Calculation of the energy performance of ventilation and cooling systems

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In the present paper, an overview of the new calculation related standards from CEN TC 156 in the area of ventilation and cooling, the prEN 16798-family, is given.

An introduction to the content of the 3 standards on ventilation is given, where an hourly and a monthly calculation method are available in separate documents for the duct system and air handling unit parts.

For the cooling related standard, the content of the standards and the interconnection is shown based on the general part prEN 16798-9, which connects the calculation pieces of the other standards for emission, distribution, storage and generation to a complete system.

The standards revised under the lead of CEN TC 156 "Ventilation for buildings" have all been allocated a new number: prEN 15798, with different parts for the different areas.

This article described the standards of this family which deal with the calculation methods for the energy performance of ventilation, air conditioning and cooling systems. The parts 1, 3 and 17 of the prEN 16798 family are not covered in this article, since there are separate articles on the indoor environment parameters (prEN 16798-1, the revision of EN 15251, see [1]), the performance requirements of ventilation and room conditioning systems (prEN 16798-3, the revision of EN 13779, see [2]) and inspection of ventilation and air conditioning systems (prEN 17898-17, the revision of EN 15239 and 15240, see [3]), including their accompanying technical reports.

The calculation standards consist of the following parts:

prEN 16798-5-1: Energy performance of buildings – Modules M5-6, M5-8, M6-5, M6-8, M7-5, M7-8 – Ventilation for buildings – Calculation methods for energy requirements of ventilation and air conditioning systems – Part 5-1: Distribution and generation (revision of EN 15241) – method 1.

prEN 16798-5-1: Energy performance of buildings – Modules M5-6, M5-8 – Ventilation for buildings – Calculation methods for energy requirements of ventilation systems – Part 5-2: Distribution and generation (revision of EN 15241) – method 2.

prEN 16798-7: Energy performance of buildings – Module M5-5 – Ventilation for buildings – Calculation methods for energy requirements of ventilation and air conditioning systems – Part 7: Emission (determination of air flow rates, revision of EN 15242).

prEN 16798-9: Energy performance of buildings – Module M4-1 – Ventilation for buildings – Calculation methods for energy requirements of cooling systems – Part 9: General.

prEN 16798-11: Energy performance of buildings – Module M4-3 – Calculation of the design cooling load.

prEN 16798-13: Energy performance of buildings – Module M4-8 – Ventilation for buildings – methods for the calculation of the energy performance of cooling systems – Part 13: Generation.

prEN 16798-15: Energy performance of buildings – Module M4-7 – Calculation of cooling systems – Part 15: Storage – General.

The documents with the even numbers are the accompanying technical reports going along with the standards. As can be seen in the titles, the standards are designed to cover specific modules in the modular structure. This is also shown in **Table 1**.

Figure 1 shows a schematic view of a ventilation and cooling system with the areas that are covered by the different standards. It also includes reference to the two standards from CEN TC 228 which have been agreed to cover cooling issues: these are prEN 15316-2 for the emission of water based cooling systems and prEN 15316-3 for the distribution of water based cooling systems.

Ventilation standards

Emission

The ventilation related systems and standards are indicated in green in **Figure 1**. The start of the calculation of ventilation systems is in the occupied space and is described in prEN 16798-7, the former EN 15242. This standard was changed to fully cover module M5-5 "emission". For this, it was extended to include:

- the calculation of air flow rates also for mechanical ventilation system, including VAV systems;
- the required conditions of the supply air (depending on system type and control).

For required air flow rates there is a reference to prEN 16798-1 (EN 15251 rev.) and for the definition of the ventilation effectiveness to prEN 16798-3 (EN 13779 rev.). The parts on the leakage of distribution systems were moved to prEN 16798-5. The accompanying Technical Report and spreadsheet are available, see [4], [5].

Distribution and generation

In the course of development of prEN 16798-5, which is intended to cover a number of modules in the areas of distribution, i.e. the duct system, and "generation", which for the ventilation and air conditioning service is meant to be the air handling unit (AHU), including humidification and dehumidification, it was decided to divide the work item into two separate documents because the scope of the two calculation methods is different:

- Part 5-1 describes a detailed method for ventilation and air conditioning systems and uses an hourly calculation step. It is a comprehensive calculation of all aspects of AC systems. The accompanying TR is available [6].
- Part 5-2 is a simplified method for compact systems, based on a proposal from TC 156 WG 2 (the residential ventilation working group). It uses a monthly calculation step and includes heat generation (like air-to-air heat pumps) and domestic hot water heating. It does, on the other hand, not cover the full range of technologies which are contained in part 5-1. Although it is

Table 1. Areas of the modular structure covered by the CEN TC 156 standards.

