Recommendations for the production of EPBD certificates for buildings heated using electricity, and an analysis of measured energy consumption for heating in relation to the calculation of buildings' energy requirements according to regulation 78/2013 Coll.

1. EPBD certificates for buildings heated using electricity

The **EPBD** energy performance certificate (hereinafter referred to as **EPBD**) is currently one of the compulsory components of the project documentation needed for new buildings. Data concerning calculated energy consumption can also be a criterion for the planning of technical systems for family homes, and a high-quality **EPBD** can provide information for constructors about the future energy consumption of constructed buildings. The information stated below is intended as reference material for the producers of **EPBD**s for houses with direct electric heating.

2. Production of EPBDs for electrically heated family homes

The fulfilment of the requirements for houses heated using electricity presents a problem in the form of the necessity to satisfy one of the three compulsory indicators of a building's energy performance – non-renewable primary energy Q_{nPE}.

Houses which use only electricity for their operation must use a certain percentage of energy originating from renewable energy sources even if they possess a high-quality building envelope. The higher the envelope quality, the lower the share of energy from renewable sources they must use; see the following graph. The graph shows only approximate shares, which can vary slightly for different homes.

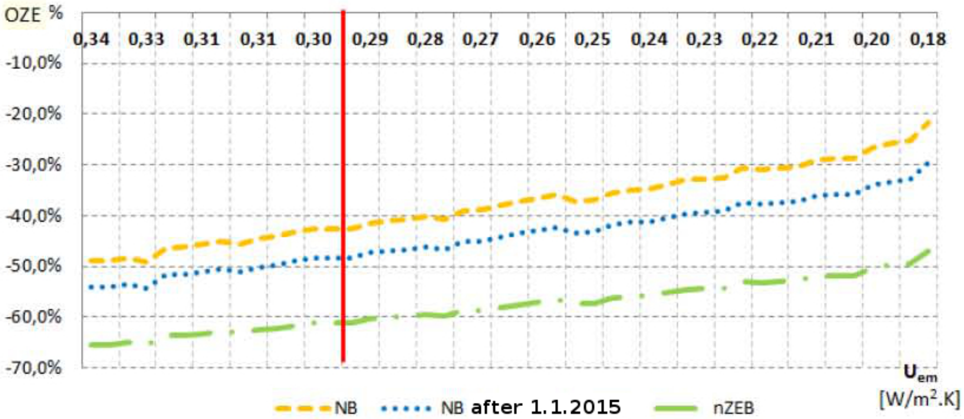

Fig.1 *The share of ERS (Energy from Renewable Sources) needed for the fulfilment of legislative requirements (NB – new buildings, nZEB – nearly zero energy buildings)*

2.1. Zoning of a family home

The first essential requirement for the calculation of the total supplied energy for a building is the execution of building zoning. The term 'building zoning' means the geometric division of a building into individual parts whose specific characteristics influence the resultant height of energy requirements and consumption. The way the building is zoned will be one of the most important aspects in the determination of the energy requirements of the building. Different numbers can be obtained for such requirements if the zoning is performed inconsistently.

A family home can be understood from the zoning perspective as consisting of two zones or one. For example, if it is a two-floor building with a garage and utility rooms placed on the first floor, these areas must be included in the total volume of the building (as these areas are usually warmed either directly or indirectly). Because of differing boundary conditions (temperature, lighting, air exchange), the building must be divided into two independent zones in this part. If the garage is part of the building but not part of the full volume of the building, it is acceptable to consider the house as a single zone building – taking into account the reduced thermal flow through the structure which separates the house from the garage; see details below. If the house is only a one-storey bungalow and the utility room is simply a room with appliances for heating and the preparation of warm water, the house is considered to be a single zone building.

