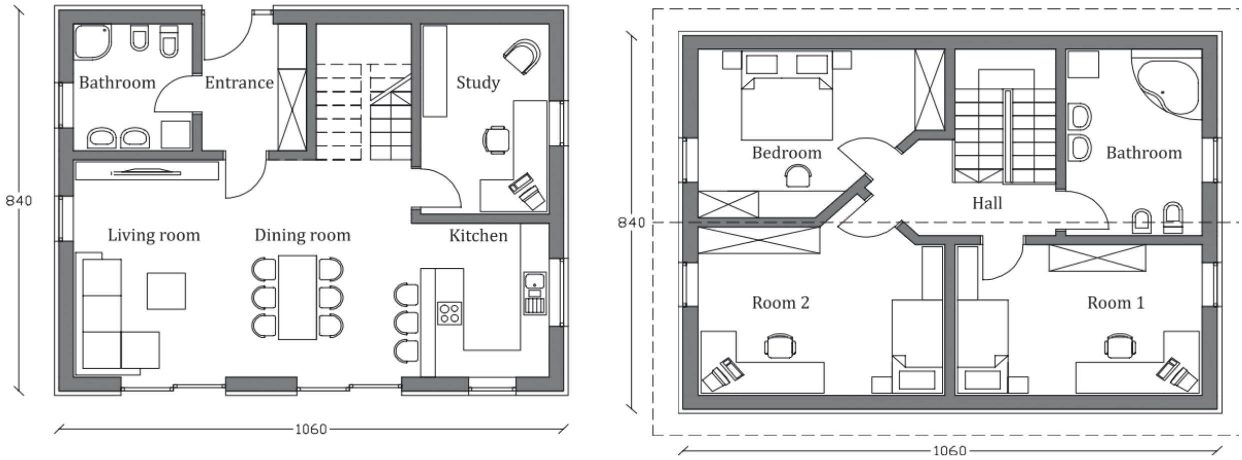

Figure 2: Floor plans of the building

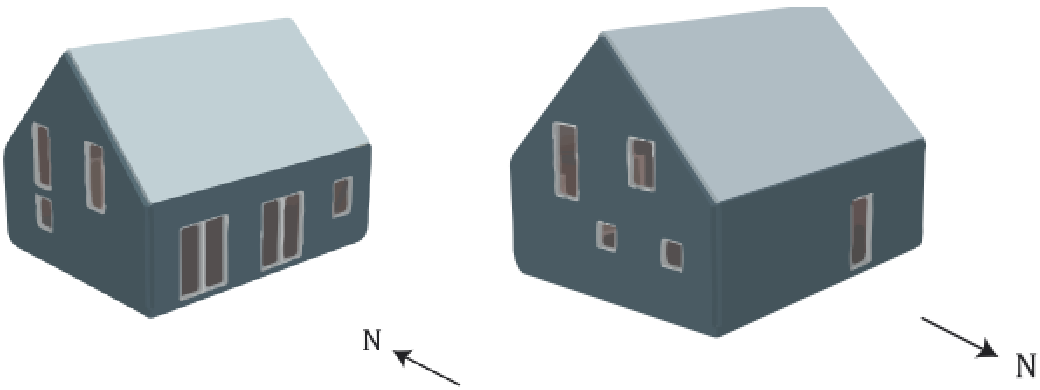

Figure 3: 3D views of the building

5.3 Technologies

The whole building is represented by one single thermal zone.

The openings for natural ventilation are defined as follows: All east and west oriented windows on both floors can be opened to 15% of their area, enabling cross ventilation as well as stack effect over the two floors.

5.4 Calculation parameters

Use profiles for occupation and internal heat sources are taken from the default profiles from EN 16798-1:2019, Annex C for the building use "Residential, Detached house".

Two different climates were used for the case study, provided by the JRC, prepared for the EN ISO 52016-1 calculation according to EN ISO 52000-10 [3]:

- the hourly climate data for the station Strasbourg, representing an average climate for Europe.
- the hourly climate data for the station Athens, representing an warm climate for Europe.

In order to avoid long calculation times, three cases of calculations were performed for a period of 45 days each (including 15 days of pre-conditioning), where a one week period from each was selected in order to analyse and illustrate the results: one with the average climate for each a winter period and a summer, and one for the summer period with the warm climate. For each of the periods, two different variants were calculated, which show a different effect as indicated in the next section.

