Methodology of establishing the 15% threshold of the most energy-efficient buildings

in the Czech Republic (the "Methodology")

Ing. Jan Antonín, Ph.D.
EnergySim s.r.o.

06/2019

prepared in cooperation with CZGBC and CPI Property Group

Aim of the methodology

The aim of this methodology is to analyze the fund of selected types of buildings in the Czech Republic, and thus to achieve a percentual classification of buildings in terms of energy performance. The percentual classification will be used to establish the 15% threshold of the most energy efficient buildings in the Czech Republic. This threshold can then be used for the purpose of individual classification and declaring, whether a building of a corresponding type belongs among the 15% of the most efficient buildings, or not.

Available input data

Data recording mechanism

For the purposes of creating the methodology, data were obtained from the database of the Ministry of Industry and Trade. It is the (so-called ENEX) database containing data from Energy Performance Certificates, which energy specialists are required to enter into the database for each certificate they prepare. It is not a public database and the data have been provided anonymously. The database has been in use for a long time, but only since the early 2017 it has been fully exploited from the statistical perspective. At that time the author of the energy performance assessment software has been allowed to export the values in a unified structure and the possibility has been opened to import such data into the system. Prior to this date, it was mandatory to enter manually only some of the data from energy performance certificates. Because there was no sufficient control over the data entered into the system, nor was such entry legally enforceable, many records from this period either do not exist or are erroneous. At the same time, it should be noted that in 2013, the Czech Republic adopted the updated Decree on the Energy Performance of Buildings (Decree 78/2013 Coll.), which has changed the method of preparing energy performance certificates both in terms of calculation as well as the method of building classification. This concerns, for example, the method of classification by comparison with the so-called reference building, or the introduction of an indicator of the delivered energy instead of energy consumed, i.e. the introduction of a different way of including the non-fuel renewable sources into the main evaluation criterion. It is therefore not possible to compare energy performance certificates with those issued prior to this legislation change. The data from certificates are thus entered by exporting the selected data from the given software into a file and by uploading the data (this is done by an energy specialist) via a web interface to the database of the Ministry of Industry and Trade. It should also be pointed out that it is still possible to enter data manually via the web interface instead of uploading the exported file. This option is preferred by some energy specialists, because they use a different, less used software which does not support the export of the file in a given format. This may be source of erroneus data in the database which would have to be filtered out.

Description of data provided

For the purposes of creating the methodology, the Ministry of Industry and Trade has provided data in the Excel format. Data were provided for this purpose to the Czech Green Building Council (CZGBC), of which the CPIPG is a member. Data were provided in the period 04/2019 - 05/2019. The type of data contained in the supplied file is shown in the Table 1 below.

Tab. 1: List of data contained in the file provided by the Ministry of Industry and Trade for preparing the methodology

	Designation	Description of the Record
1	EvidencniCisloCele	certificate registration number (unique)
2	RokU	year of entry into operation (or expected year)
3	DatumVyhotoveni	date of issue of the certificate
4	UcelVypracovani	purpose of the certificate - ID
5	Ucel	purpose of the certificate
6	UcelJiny	description of a "different purpose" category (e.g. subsidy)
7	ObecBudovy	municipality in which the building is located
8	IdTypBudovy	building type - ID
9	Nazev	type of building
10	JinyTypB	description of the building type in case of a "different type"
11	PlochaEvzB	reference floor area
12	CelkDodEner	total energy delivered
13	CelkDodEnerZAT	total energy delivered - classification
14	NeobPrimEner	non-renewable primary energy
15	NeobPrimEnerZAT	non-renewable primary energy – classification
16	SoucProTepla	average heat transfer coefficient
17	SoucProTeplaZAT	average heat transfer coefficient - classification
18	Vytapeni	energy delivered for heating
19	VytapeniZAT	energy delivered for heating - classification
20	Chlazeni	energy delivered for cooling
21	ChlazeniZAT	energy delivered for cooling - classification
22	Vetrani	energy delivered for ventilation
23	VetraniZAT	energy delivered for ventilation - classification
24	UpravaVlhkosti	energy delivered for humidity adjustment
25	UpravaVlhkostiZAT	energy delivered for humidity adjustment - classification
26	TeplaVoda	energy delivered for hot water preparation
27	TeplaVodaZAT	energy for hot water preparation - classification
28	Osvetleni	energy delivered for lighting
29	OsvetleniZAT	energy delivered for lighting - classification
30	Datum	date of entering the record into database