Overarching		Technical Building Systems					
	Descriptions		Descriptions	Cooling	Ventilation	Humidification	Dehumidification
sub1	M1	sub1		M4	M5	M6	M7
1	General	1	General	prEN 16798-9	prEN 16798-3		
2	Common terms and definitions; symbols, units and subscripts	2	Needs				
3	Applications	3	Maximum Load and Power	prEN 16798-11			
4	Ways to Express Energy Performance	4	Ways to Express Energy Performance	prEN 16798-9	prEN 16798-3		
5	Building Functions and Building Boundaries	5	Emission & control		prEN 16798-7	prEN 16798-5	prEN 16798-5
6	Building Occupancy and Operating Conditions prEN 16798-1	6	Distribution & control		prEN 16798-5		
7	Aggregation of Energy Services and Energy Carriers	7	Storage & control	prEN 16798-15			
8	Building Partitioning	8	Generation & control	prEN 16798-13	prEN 16798-5	prEN 16798-5	prEN 16798-5
9	Calculated Energy Performance	9	Load dispatching and operating conditions				
10	Measured Energy Performance	10	Measured Energy Performance				
11	Inspection	11	Inspection	prEN 16798-17	prEN 16798-17	prEN 16798-17	prEN 16798-17

primarily dedicated to residential systems, the scope is intentionally not restricted to these, since there are many non-residential applications with smaller units of this type. A separate TR and a spreadsheet are available [8], [9].

Part 5-1 has a lot of options to be chosen, many of them being control options with a link to the building automation CEN TC 247, especially EN 15232 rev., which will be updated to reflect these options:

- Different air flow control types
- Supply air temperature and humidity control types
- Different types of heat recovery:
  - flat plate;
  - Rotary;
  - Pumped circuit.

  For the calculation there is a connection to product standards (EN 308, 13053), and it includes the aspects of
  - Control;
  - Frost protection;
  - Auxiliary energy consumption.
- Recirculation control
- Fan control
  - Several options, based on an input from CEN TC 247, different for single zone / multi zone systems; experience showed that this has a big impact on the fan energy consumption and was too optimistic in the current version of EN 15241;
  - Link to inputs from product standards (on fans, from WG 17 in TC 156).
- Ground preheating / -cooling
- Adiabatic cooling by humidification of extract air and heat recovery.

Figure 2 shows the scheme used for the explanation of the nomenclature in the standard, which is also used in the accompanying spreadsheet [7]. The latter is fully functional and covers all options offered in the standard. In order to ease its use, the options choices are given in drop down menus as shown in **Figure 2**.

Cooling calculation standards

General

The core of the cooling related calculation standards is prEN 16798-9, the "general" part, which is supposed to be the revision of the current EN 15243. However, not much of the content of the latter remained in the new draft: some parts were moved to other standards (such as the cooling load related issues to prEN 16798-11 or the generation related information, as far as normative, to prEN 16798-13). A big part of the content was in informative annexes, and some remaining part of this was moved to the accompanying prCEN TR 16798-10 [10].