In addition, two whole year calculations were performed for a fourth case, in order to quantify the effect on the cooling energy needs.

5.5 List of selected cases and variants

5.5.1 Case 1

5.5.1.1 Average climate, winter period

Two different cases of ventilation for the purpose of fresh air supply are compared. As a criterion for the effect, the hourly energy needs for heating is illustrated (see results below, sections 6.3.1 and 6.4.1).

5.5.1.2 Variant 1

Ventilation strategy provides an airing 3 x daily (6am, 12am, and 6pm), with an opening of 15% of the window area during 30% of 1 h(-> resulting in +/- 1 ACH). With an hourly calculation, this proportion of an hour is approximated by a reduction of the flow rate to 30% during 1 h. See discussion below in section 6.3.2 to this aspect.

5.5.1.3 Variant 2

Continuous reduced opening of the windows, resulting in roughly the same daily amount of air as for variant 1. Because it depends on the conditions, the exact amount cannot be reached, but approximated.

5.5.2 Case 2

5.5.2.1 Average climate, summer period

The airing of case 1, variant 1 is kept for the supply of fresh air. In variant 2, this is complemented by a ventilative cooling strategy, with larger openings during times when appropriate. As a criterion, in this case the zone operative temperature without cooling is shown.

5.5.2.2 Variant 1

Airing as in case 1, variant 1. No ventilative cooling.

5.5.2.3 Variant 2

Airing as in case 1, variant 1. In addition, ventilative cooling is added as follows:

An opening of 15% of the window area (resulting in max. +/- 5 air changes, found by try-and-error), is applied under the following conditions (control strategy):

- When outdoor temperature < operative temperature, and
- when operative temperature > 24°C

5.5.3 Case 3

5.5.3.1 Warm climate, summer period

Case 3 is the same as case 2, but with the warm climate.

5.5.3.2 Variant 1

As case 2, variant 1.

5.5.3.3 Variant 2

As case 2, variant 2.

5.5.3.4 Warm climate, whole year with cooling

Case 3 is the same as case 3, but a whole year calculation with the cooling system in operation.

5.5.3.5 Variant 1

As case 3, variant 1, but cooling system operated.

5.5.3.6 Variant 2

As case 2, variant 2, but cooling system operated.

5.5.4 Calculation cases summary

The table of the calculation cases is given in the Table 1.

Table 1: List of considered cases

CASE	Climate	Season	Window operation control	Ventilative cooling	Cooling
A_W_A_NVC	average	winter	Airing 3 x daily	No	off
A_W_C_NVC	average	winter	continuous	No	off
A_S_A_NVC	average	summer	Airing 3 x daily	No	off
A_S_A_VC	average	summer	Airing 3 x daily	yes	off
W_S_A_NVC	warm	summer	Airing 3 x daily	No	off
W_S_A_VC	warm	summer	Airing 3 x daily	yes	off
W_Y_A_NVC	warm	summer	Airing 3 x daily	No	on
W_Y_A_VC	warm	summer	Airing 3 x daily	yes	on

6 Calculation details

6.1 Calculation tools

6.1.1 EN ISO 52016-1 spreadsheet

An enhanced version of the spreadsheet about EN ISO 52016-1 has been prepared for the case study. A coupling routine was added to the code and an interface for the data exchange with the coupled spreadsheets was added, firstly for the coupling with the heat pump calculation [4], then generalised and extended for natural ventilation with the EN 16798-7 spreadsheet. The EN ISO 52016-1 acts as the "master" spreadsheet, controlling the data exchange and the launch of the "slave" spreadsheet(s) calculations, in this case the EN 16798-7natural ventilation calculation.

An additional sheet "EN_16798-7" contains the information on the data exchange (see Figure 4):

- Which data from which sheet is to be transferred to the respective column in the "INPUT_SERIES" sheet of the "slave" spreadsheet;
- Which data is to be transferred from the "OUTPUT_SERIES" sheet of the "slave" spreadsheet to which column in which sheet in the EN ISO 52016-1 spreadsheet.