Overall, the database contains information from **97 181** Energy Performance Certificates. Building type data are divided into the following 10 categories, while the buildings that cannot be classified clearly fall into the "Other types of building" category:

- Family house
- Apartment building
- Accommodation and catering building
- Office building
- Healthcare building
- Educations Building
- Sport Building
- Retail building
- Culture Building
- Other types of building, specify:

Furthermore, the database contains information on the purpose of the energy performance certificate calculation with the following 6 options:

- New building
- Significant change of a completed building
- Sale of a building or its part
- Renting a building or its part
- A building used by a public authority
- Another purpose of the certificate

The following Table 2 shows the number of records in the supplied database according to the building type and the purpose of the certificate.

Tab. 2: Number of records in the database according to the building type and the purpose of the certificate

Buidling Type	Number
Family house	68 454
Apartment building	14 632
Accommodation and catering building	1 502
Office bulding	3 700
Healthcare building	459
Educations building	1 208
Sport building	483
Retail building	1 711
Culture building	385
Other types of building, specify	4 647
Total number	**97 181**

Purpose of the energy performance certificate	Number
New building	43 146
Significant change of a completed building	16 291
Sale of a building or its part	23 248
Renting a building or its part	4 842
A building used by a public authority	3 482
Another purpose of the certificate	6 172
Total number	**97 181**

From the information above it is clear that the records from certificates in the category of office buildings contain a total of 3700 entries. In the case of retail buildings the number is 1 711. The category"Other types of buildings" contains 4 647 entries. Within this group, we can expect primarily combinations of the above mentioned categories, i.e. multifunctional objects, with one dominant use (office function combined with hotel for example) or other types of buildings, which are not included in the list of building type above.

Description of the methodology

For the purpose of the assesment, a group of specific category building types will be established: office buildings, retail buildings and buildings for accomodations and catering. Some buildings from the category "Other types of buildings" will also be included. This category will be analyzed on the basis of a note provided by the energy specialist. If it becomes clear from the note that a particular building has dominant function among the three above, it will also be included into the group of buildings under assessment. Buildings marked as "multifunctional" will also be included in this category.

Within this group of buildings, statistical analysis of individual indicators of energy performance and specific values of these indicators will be performed, including their classification within the energy performance certificates.

The percentage of individual buildings and the percentage of the buildings' reference floor area will be evaluated on the basis of the value of the particular indicator. Thus, in practice, the analysis of frequency distribution according to individual resulting parameters of buildings will be performed. In this way more of the resulting building parameters will be assessed. Values that would be obviously erroneously entered or unrealistic won't be included in the assesment. This concerns for example the buildings with the reference floor area smaller than 50 m^2, buildings with a total delivered energy of less than 10 kWh / (m^2a), or with the primary energy exceeding 3000 kWh / (m^2a).

The main assessment criterion will be established as the specific consumption of primary energy. This criterion has been chosen fom several reasons. It should be noted that unlike in many other European countries, in the Czech Republic this is not the main indicator of the energy performance of a building.

In the Czech Republic, the main indicator is the so-called total delivered energy, which expresses the energy delivered to a specific building through the system boundary regardless of its origin. Therefore it also includes the energy of the ambient environment (for example, the energy obtained with the use of a heat pump for free and without generating emissions) or the energy from renewable resources. This is why the methodology consideres this criterion as improper. Another reason is that the Directive of the European Parliament and the Council (EU) 2018/844 on the Energy Performance of Buildings, the so-called EPBD3, explicitly establishes the obligation to express the energy intensity in terms of primary energy. Looking at the legislative development in the Czech Republic, it is now evident that in the next update of the Decree on the Energy Performance of Buildings (according to which energy performance certificates are prepared), this criterion will be considered the main one.

Individual records of buildings and floor areas will be categorized according to the value of the primary energy consumption indicator. On the basis of the above-mentioned statistical analysis, the upper 15% percentile will be established, serving as the basis for setting the resulting 15% threshold for the most energy-efficient buildings.