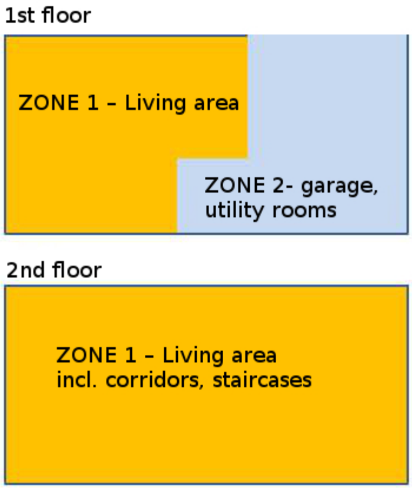

Fig. 1) Two-zone division of a family home

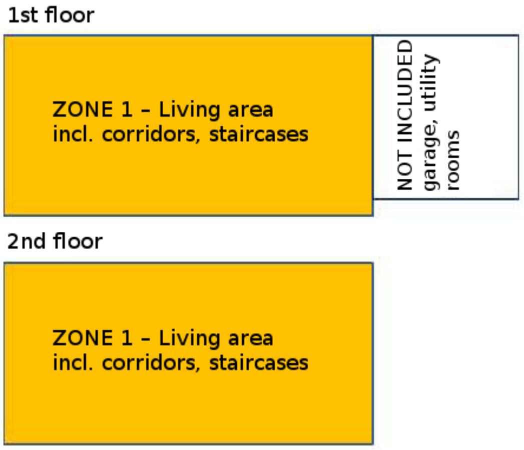

Fig. 2) One-zone division of a family home (garage and utility rooms are excluded)

2.2. A typical usage profile

Every zone, building – if it is designed as a one-zone model – must have an assigned typical usage profile. This is a set of basic boundary conditions which define the anticipated conditions for the calculation of the building's energy requirements and are listed for house zones in TNI 7303031, attachment B.

The values listed in the typical usage profile are a recommended example. Every building is different and it is necessary/possible to adapt these values (boundary conditions for calculations) for certain types of building. When creating a general model of a family home for the purpose of determining the expected amount of supplied energy, it is almost always advisable to adapt the standardised usage profile to the form of operation which corresponds to the given house – this is of particular relevance to, e.g. homes with a very small floor area (up to 100 m^2), as well as larger family homes (villas).

2.3. Technical systems – electric heating

The calculation of the part of energy supplied for heating, or the calculated energy consumption on heating, is derived from the calculation of energy requirements in which the efficiency of the transformation of the energy source to heat, system losses and the efficiency of transferring the heat into interior areas are included, along with the effect of system regulation on the transfer of energy. It is considered in the calculation of a building's energy requirements with the help of three efficiencies:

-The efficiency of the transfer of heating energy $\eta_{H,em,z}$ (%),
- the efficiency of heating energy distribution to the z^{th} zone $\eta_{H,dis,z}$ (%),
- the efficiency of energy production in the relevant heat source $\eta_{H,gen,z}$ (%),

In the case of direct electric heating (direct heating or storage), only losses affecting the system for the transfer of heat into interior areas are considered; these depend on the type of regulator used and its ability to react to the set requirement. In the calculation it is assumed that the distribution efficiency $\eta_{H,dis}$ = 100% and production efficiency $\eta_{H,gen}$ = also 100% for direct-heating systems. The efficiency of heat transfer is then influenced by the type of system used and its possible incorporation into the building's structure in the case of surface heating systems.

In the tables below there is an overview of systems which use electricity as the main energy source for heating, with recommended values of constituent efficiencies which are usable in the calculation of the evaluation of the energy requirements of the building. Simultaneously, these values are derived and determined in relation to TNI 7303331.

Tab. 1 *Heating system efficiency for electric direct-heating systems*

Type of system	$\eta_{H,gen}$ (%)	$\eta_{H,gen}$ (%)	$\eta_{H,gen}$ (%)	*total efficiency*
electric direct heating (P regulation)	100%	100%	88-91%	88-91%
electric direct heating (PI regulation)	100%	100%	93-96%	93-96%
surface electric storage heating (P regulation – proportional band 1 K)	100%	100%	80-85%	80-85%
Surface electric direct heating (P regulation – proportional band 1 K)	100%	100%	88-90%	88-90%
electric direct-heating radiant panels (P regulation – proportional band 1 K)	100%	100%	88-90%	88-90%
surface electric storage heating (PI/PID regulation with the option of controlling each room/zone of the room, proportionality band 0.3-0.5 K)	100%	100%	85-87%	85-87%
surface electric direct heating (PI/PID regulation with the option of controlling each room/zone of the room, proportionality band 0.3-0.5 K)	100%	100%	95-97%	95-97%

electric direct-heating radiant panels (PI/PID regulation with the option of controlling each room/zone of the room, proportionality band 0.3-0.5 K)	100%	100%	95-97%	95-97%

In the case of the component of energy supplied for heating and its advantages, the technical system of heating via electric surface systems reaches approximately 20 – 25% greater efficiency than the standard warm-water system.