Parameters for macro:

Time interval number (

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
	WB_slave filename	Demo_EN_16798-7_2020-10-18_nat.xlsm					
	Read from this WB on ISO_52016-1...				**.. And write in WB_slave Input_series**		
	Number of data	4					
1	Outdoor air temp. (C)	ClimData	13	21	External temp. (C)	5	1
2	Wind speed (m/s)	ClimData	14	21	Meteo windspeed (m/s)	7	1
3	$\vartheta_{int;a}$	Output_t	32	7	Vent.zone temp. (C)	6	1
4	$\vartheta_{int;op}$	Output_t	31	7	Operative temperature	11	1
5							
6							
7							
8							
9							
10							

No	Description (just as info)	Column (start from 1st Data)	Description (just as info)	Sheet	Column (start from A)	First data row in this sheet	Multipl.factor
	Read from WB_slave Output_series		**.. And write in this WB on ISO_52016-1**				
	Number of data	1					
1	The total volume airflow rate entering the zone (m3/h)	1	Air flow rate	Input_t	30	7	1
2							
3							
4							
5							
6							
7							
8							
9							
10							

Figure 4: Data transfer parameters for the coupling with the EN 16798-7 spreadsheet in the "EN_16798-7" sheet of the EN ISO 52016-1 spreadsheet

The input data for the thermal zone calculation was imported from a pre-defined input data file *Demo_ISO_52016-1_Input_SFH_2020-10-05a.xlsx*.

The updated spreadsheet on EN ISO 52016-1 will be available on EPB Center website.

6.1.2 EN 16798-7 spreadsheet

An enhanced version of the spreadsheet about EN 16798-7 has been prepared for the case study. In order to reduce "ballast" information for the intended purpose, the original spreadsheet was divided into two separate spreadsheets on natural and on mechanical ventilation (for the use of the latter see [5]).

For the representation of the control strategy described in 5.5.2.3, additional columns were added to the "INPUT_SERIES" sheet (Figure 5).

Start vent. cooling if temp.diff. is >:		0	K
and if outdoor temp. is higher than:		-10	C
and if indoor temp. exceedes: ($\theta_{c;set}$ - x)		2	K
Cooling setpoint		26	C
Window operation control signal	Criterion for ventilative cooling	Operative tepmerature from EN ISO 52016-1 spreadsheet	
$f_{op;w}$			
-			
0.00	0.00	19.90	
0.00	0.00	19.87	
0.00	0.00	19.83	
0.00	0.00	19.80	
0.30	0.00	19.76	
0.00	0.00	20.00	

Figure 5: Additional columns and setting parameters for ventilative cooling in sheet "INPUT_SERIES" of the EN 16798-7 natural ventilation spreadsheet

As can be seen from Figure 5, the parameter setting for the natural ventilation is flexible and not restricted to the settings mentioned in 5.5.2.3.

Since the opening of the windows depends on the operative temperature of the thermal zone, this variable is transferred to one of these columns for further calculations (as can be seen in Figure 4).

The parameters for the window size, placement and opening are set in the sheet "Product_tech_data" (see Figure 6). The simplified calculation is chosen for this case study, since the detailed calculation involves an iteration within the spreadsheet, and this is not implemented to work with time series inputs. Also, it would, in the frame of the coupling, lead to too slow calculations.

	To be completed	Calculated automaticaly (do not modify)	Not used in the choosen configuration
Windows	N_w	2	
Choose the kind of calculation (WIN_FLOW_CALC) you want to use in Process_design_data Fill the number of window (Nw) Fill below the description of each window of the building, blue cells only brown ones are calculated automaticaly. Grey ones are not used for the kind of calculation choosen. Use one column for each window Do not leave void Those data are not used if you make a simplified calculation			
Maximum window opening area	$A_{w;max,i}$	4.88	5.8
Ratio of window opening area to maximum window opening area for a window 'i'	$R_{w;arg,i}$	0.15	0.15
Window opening free area (40)	$A_{w,i} = R_{w;arg,i} \cdot A_{w;max,i}$	0.732	0.87
Mid-height of the window relative to ventilation zone floor level	$h_{w;path,i}$	1.5	4
Free area height of the window	$h_{w;fa,i}$	1.6	1.6
Maximum height	$\left(h_{w;path,i} + \frac{h_{w;fa,i}}{2}\right)$	2.3	4.8
Minimum height	$\left(h_{w;path,i} - \frac{h_{w;fa,i}}{2}\right)$	0.7	3.2
Window orientation (0° = South, 90°= West, 270° = East, 180°= North) only use for cross ventilation	$\alpha_{w,i}$	0	180
Window angle (0° = horizontal, 90° = vertical) only use for cross ventilation	$\beta_{w,i}$	90	90

Figure 6: Parameters for the openable windows in EN 16798-7 spreadsheet

The parameters for all other types of openings and natural ventilation schemes were set to 0, so that the only natural ventilation occurring is the openable windows as specified.