Data processing

Excluding buildings with remote or unrealistic values

The first step in analysing the data provided is the exclusion of records with unrealistic values of some parameters. As mentioned above, the supplied database contains 97 181 building records. Incorrect records have been identified during processing as far as several parameters are concerned. As described above, errors are likely to occur when data are entered manually, or when energy performance certificates are prepared erroneously. In case of some records, some parameter values are missing completely. Based on the author's experience, it has been decided to exclude records that show the following parameter values:

- total delivered energy
  - > 2 000 kWh/(m^2a)
  - < 10 kWh/(m^2a)
- primary energy
  - the record is completely missing
  - classification record is missing
  - > 3 000 kWh/(m^2a)
  - The lower limit has not been set, because e.g. the production of the photovoltaic power plant exported outside the building can show also negative values.
- energy reference area
  - < 50 m^2

Note: Buildings with the energy reference area smaller than 50 m^2 do not have to comply with the energy performance requirements and they do not require the energy performance certificate. Those are either mistakenly entered in the system and don't belong to the group of analysed buildings.

930 records from the total 97 181 have been eliminated utilizing the criteria listed above. The group of buildings broken down into the individual building types is as follows:

Tab. 3: Number of records in the database according to the building type and the purpose of the certificate (After removing unrealistic values)

Buidling Type	Number
Family house	67 874
Apartment building	14 502
Accommodation and catering building	1 491
Office bulding	3 642
Healthcare building	454
Educations building	1 190
Sport building	477
Retail building	1 689
Culture building	382
Other types of building, specify	4 550
Total number	**96 251**

Purpose of the energy performance certificate	Number
New building	42 696
Significant change of a completed building	16 132
Sale of a building or its part	23 063
Renting a building or its part	4 780
A building used by a public authority	3 459
Another purpose of the certificate	6 121
Total number	**96 251**

Analysis of the „other types of buildings“ category

As mentioned above, there are also buildings labelled as the "other types of buildings" that should be included in the assessment. The use of a building is noted by an energy specialist through a specific text. The analysis of this group is based on the content of a text string.

The buildings from this category that are listed in the following table, will be included in the assessment. The table also lists the number of records.

Tab. 4: Number of records in the “other types of buildings” category, which are included in the assessment.

Text string filtered	Full name CZ	Full name EN	Number
Více	**Více**účelový	**Multi**purpose	83
Poly	**Poly**funkční	**Poly**functional	490
Multi	**Multi**funkční	**Multi**functional	56
Adm	**Adm**inistrativní	**Office**	372
Obch	**Obch**odní	**Retail**	132
Ubyt	**Ubyt**ování	**Accomm**odation	127
Strav	**Strav**ování	**Cater**ing	34
Hotel	**Hotel**	**Hotel**	4
Komer	**Komer**ční	**Commer**cial	24
Total of records containing the text description			***1209**

*Note: Total number of buildings is smaller than the total number of items, as text descriptions contain also combinations of the above mentioned text parts.

Assessment of the sample of selected building categories

After excluding non-compliant records and analysing the selected buildings from the "other building types" category, the numbers of records in the categories are as follows:

Tab. 5: The numbers of records in the “other types of buildings”, which are included in the assessment.

Typ budovy	Number of records
Accommodation and catering building	1 491
Office bulding	3 642
Retail building	1 689
Other types of building, specify	1 209
Total number	**8 031**

For orientation, the selected set of buildings has been analysed in terms of the energy performance class from the point of view of 3 main energy performance indicators according to the Decree, i.e. the total energy delivered, primary energy and the average heat transfer

coefficient - U_{em}. The numbers of buildings in each class are listed in the following table. From the table it is clear that, for example, only 6% of buildings achieve the A class of primary energy; 17% of buildings achieve B class and 26% C class.