2.4. Technical systems – supplementary sources of heat

In the majority of designed family homes, there is a supplementary source of heat in the form of a fireplace stove or a fireplace insert. The determination of the yearly share of this supplementary source of heat in a building's heating energy requirements is of key importance in the production of a **EPBD**. With regards to the fact that it is a supplementary source of heat that is supplied manually, a 15 – 35% share in the coverage of the yearly energy requirement for heating has been assumed for the purposes of this paper. Typical seasonal efficiency values for local heaters are shown in the following table.

Tab.2 *Seasonal efficiency of heat production using a heat source* $\eta_{H,gen}$ *for local solid fuel heaters*

Type of local heater	$\eta_{H,gen,sys}$ (%)
Pellet stoves	80 (%)
Storage stove (tiled)	73 (%)
Freestanding stoves	75 (%)
Fireplaces and fireplace inserts	
- with open hearth	35 (%)
- with closed hearth	75 (%)

2.5. Technical systems – preparation of warm water using electricity

In buildings which use electricity for heating, the preparation of hot water is usually provided by an electric warm water exchanger operating on the principle of direct heating, possibly supplemented by indirect heating using a solar powered system. Just as in the case of a heating system, the calculation includes losses from three processes – the production, storage, distribution and preparation of warm water.

If an electric heating insert is used for the preparation of warm water, the efficiency of the heat production using that insert is $\eta_{W,gen}$ = 100% as there are no heat losses and all energy goes straight into the storage volume of the storage tank.

The heat loss of the storage volume $Q_{W,gen,ls,d}$ depends on the volume of the storage tank, and if the manufacturer of the storage tank doesn´t state it, values from the following table are recommended for new storage tanks.

Tab. 3 *Typical daily heat loss for a storage tank* $Q_{W,gen,ls,d}$

Volume of storage tank	**30**	**50**	**80**	**100**	**120**	**150**	**200**	**300**	**400**	**500**
$Q_{W,gen,ls,d}$ **(Wh/(l·day))**										
	25.0	18.0	13.8	13.0	11.7	10.7	10.5	8.7	7.8	7.0

Volume of storage tank	600	700	800	900	1000	1100	1200	1300	1500	2000
$Q_{W,gen,ls,d}$ (Wh/(l·day))										
	6.3	5.9	5.4	5.0	4.7	4.4	4.1	3.8	3.4	2.6

The heat loss from distribution lines depends on their length. For family homes which are heated using electricity, it is not expected that warm water circulation will be necessary. The specific heat loss of the warm water distribution network can then be considered according to the following table.

Table A.59 – Daily heat loss from a warm water distribution network for an insulation thickness of 20 mm $Q_{W,dis,ls}$

DN	(inches)	3/8"	1/2"	3/4"	1"	3/4"
DN	**(mm)**	**9.5**	**12.7**	**19.1**	**25.4**	**31.8**
Thermal insulation 20 mm		$Q_{W,dis,ls}$ (Wh/(m·day))				
without circulation (6 withdrawals/day)		17.4	30.5	60.7	87.8	110.0
without circulation (8 withdrawals/day)		23.2	40.7	80.9	117.0	146.7
without circulation (10 withdrawals/day)		29.0	50.8	101.1	146.3	183.4

3. Calculated energy consumption and measured energy consumption

Often a question arises regarding the relevance of the calculated data listed in a **EPBD** with regards to the real energy consumption in family homes. An analysis was performed with regard to the energy consumption for three existing houses, all of which are used in a standard way. The aim of the analysis was to check that the energy consumption recorded during real house operation corresponds with the calculated energy consumption which is declared to the user/investor via a compulsory **EPBD**.