The spreadsheet is available on EPB Center website under the name *Demo_EN_16798-7_2021-07-12_nat.xlsm*.

6.1.3 Coupling

As outlined in section 4.2, the coupling is in principle an iterative process, which needs to be resolved when implementing the calculations in a software. It is, however, not the intention of the spreadsheets provided for the single calculation method of each module, to resolve for this iteration in the case of coupling. Some calculation modules involve iterations within the module, so in total, a full implementation of nested iterations would lead to very slow calculations.

The simplification applied in order to avoid the iteration in the present case is a time shift of 1 h. This means, for the calculation of the control of the window opening and, as a consequence, the calculation of the flow rate in case of ventilative cooling, the indoor operative temperature is taken from the previous hour. This is done in the "Criterion for ventilative cooling" column in the "INPUT_SERIES" sheet of the EN 16798-7 spreadsheet (Figure 5).

6.1.4 Supporting calculations

6.1.4.1 Use profiles

The use profiles are taken from EN 16798-1 default profiles for detached house.

6.1.4.2 Climatic data

Climatic data are calculated with the EN ISO 52010-1 module, using data from the JRC data-base for the stations of Strasbourg (average climate) and Athens (warm climate).

6.2 Definitions of the cases

6.3 Case 1: Average climate, winter

6.3.1 Calculation results

The results of the hourly calculation are given in Figure 7 and Figure 8.

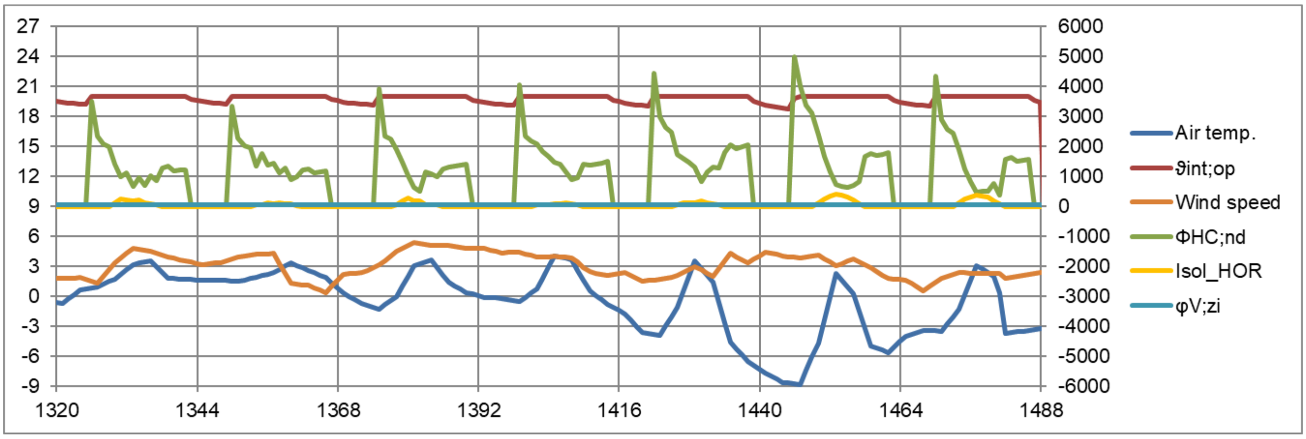

Figure 7: Hourly courses of the outdoor and indoor conditions, the ventilation flow rate and the heating need for a selected week for the variant 1 with continuous window opening