Tab. 6: The numbers of records in the "other types of buildings", which are included in the assessment.

total energy delivered			non-renewable primary energy			average heat transfer coefficient U_{em}		
classif.	number		classif.	number		classif.	number	
A	267	3%	A	474	6%	A	250	3%
B	1933	24%	B	1397	17%	B	655	8%
C	1996	25%	C	2101	26%	C	1956	24%
D	1404	17%	D	1684	21%	D	1481	18%
E	934	12%	E	974	12%	E	769	10%
F	674	8%	F	598	7%	F	660	8%
G	823	10%	G	803	10%	G	2260	28%
total n.	8031			8031			8031	

As described above, the selected indicator for establishing the TOP 15% threshold has been the specific primary energy consumption. In total, a selected set of 8.031 buildings has been analysed.

Specific energy consumption of primary energy (hereinafter referred to as primary energy) within the assessed population has been limited to a maximum of 3000 kWh/(m^2a), where higher values are considered unrealistic, and therefore have been excluded from the evaluation. As a result, the observed value of the indicator falls within the following range:

- min: -8 kWh/(m^2a)
- average: **326** kWh/(m^2a)
- median: **248** kWh/(m^2a)
- max: 2 986 kWh/(m^2a)

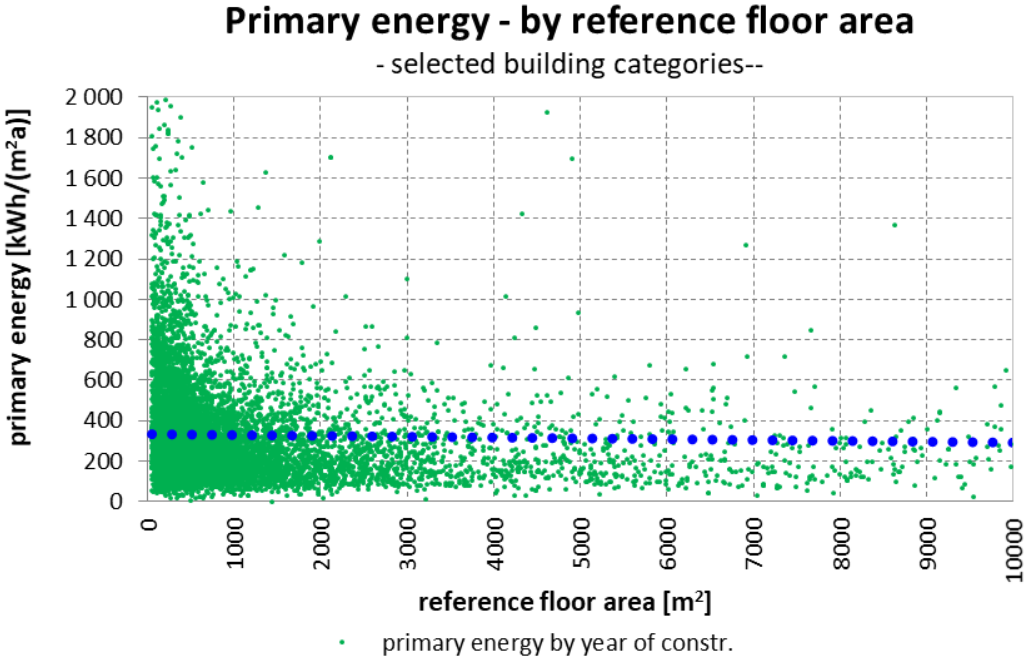
Buildings in the assessed group are of a different size and the energy reference area of buildings falls within the following range (buildings of less than 50 m^2 have been excluded from the assessment):

- min: 50 m^2
- average: **1 793** m^2
- median: **651** m^2
- max: 302 533 m^2

The following graph shows the link between the primary energy and the energy reference area (limited to 10000 m^2 and 2000 kWh / (m^2a)). The graph shows a slight decrease in primary energy consumption with the increasing building area. This is mainly due to the so-called