The selected three homes that were subjected to energy consumption analysis are located in different climatic conditions. A comparison of the calculations of the total energy supplied to each building over one year was carried out for the houses using boundary conditions for the given locality and the given house operation with invoiced consumption.

For the selected sample of family homes whose operation was analysed in detail the difference between the calculated model and reality was seen to range between 1% and 12% for the whole electricity consumption of the building. If this issue is approached from the aspect of the average of all measured consumptions, and with the use of a calibrated computational model which includes average climatic data listed in TNI 730331, the deviation varies from 2 – 4% in favour of the calculated electricity consumption, i.e. the calculated amount of electricity is lower.

Tab. **4 Family home in Hošťálkovice** – *Comparison of real and calculated values for a multiple-zone model*

period/climatic data	real consumption of el. energy (kWh)	calculated supplied el. energy (kWh)	deviation (reality/calculation) (%)

2010 (first year of operation of the family home)	9149	7781	15.0%
2011	7096	7244	-2.1%
2012	7199	7305	-1.5%
winter 2013/2014	4238	3760	11.3%
TNI climatic data [1)]	7815[2)]	7454	4.6%

1) climatic data from TNI 730331 were used for the period
2) the average value of the measured electricity consumption from 2010-2013 was used for the comparison with the calculation using climatic data from TNI 730331

Tab. 5 **Family home in Rasošky** - *Comparison of real and calculated values for a multiple-zone model*

period/climatic data (note: related to the April-April billing period)	**real consumption of el. energy (kWh)**	**calculated supplied el. energy (kWh)**	**deviation (reality/calculation) (%)**
2010/2011	7757	8219	-5.6%
2011/2012	8037	7997	0.5%
2012/2013	9271	8158	13.6%
2013/2014	6732	7182	-6,3%
winter 2013/2014	3683	4302	-13.9%
TNI climatic data [1)]	7949[2)]	7660	3.8%

1) climatic data from TNI 730331 were used for the period
2) the average value of the measured electricity consumption from 2010-2014 was used for the comparison with the calculation using climatic data from TNI 730331

Tab. 6 **Family home in Jeseník** – *Comparison of real and calculated values for a multiple-zone model*

period/climatic data	**real consumption of el. energy (kWh)**	**calculated supplied el. energy (kWh)**	**deviation (reality/calculation) (%)**
2010	9665	11167	-13.5%
2011	10755	10178	5.7%
2012	9377	10311	-9.1%
2013	9216	10407	-11.4%
winter 2013/2014	6446	5788	11.4%
TNI climatic data [1)]	9753[2)]	9534	2.3%

1) climatic data from TNI 730331 were used for the period
2) the average value of the measured electricity consumption from 2010-2013 was used for the comparison with the calculation using climatic data from TNI 730331

3.1. **Comparison of approaches to the production of a EPBD**

When producing a certificate, three approaches to the creation of a model and the calculation of the total energy supplied to the building can be used in principle. The difference between the three possible approaches to the production of a **EPBD** is shown for the purpose of comparison

- Approach 1 – a multiple-zone calibrated model with climatic data from TNI 730331 and a typical usage profile which corresponds to real operation, including electricity for home appliances in the total energy supplied to the building
- Approach 2 – a one-zone model with climatic data and a typical “Family homes – living areas” usage profile according to TNI 730331; it includes electricity for home appliances in the total energy supplied to the building
- Approach 3 – one-zone model with climatic data and a typical “Family homes – living areas” usage profile according to TNI 730331; it does not include the electricity for home appliances in the total energy supplied to the building

The calculation according to approach 3 is used in the vast majority of **EPBD** certificates produced. However, as the electricity consumed by domestic appliances isn´t included, it does not necessarily reflect the whole consumption of the building.