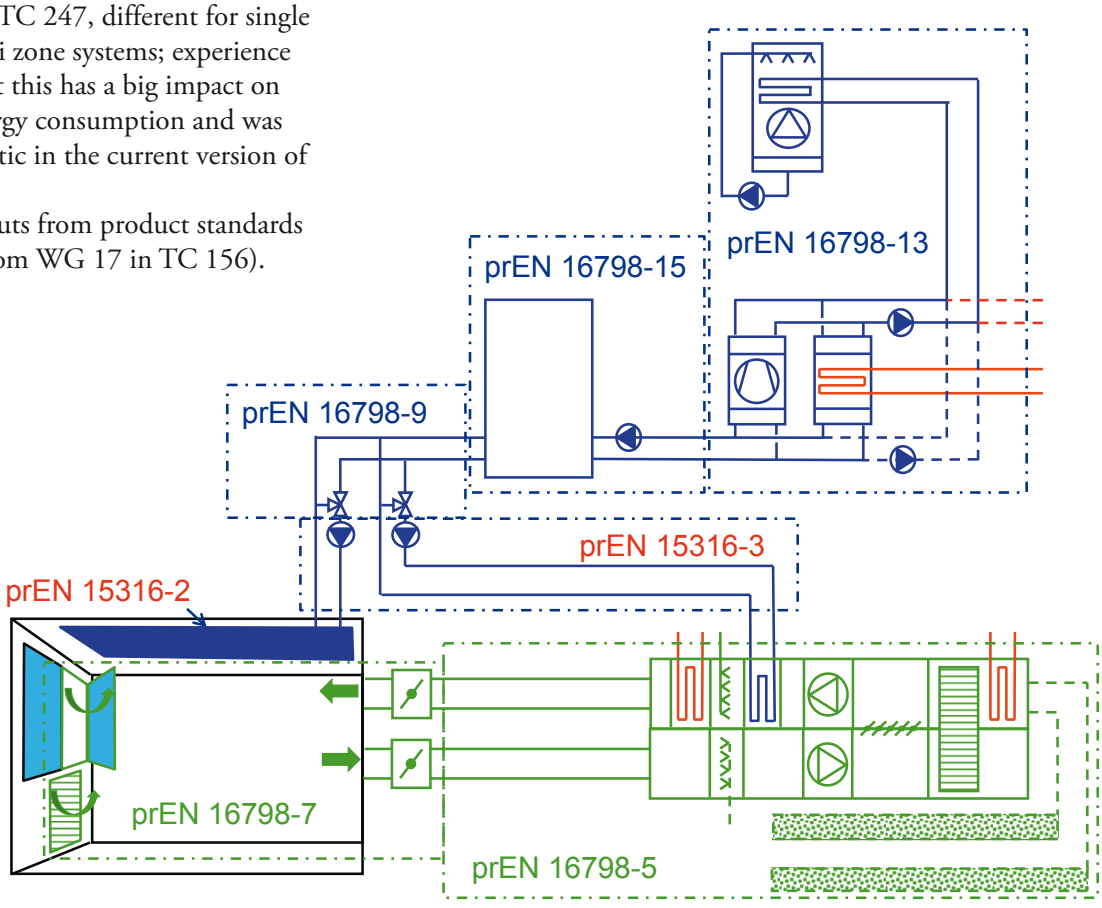


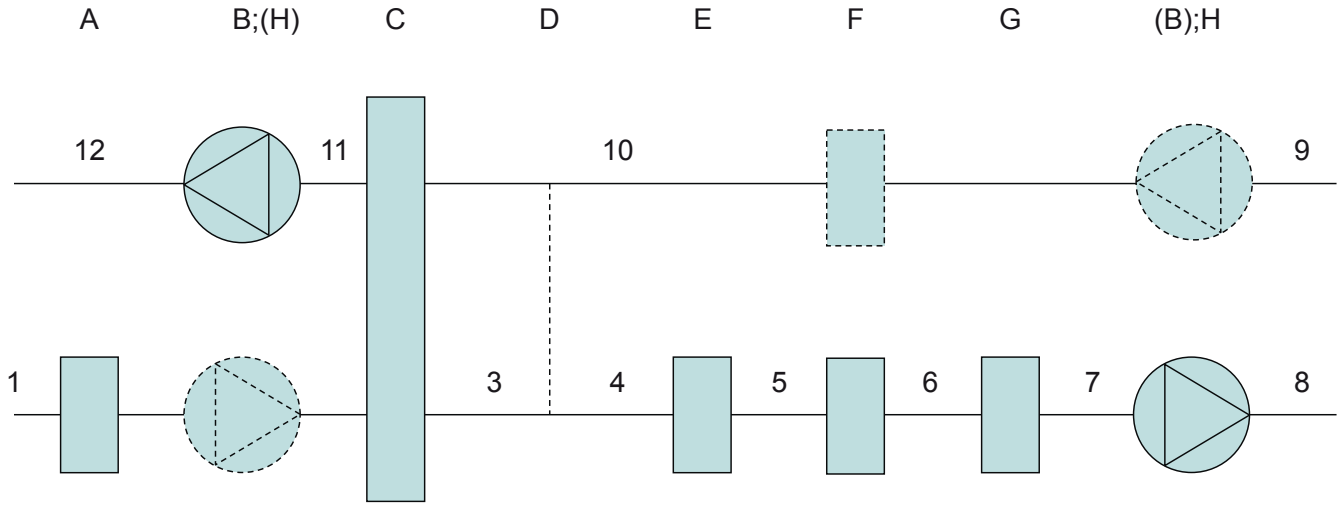
Figure 1. System schematic with the covered areas of the different standards.