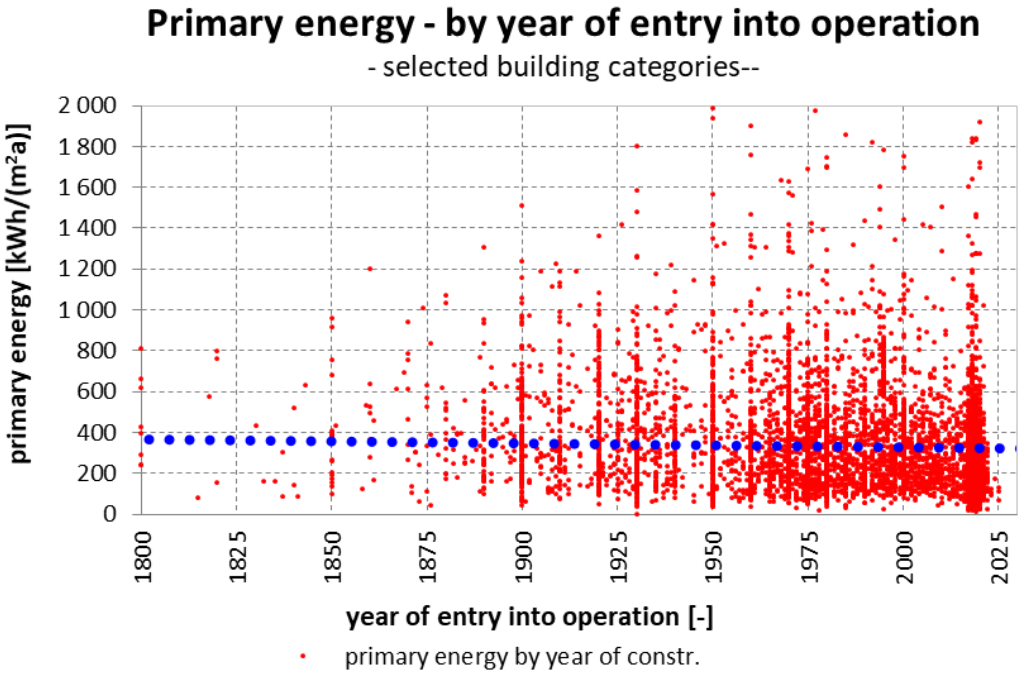
shape factor, i.e. the ratio of the cooled area to the volume, where the specific consumption of small buildings is mainly higher for heating.

Figure 1: Primary energy depending on the reference floor area



Similarly, the graph below shows the dependence of the primary energy consumption on the year (or expected year) of entry of the building into operation. It is clear from the graph, that the primary energy consumption does not decline significantly in case of newer buildings. This can be explained by the fact that although older buildings must necessarily have worse envelope parameters, newer buildings are usually more often equipped with mechanical ventilation, cooling, or moisture management systems. Older buildings also usually have lower lighting consumption, although the systems are less efficient, they are also often under-sized.

Figure 2: Primary energy depending on year of entry into operation



Criteria representing Typical best practice

It is assumed that most efficient buildings are those built according to best practice and meeting or exceeding current building code requirements. Therefore, it was the intention of the methodology to define the threshold among buildings that were built recently and equipped with building systems per local market standard (applying minimum limits for cooling and ventilation energy consumption).

Most of the 8 031 buildings in the evaluated group do not have either air conditioning system or mechanical ventilation, mainly because the buildings are old. The evaluated set of buildings has been further refined to reflect on building type and specification representing typical best practice in the local market (including both air conditioning and mechanical ventilation systems).

It should be mentioned that the supplied data contain information about the specific energy delivered and the classification of individual components of energy consumption (such as HVAC). Unfortunately, the data does not contain more information about the zoning of objects, nor does it contain information on where in the building the energy is consumed. Thus, the data includes both the buildings without air conditioning as well as the buildings fully conditioned, but also buildings where only a small part (e.g. 5% of the floor area) of the building is conditioned. This is then also reflected in the record of the cooling energy delivered (for example, 0.1 kWh/(m2a)). This applies to all components of the energy consumption. For this reason, it is not possible to divide the selected set of buildings into subcategories with the system/consumption and without it.

However, in order to distinguish the buildings that include the air conditioning and mechanical ventilation system, the threshold of ≥3 kWh /(m2a) has been established for both types of consumptions. This threshold will exclude the buildings where only a small part is air conditioned or ventilated (or not cooled or ventilated at all) and, at the same time, it will retain the buildings where air conditioning or mechanical ventilation systems are highly efficient.