As part of the study, a comparison of the one-zone and multiple-zone model conceptions was carried out in which measured consumptions were compared. The following table shows clearly that the use of a one-zone model with standard boundary condition values from TNI 730331 leads to a generally lower calculated consumption of energy, or total supplied energy. The difference for individual buildings ranges from 1.8 – 4.7% of the total energy supplied. The difference in favour of a one-zone model is caused by several factors:

- the consumption of electricity by home appliances isn´t included (it ranges between approx. 300-800 kWh/year),

- with regard to the one-zone model, the heat gain from lighting, persons and appliances (these being determined from measured values related to m^2 in W/m^2) is also calculated for areas where it isn’t actually relevant (corridors, staircases, technical facilities), thus causing this factor to have a positive effect in terms of the energy balance,
- for living areas, a lower indoor temperature (20°C) is assumed according to the typical usage profile than in the case of a multiple-zone calibrated model (usually 22°C)

Tab. 7 *Comparison of approaches to the production of a **EPBD***

Comparison – EN indicator	**Hošťálkovice**	**Rasošky**	**Jeseník**
Approach 1 – Multiple-zone calibrated model with appliances included			
Total energy supplied (kWh/year)	8508	10320	10741
Energy source: electricity (kWh)	7454	7660	9534
Energy source: wood (kWh)	1054	2660	1207
Approach 2 - One-zone standard model with electric energy for appliances calculated			
Total energy supplied (kWh/year)	8289	10428	10856
Energy source: electricity (kWh)	7153	7769	10289
Energy source: wood (kWh)	1136	2658	1550
Approach 3 - One-zone standard model w/o calculation of el. energy for appliances (most common)			

Total energy supplied (kWh/year)	7661	9876	9872
Energy source: electricity (kWh)	6525	7217	8322
Energy source: wood (kWh)	1136	2658	1550
Deviation in % approach 2/approach 1			
Energy source: electricity (%)	-4.0%	1.4%	7.9%
Total energy supplied (%)	-2.6%	1.0%	1.1%
Deviation in % approach 2/approach 3			
Energy source: electricity (%)	-8.7%	-7.1%	-19.1%
Total energy supplied (%)	-7.6%	-5.3%	-9.1%

The use of the most common approach, No. 3 (the most common approach to the production of **EPBD** certificates), leads to the lowest calculated balance of total energy supplied and logically also to a lower share for the “electricity” energy source.

4. EPBD interpretation

The **EPBD** energy performance certificate consists of two parts:

- Graphical representation of the **EPBD**,
- **EPBD** protocol.

EPBDs are used to prove the fulfilment of demands on building energy performance (this can only be found in a **EPBD** protocol) and for the ranking of buildings into energy consumption classes (the graphical representation of the **EPBD**).

Under the evaluation scale applied to the total energy supplied to a given building in the graphical representation of the **EPBD** there is also information about the absolute amount of energy supplied. However, this value includes all energy sources – e.g. the energy contained in the wood and electricity used in MWh/year. Energy consumption figures for the individual energy sources must be looked for on the other side of the graphical representation, where they are shown in a pie chart in KWh/year. These values must be used in the event that estimated electricity consumption needs to be documented rather than the total energy supplied to the building. The individual energy flows are then described in the **EPBD** protocol in more detail.

It needs to be mentioned at the same time that electricity for home appliances and other activities taking place in the household (e.g. cooking) isn´t included in the total energy supplied. This consumption commonly ranges from 300-800 kWh/year at present. If a calculation of the total operating costs of a family home is needed, it is essential to add this value to the calculated consumption if it hasn´t already been included by the **EPBD** producer (an option offered by the majority of computer software); see approach 1 to the production of **EPBD**s.

The majority of computer programmes for the evaluation of the energy requirements of buildings currently enable the export of their own outputs – printouts – alongside the compulsory outputs in the form of graphical representations and **EPBD** protocols. These often contain more detailed information about total energy flows than **EPBD** provides. Simultaneously, these outputs often reveal boundary conditions used for the calculation itself, and a relatively easy check of the relevance of the produced **EPBD** can be carried out with their help.

Based on the analysis of the operation of family homes and a comparison of the results of computational models it can be claimed that **EPBD**s can provide relevant information for constructors about the future energy consumption of buildings with a deviation of approximately up to 10%, if typical user behaviour is assumed.