Similar to prEN 15316-1, the general part of the heating and DHW calculation standards, part 9 connects the calculation pieces of the other standards for emission, distribution, storage and generation to a complete system, considering the flow rate and temperature control of the distribution branches and the load dispatching in case of insufficient energy supplied by the generation system. It follows (as the other parts do) the principle (agreed by the CEN TC 371 CTL), that a subsequent energy using module reports the **required** energy supply to the delivering module per calculation interval, and this in turn reports the energy **really delivered**, based on its operational conditions, back to the using module per calculation interval.

Figure 3 shows the schematic representation from the standard, illustrating the boundaries of the involved modules and the nomenclature used in the standard.

As already mentioned, modules M4-5 and M4-6 are supposed to be covered by the TC 228 standards prEN 15316-2 and 3. The (non-exhaustive) system shown in **Figure 3** with a generation, storage and two distribution branches, each serving two thermal zones and one air handling unit, is exactly represented in the spreadsheet going along with the standard [11]. In this spreadsheet, a full annual data set of hourly values is implemented to test the calculation. This also to test the partial performance indicator calculation as mentioned below. Apart from the water based systems shown above, the standard also addresses direct expansion (DX) systems. In this case the calculation becomes generally simpler. A schematic representation is given in the accompanying TR [10].

Part 9 also covers module M4-4 with two partial performance indicator proposals for cooling systems:



General	A	B	C	D	E	F	G	H
Volume flow rates	Frost protection / ground preheating/-coo-ling	Exhaust air fan	Heat recovery	Recirculation	Cooling / dehumidification	Humidification	Heating	Supply fan
Detailed								
Air handling unit localosation	Ground air preheating and -cooling	localisation	Heat recovery type			Humidifier type		Fan motor localisation
NC	else	DOWN_HR	ROT_SORBT	yes		CONTACT		OUTS_AIR
Supply air temperature control	Frost protection type		only for FLAT_PLATE and ROT_HYG	Recirculation control		humidifier control		System type for variable air volume flow rate fan energy calculation
ODA_COMP	PREH		-	VARIABLE		SPEED		SINGLE_ZONE
Control of the volume flow rate	Control of the frost protection		Control of the heat recovery device			Adiabatic cooling		Control of the fan
VARIABLE	INDIRECT		SPEED					DIRECT
								localisation
								DOWN_HR

Figure 2. Ventilation/AC-system scheme and technology choice options in prEN 16798-5-1.

The annual efficiency of the total cooling system can be calculated with **Equation (1)** and the annual efficiency of the cooling generation system with **Equation (2)**.

An issue of importance repeatedly mentioned by stakeholders is ventilative cooling, i.e. cooling by enhanced natural and/or mechanically assisted ventilation. This cannot be covered by one standard; since it involves the thermal zone calculation as well as flow rate calculations and control issues. Therefore, a description of the necessary procedure, the modules involved and the information flow is given in the accompanying TR [10]. The respective scheme is shown in **Figure 4**.

Generation

prEN 16798-13 is a new standard for the cooling generation calculation, which was until now covered only in an informative annex of EN 15243. It contains 2 Methods:

- Method A for an hourly calculation step;
- Method B for a monthly calculation step.

$$\eta_{C;tot;an} = \frac{\sum_{t_{ci}} \sum_{i} \left(\sum_{j} Q_{C;zt,j;i} + \sum_{k} Q_{C;ahu,out;k;i} \right)}{\sum_{t_{ci}} \left(E_{C;gen;el;in} + Q_{H;C;gen;abs;in} + W_{C;aux;gen} + W_{C;aux;sto} + \sum_{i} W_{C;aux;dis;i} + \sum_{i} \sum_{j} W_{C;aux;em;j;i} \right)} \quad (1)$$

$$\eta_{C;gen;an} = \frac{\sum_{t_{ci}} Q_{C;dis;in}}{\sum_{t_{ci}} (E_{C;gen;el;in} + Q_{H;C;gen;abs;in} + W_{C;aux;gen})} \quad (2)$$