Therefore, records with the following parameter values have been excluded from the assessed set of buildings:

- energy delivered for cooling
  - ≤ 3 kWh/(m^{2}a)
  - record is missing
- energy delivered for mechanical ventilation
  - ≤ 3 kWh/(m^{2}a)
  - record is missing

Using the above mentioned criteria, the number of assessed buildings has been limited to **555 buildings**. The specific primary energy consumption then falls within the following range:

- min: 11 kWh/(m^{2}a)
- average: **393** kWh/(m^{2}a)
- median: **323** kWh/(m^{2}a)
- max: 2 514 kWh/(m^{2}a)

Establishing the TOP 15% threshold of the most efficient buildings

As stated in the description of the methodology, the assessment includes the classification of buildings according to the primary energy. The results are shown in the following table and graph. Both the frequency distribution (histogram, black curve) as well as the cumulative frequency (red curve) are illustrated.

Figure 3: Primary energy depending on the year of entry into operation

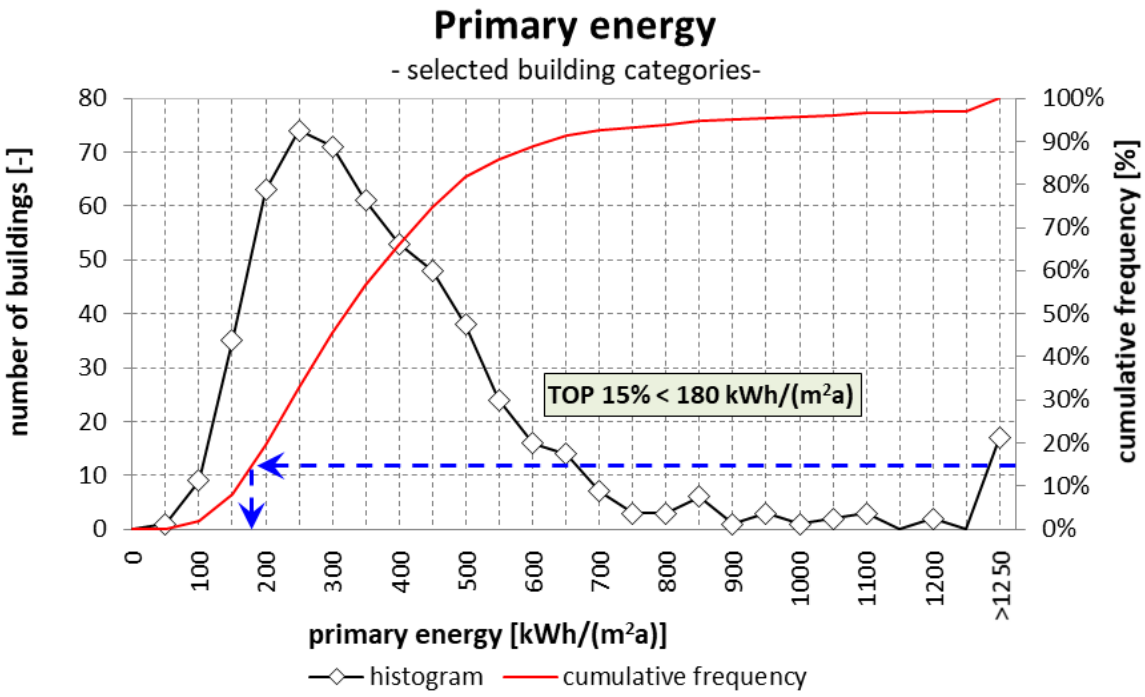
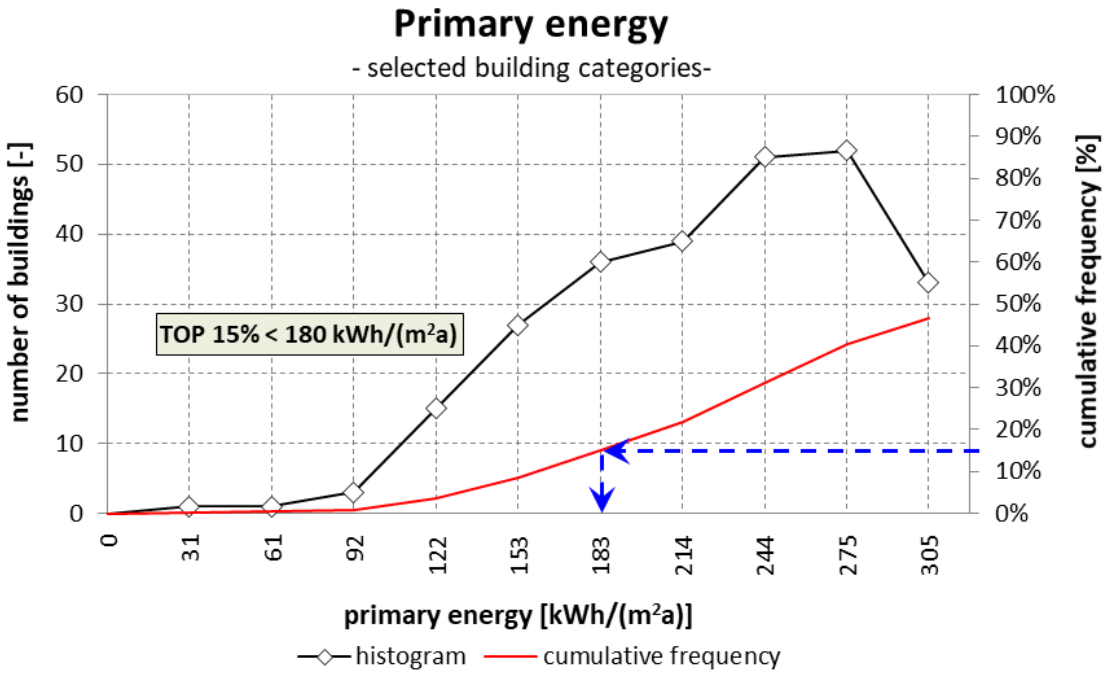