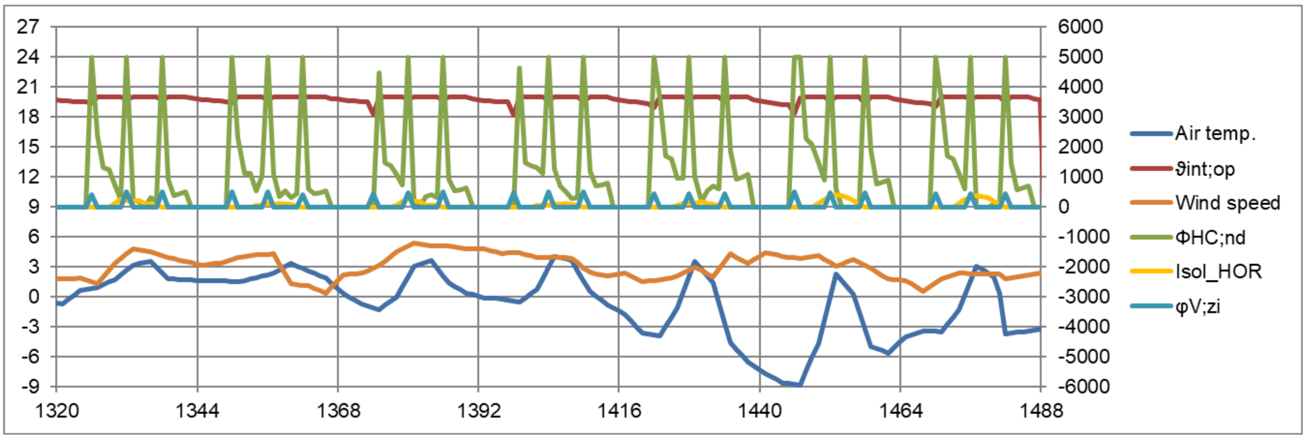

Figure 8: Hourly courses of the outdoor and indoor conditions, the ventilation flow rate and the heating need for a selected week for the variant 2 with airing 3 x per day

6.3.2 Discussion

Comparing Figure 7 and Figure 8, the following differences can be seen:

- While in Figure 7 the ventilation flow rate (bright blue curve) can hardly be seen (due to the scale of the secondary axis), the 3 peaks of the airing 3 times a day are clearly shown in Figure 8.
- The heating needs in Figure 7 show peaks in the morning at the starting point of the heating operation, due to the interrupted operation of the heating system. The heating needs then decrease due to the termination of the heating-up, the milder temperatures and the heat gains during daytime. The peak of 5'000 W is sharply hit in the morning of day 6.
- The heating needs in Figure 8 show peaks at every hour when the airing is active. The peaks regularly reach the maximum of 5'000 W, which is the limit of the heating system. On day 6, this limit is kept during > 1 h.
- The decrease of the indoor operative temperature during night time is weaker in variant 3 (Figure 8), due to the absence of ventilation losses.

It must be noted that the representation of the airing in variant 2 actually is a compromise in the hourly calculation interval, since it is actually a sub-hourly effect (30 % of the max. opening during 1 h to represent 30% of the time with 100% of the max. opening). This is of importance for the effect on the total heating needs, where the expectation is, that it is reduced for the case of short time boost airing versus continuous opening. This effect is only partly represented due too the 1 h calculation interval limitation.

6.4 Case 2: Average climate, summer

6.4.1 Calculation results

The results of the hourly calculation are given in Figure 9 and Figure 10.

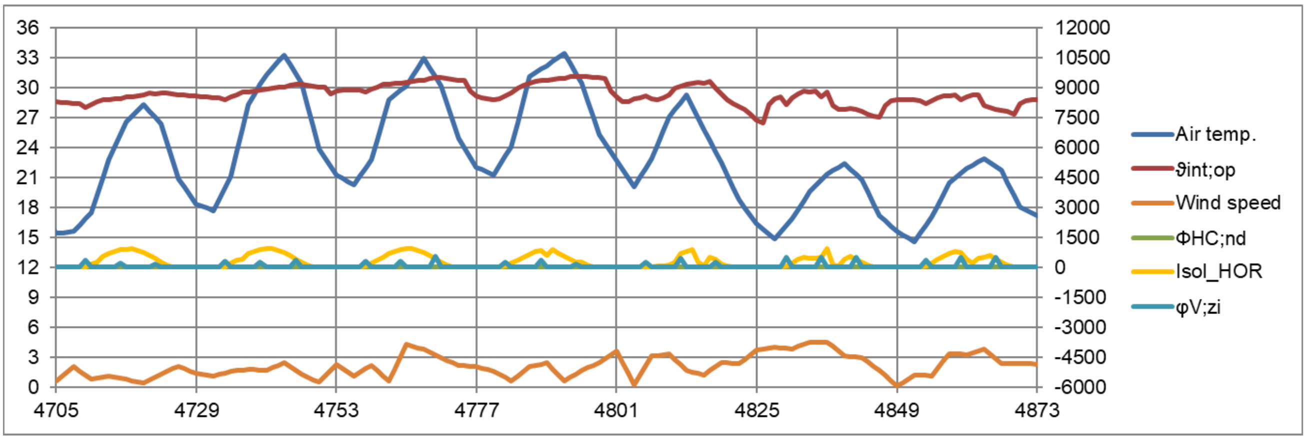

Figure 9: Hourly courses of the outdoor and indoor conditions and the ventilation flow rate for a selected week for the variant 2 with airing 3 x per day