Where:

t_{ci} = Calculation interval [h]
$E_{C;gen;el;in}$ = Electric energy input to the cooling generation [kWh]
$Q_{H;C;gen;abs;in}$ = Heat input to the absorption cooling generation [kWh]
$W_{C;aux;gen}$ = Auxiliary energy input to the cooling generation [kWh]
$W_{C;aux;sto}$ = Auxiliary energy input to the cooling storage [kWh]
$W_{C;aux;em;j;i}$ = Auxiliary energy input to the cooling emission in zone j of distribution system i [kWh]

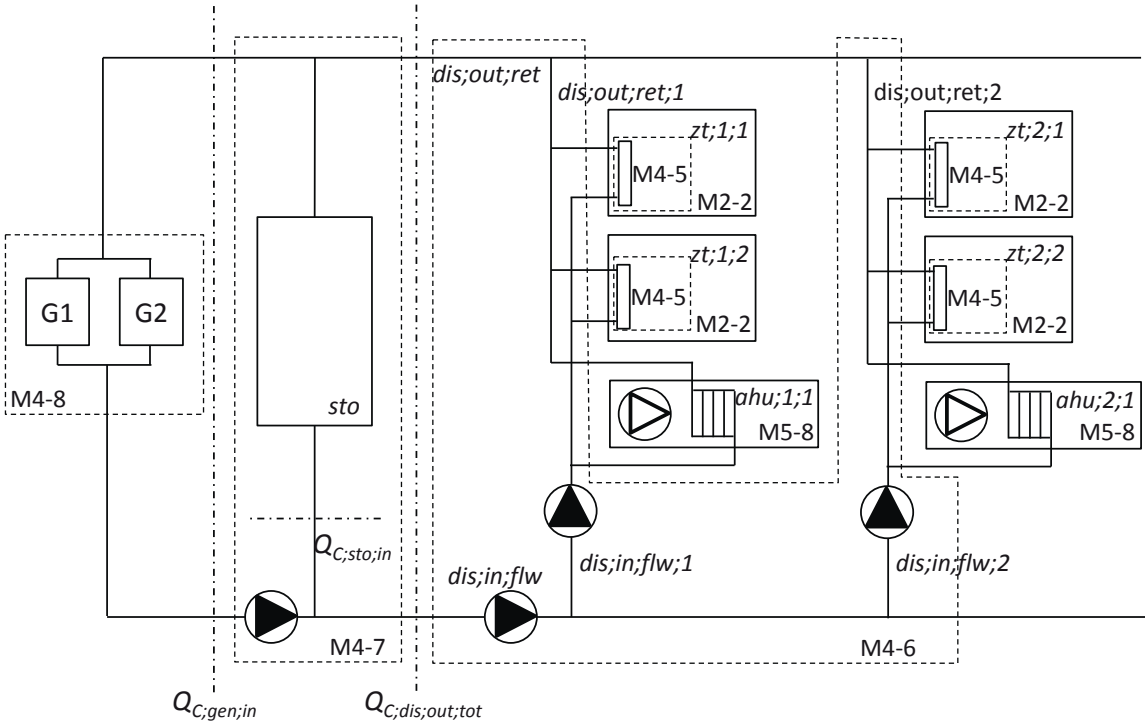


Figure 3. Cooling system scheme with module boundaries and nomenclature given in prEN 16798-9.

The technologies covered in both methods are

- Compression and absorption chillers;
- Place holder for "other" type of generator, being used for direct use of boreholes, ground or surface water;
- Multiple generators handling;
- "Free cooling" control option, i.e. direct cooling via heat rejection device
- Different Heat rejection types:
  - Air cooled condensers;
  - Dry, wet and hybrid heat recovery devices;
  - Control options for the heat rejection (e.g. switch between dry and wet operation for hybrid heat rejectors);