Figure 4: Primary energy depending on year of entry into operation



The TOP 15% threshold is then based of the 15% frequency of buildings with the lowest specific consumption of the primary energy (blue arrows). The final assessment evaluates the set of 555 buildings representing typical best practice in the region with both systems of air conditioning and mechanical ventilation in place.

Tab. 7: Expression of the cumulative frequency of buildings based on the primary energy

primary energy		
class boundary	frequency (number of buildings)	cumulative frequency
[kWh/(m^{2}a)]	[-]	[-]
0	0	0%
31	1	0%
61	1	0%
92	3	1%
122	15	4%
153	27	8%
183	36	15%
214	39	22%
244	51	31%
275	52	41%
305	33	46%
336	36	53%
366	38	60%
397	31	65%
427	31	71%
458	24	75%
488	29	81%
519	18	84%
549	12	86%
580	9	88%
610	9	89%
641	11	91%
671	5	92%
702	3	93%
732	2	93%
763	2	93%
>762,5	37	100%
sum	**555**	

We can conclude that the buildings with the specific primary energy consumption lower than 180 kWh/(m2a) equipped with mechanical systems (such as HVAC) can be included among the 15% of the most efficient buildings.

References of the author

The author of the methodology, Ing. Jan Antonín, Ph.D., has long been engaged in energy performance of buildings. He is the author of The Survey of Residential Buildings Fund in the CR and Energy Saving Options, and The Survey of Non-Residential Buildings Fund in the CR and Energy Saving Options, and the co-author of The Building Renovation Strategy According to the Article 4 of the Energy Efficiency Directive (201/27 / EU), prepared in cooperation with The Buildings Performance Institute Europe (BPIE). The above mentioned documents were subsequently used by the Ministry of Industry or Trade in order to prepare the National Energy Efficiency Action Plan of the Czech Republic pursuant to Article 24 (2) of Directive 2012/27 / EU of the European Parliament and the Council of 25 October 2012 on Energy Efficiency , and together they form part relating to the renovation of buildings. The author provides technical support to the Chance for Buildings Alliance which has for a long time been supporting favorable legislative environment in the field of energy efficient buildings, and represents over 300 companies in the construction sector. The author is also a founding member of the Energy Specialists Association. He is an executive director of the EnergySim consulting company and is also active as an energy specialist (auditor).

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References of CPI Property Group

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