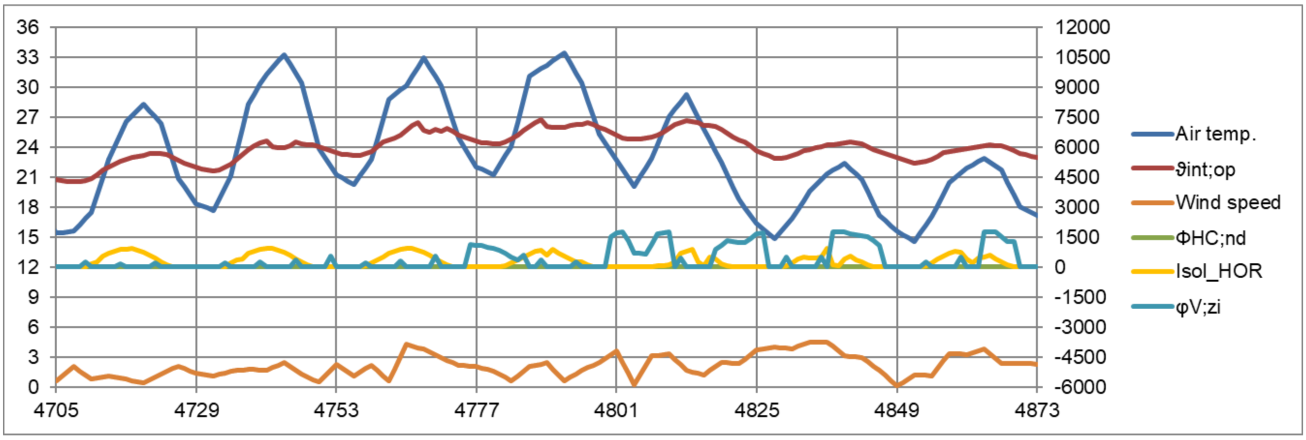

Figure 10: Hourly courses of the outdoor and indoor conditions and the ventilation flow rate for a selected week for the variant 2 with airing 3 x per day and ventilative cooling

6.4.2 Discussion

Comparing Figure 9 and Figure 8, the following differences can be seen:

- The height of the peaks in the air flow rate from the airing in Figure 9 are varying with the conditions, which is due to the varying driving forces (wind and temperature difference).
- The height of the peaks in the air flow rate from the airing in Figure 9 are lower that those in the heating case (Figure 8). This is due to the lower driving forces, especially the lower temperature differences during certain times. This is a signal that the airing effect may be insufficient with the chosen opening during summer time, and a respective reaction would be necessary.
- The ventilative cooling operation in Figure 10 leads to considerable lower indoor operative temperatures (maxima always below 27°C) than without ventilative cooling (Figure 9, maxima above 30°C). It needs to be noted that the decrease in these maxima is a result not only of the ventilative cooling during the week shown in the figure, but also during the time before.

- The effect of the ventilative cooling control can be seen from the air flow rate in Figure 10: There are times when no ventilative cooling is active, although the outdoor temperature is cool enough, because the indoor temperature does not reach the threshold (night between days 1 and 2, days 2 and 3 and days 6 and 7). There are also times, when no ventilative cooling is active, although the indoor temperature is high (> 24°C), because the outdoor temperature is higher than the indoor temperature (days 1 to 5, daytime).
- The start and stop time of the ventilative cooling operation are delayed by 1 h against the criteria (temperature difference and indoor temperature threshold). This is due to the 1 h time shift simplification described in section 6.1.3.

6.5 Case 3: Warm climate, summer

6.5.1 Calculation results

The results of the hourly calculation are given in Figure 11 and Figure 12.