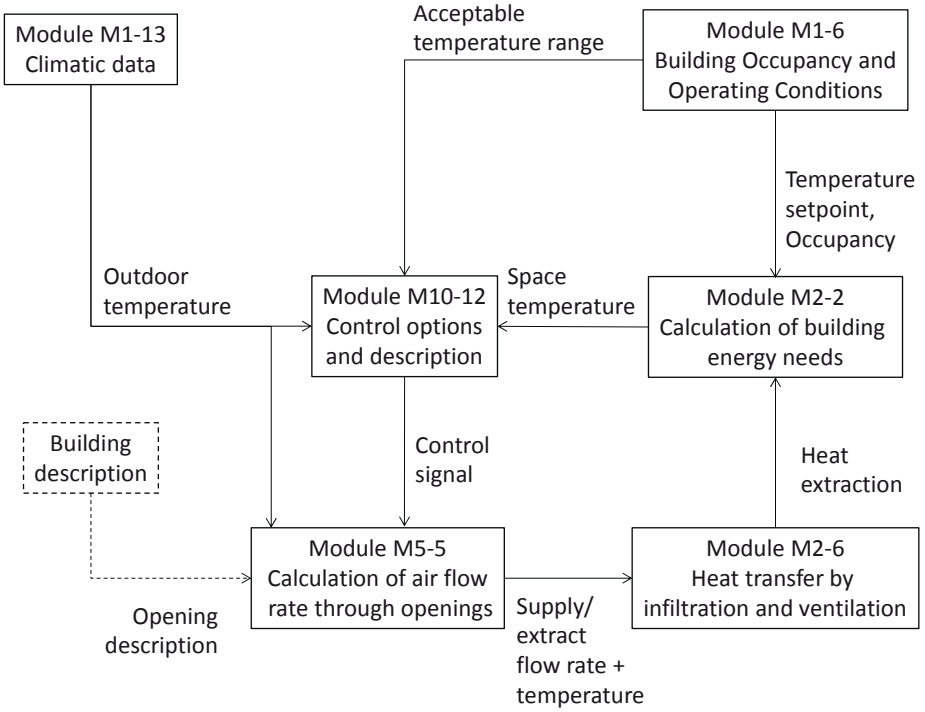


Figure 4. Scheme from prCEN TR 16798-10 for the calculation of ventilative cooling.

In method A, there is a connection to product standards for compression chillers: A performance map is used, which is generated on the base of the measurement points from EN 14511 tests, which are used in EN 14825 for the calculation of the SEER. However, the 4 measurement points are not sufficient; a fifth point outside the range of the four is needed. Discussions with manufacturers have shown that there is willingness in the industry that more data shall be made available.

An accompanying TR [12]and two separate spreadsheets for the two methods ([13] and [14]) are available for this standard.

Storage

A new standard prEN 16798-15 was developed for the calculation of cooling storage systems. This was done in close collaboration with TC 228, to ensure the same philosophy as for heating and DHW storage calculation. The method is applicable to any calculation time step and covers different storage types:

- Water tanks
- Ice storage
- Phase change materials (PCM)

The calculation of the storage charging circuit is included in the standard, as shown in **Figure 3**. There is an accompanying TR [15] and a spreadsheet for PCM devices [16] available.

Outlook

All standards of the prEN 16798 family are in public enquiry until April 2015. ■

References

[1] See separate article from Bjarne W. Olesen in this issue.

[2] See separate article from Claus Händel in this issue.

[3] See separate article from Rémi Carrié in this issue.

[4] CEN/TC 371 N377 – CEN/TC 156 N1281 – prCEN TR 16798-8 WD.

[5] CEN/TC 371 N378 – CEN/TC 156 N1282 – prEN 16798-7 spreadsheet.

[6] CEN/TC 371 N379 – CEN/TC 156 N1283 – prCEN TR 16798-6-1 WD.

[7] CEN/TC 371 N380 – CEN/TC 156 N1284 – prEN 16798-5-1 spreadsheet.

[8] CEN/TC 371 N398 – CEN/TC 156 N1302 – prCEN TR 16798-6-2 WD.

[9] CEN/TC 371 N397 – CEN/TC 156 N1301 – prEN 16798-5-2 spreadsheet.

[10] CEN/TC 371 N381 – CEN/TC 156 N1285 – prCEN TR 16798-10 WD.

[11] CEN/TC 371 N382 – CEN/TC 156 N1286 – prEN 16798-9 spreadsheet.

[12] CEN/TC 371 N383 – CEN/TC 156 N1287 – prCEN TR 16798-14 WD.

[13] CEN/TC 371 d N384 – CEN/TC 156 N1288 – prEN 16798-13 method A spreadsheet.

[14] CEN/TC 156 WG21 N93–M4-8_ prEN 16798-13 –Cooling-generation-draft-method B spreadsheet.

[15] CEN/TC 371 N351 – CEN/TC 156 N1255 – prCEN TR 16798-16 WD.

[16] CEN/TC 156 N1241 – prEN 16798-15 PCM spreadsheet.