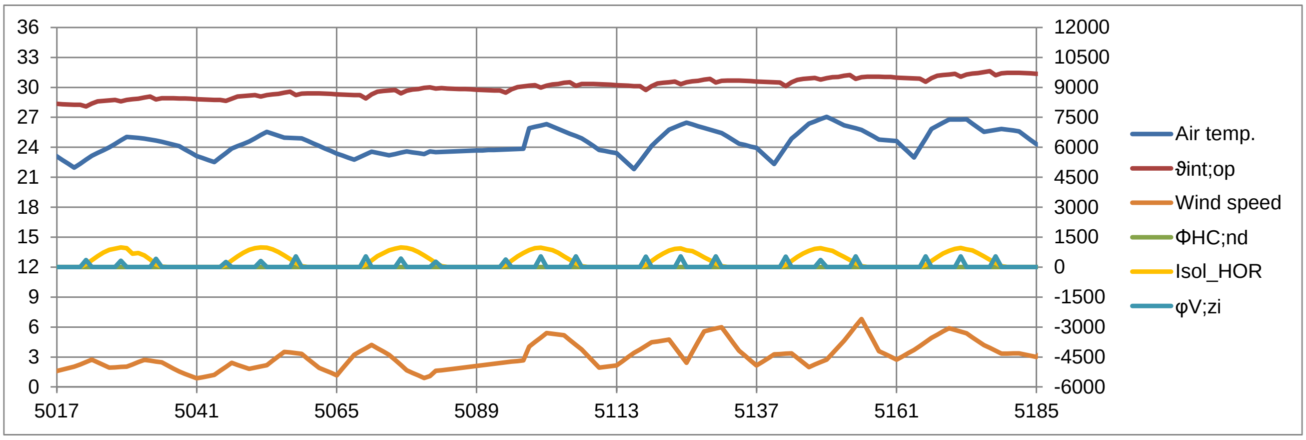

Figure 11: Hourly courses of the outdoor and indoor conditions and the ventilation flow rate for a selected week for the variant 2 with airing 3 x per day

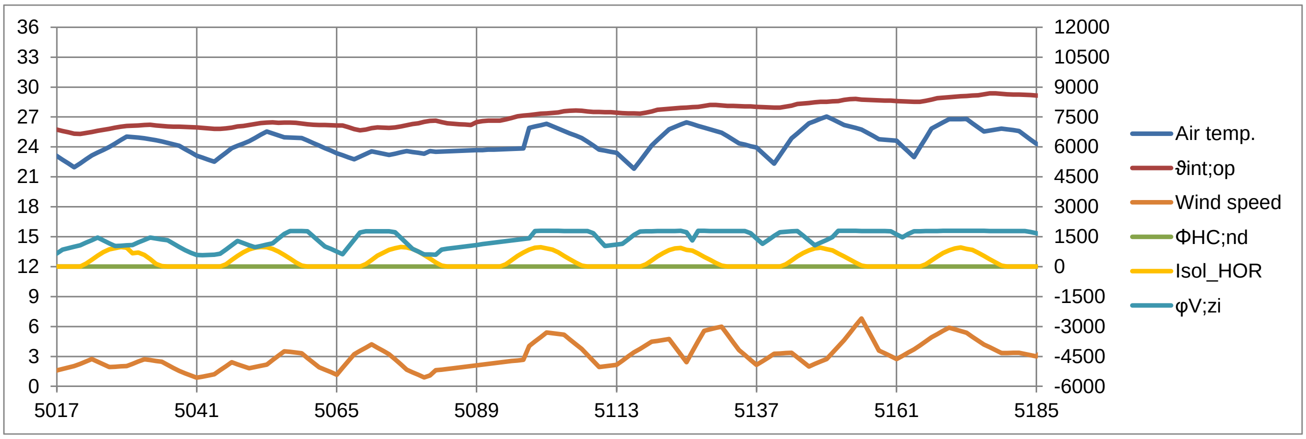

Figure 12: Hourly courses of the outdoor and indoor conditions and the ventilation flow rate for a selected week for the variant 2 with airing 3 x per day and ventilative cooling

6.5.2 Discussion

Comparing Figure 11 and Figure 12, the following differences can be seen:

- Although the outdoor temperature during the week shown is in average not very high, it has quite high minima, i.e. these are "tropical nights", where the minimum temperature does not fall below 20°C. The indoor temperature without ventilative cooling in Figure 11 is far too high and still increases.

- The indoor temperature with ventilative cooling in Figure 12 is lower, but at least in the second half of the week still not in a comfortable range, although the ventilative cooling is active all the time. This shows the limitation of the ventilative cooling in this climate, mainly due to the high night time temperatures.

6.6 Case 4: Warm climate, whole year, with cooling

6.6.1 Calculation results

The results of the hourly calculation are given in Table 2, comparing the cooling energy needs of both variants.

Table 2: Cooling energy needs for case 4, with and without ventilative cooling

	Ventilative cooling		
	no	**yes**	
	Cooling energy need, $Q_{C;nd;hrly}$		Difference
	kWh	kWh	%
Jan	0	0	0.0
Feb	0	0	0.0
Mar	0	0	0.0
Apr	10	0	100.0
May	419	0	100.0
Jun	733	193	73.6
Jul	930	799	14.0
Aug	942	806	14.4
Sep	529	112	78.8
Oct	344	0	100.0
Nov	97	0	100.0
Dec	0	0	0.0
Year	**4004**	**1911**	**52.3**

6.6.2 Discussion

From Table 2, the following differences can be seen:

- The annual cooling energy needs are slightly more than 50% lower with ventilative cooling than without.
- During the intermediate season, the whole cooling energy needs can be economised by ventilative cooling.
- During the hot summer months, only a small proportion of the cooling energy needs can be eliminated by ventilative cooling. This is due to the limitations, especially during the nights, where the outdoor temperatures remain quite high (see also 6.5.2).

7 Analysis

7.1 Completeness

This case demonstrates that the coupled spreadsheets of EN ISO 52016-1 and EN 17898-7 are able to represent the effect of a controlled and calculated natural ventilation.

The inputs and outputs are present to exchange the necessary data. Some slight changes in the EN 16798-7 spreadsheet, not affecting the actual calculation method, were necessary (such as the conversion of the unit of the zone air temperature from K to °C).

7.2 Functionality

The case study is restricted to the demonstration of the functionality of the simplified openable window calculation in interaction with the energy needs for heating and cooling and the temperature calculation for a thermal zone.

This functionality could be proofed.

The principle applied here can easily be adapted to other natural ventilation types covered by EN 16798-7. However, the use of the detailed (iterative) calculations provided by EN 16798-7 could not be tested in this case study.

7.2.1 Sensitivity

The focus of the study is on the functionality of the coupling.

The results show an expected behaviour of the thermal zone under the influence of the ventilation boundaries, and vice versa. The order of magnitude of the calculated air flow rates is plausible.

In the course of the "try-and-error" process for the determination of the input parameter settings for this restricted study, the sensitivity of the flow rate calculation in EN 16798-7 could be explored to some extent. This is not documented and reported, however.

7.3 Usability

As can be seen from Figure 6, the input required for the applied simplified window calculation is minimal. More input date would be required for the detailed calculation and for other types of natural ventilation.

The standard proved to be very useful for the purpose of this study, as far as its possibilities were used.

8 Conclusions and recommendations

The standard covers adequately the scope, as far as it could be explored by this study.

The spreadsheet needed to be updated for data exchange reasons and will be made available on the EPB Center web site.

Annex A

List of supporting files

A_S_A_NVC_EN_ISO_52016-1.xlsm

A_S_A_VC_EN_ISO_52016-1.xlsm

A_W_A_NVC_EN_ISO_52016-1.xlsm

A_W_C_NVC_EN_ISO_52016-1.xlsm

W_S_A_NVC_EN_ISO_52016-1.xlsm

W_S_A_VC_EN_ISO_52016-1.xlsm

W_Y_A_NVC_EN_ISO_52016-1.xlsm

W_Y_A_VC_EN_ISO_52016-1.xlsm

Demo_EN_16798-7_2020-10-18_nat.xlsm

Demo_EN_16798-7_2020-10-18_nat_cont.xlsm

EPB_Center_Webinar_8_20201020_nat_Vent_V2.pdf

Bibliography

[1] https://epb.center/news/news_events/eighth-webinar-calculations-needs-systems/

[2] 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

[3] TMY-ISO-52010-1_conversion_2021-01-05.zip on https://epb.center/support/documents/tmy-iso-52010-1_conversion/

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

[5] ENERC32017-437-SI2-785.185, Case study on EN 16798-7 and EN 16798-5-1, Mechanical ventilation
October 31, 2021

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

Link: EPB Center support documents

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