PRELIMINARY VERSION

EXPLORING METHODOLOGIES AND CONCEPTS FOR THE IMPLEMENTATION OF NEW ENERGY PERFORMANCE CERTIFICATES FEATURES FOR BETTER DATA HANDLING

EPC DATABASES

JUNE 2021

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Preliminary version

This document is a preliminary version. It will be further adapted in the coming months through the findings of the test phase of the project.

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EXECUTIVE SUMMARY

The X-tendo project is developing a framework of ten "next-generation EPC features", aiming to improve compliance, usability and reliability of the EPC. These features are divided in two categories, innovative indicators and innovative data handling.

This report describes the methodologies and concepts for the technical implementation of each innovative data handling feature - **EPC databases, building logbooks, enhanced recommendations, financing options and one-stop shops**. It also presents more in detail how the developed methodologies will be country specific implemented in the X-tendo target countries.

The present report builds on past projects activities. Upcoming project activities include the technical implementation with excel spread and programming code, providing guidelines to handle with the tools as well as the testing of the present methodology in each implementing country. Below, the series of previous project reports are listed, which include complementary information:

1. Introductory reports of the 10 innovative EPC features (Deliverable 2.3)
2. Description of implementing partners' user needs and detailed technical specifications regarding features on handling and user of EPC data (Deliverable 4.2)
3. Summary of implementing partners' user needs and detailed technical specifications (Deliverable 4.3)
4. Tools, concepts (country-specific for the Logbook feature) and guidelines for features Enhanced recommendations and EPC Database) (Deliverable 4.5)

Beyond that, the described the methodologies and concepts for the technical implementation methodology will be technically implemented and tested during the forthcoming stages of the project. The complete material will be online accessible in the X-tendo Toolbox.

This document is the revised version of the report completed in April 2021.

1 INTRODUCTION

EPCs are the most widely available information documents on building energy performance across Europe. They have the potential to be used as more than just an informative document, as they have the potential to provide market participants with relevant information to assess, benchmark and improve the building's energy performance. Besides the information included in each document, the usage of these information and data handling are becoming more and more important. The recent Renovation Wave Communication published by the European Commission in October 2020 reinforced the importance of the existing EPC frameworks to improve the data gathering, storage and overall quality of EPCs.

In this context, the five X-tendo EPC features **EPC databases, building logbooks, enhanced recommendations, financing options and one-stop shops** play a relevant role, targeting to improve the way EPC data is being handled and used for different objectives and targeted stakeholders. The main objectives of the features are summarized below. The present document describes in detail the methodologies and concepts for the technical implementation of each feature: EPC databases (Chapter 2), logbook (Chapter 3), enhanced recommendations (Chapter 4), Financing options (Chapter 5) and one-stop-shops (Chapter 6).

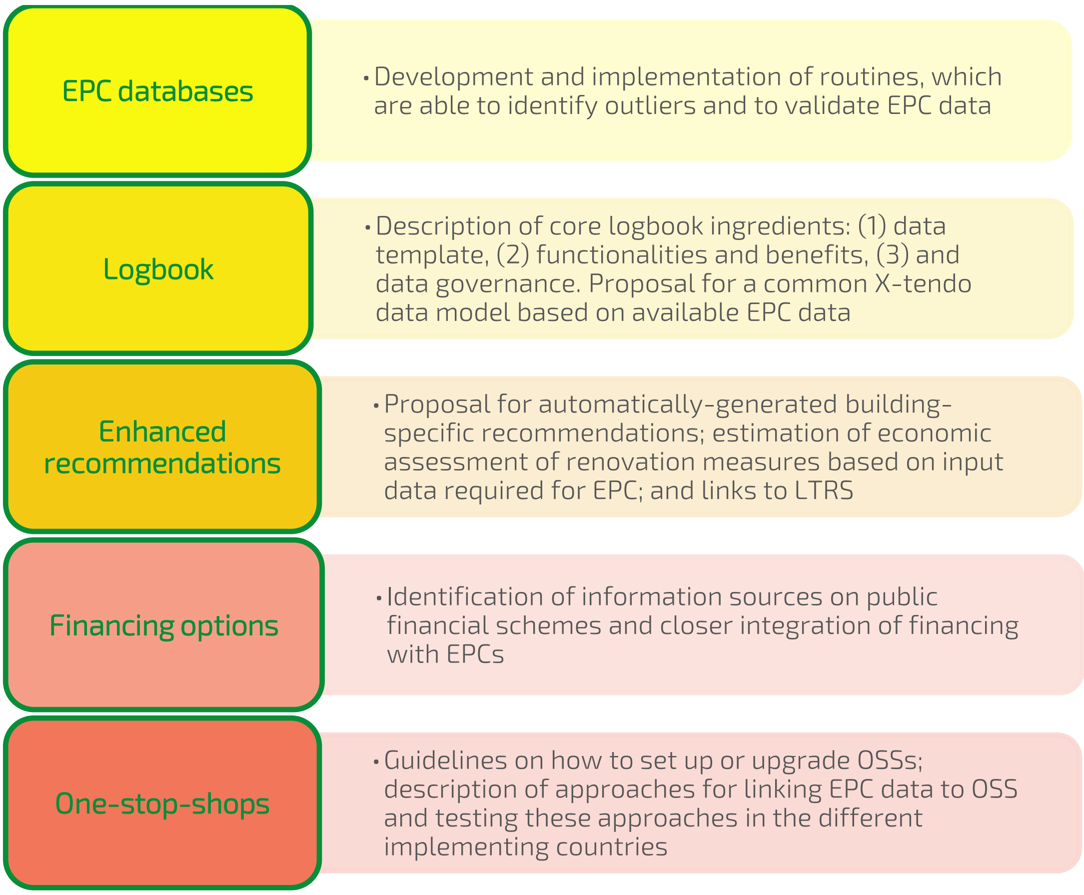

Figure 1: X-tendo methodology for features EPC Databases, Logbook, Enhanced recommendations, Financing options and One-stop-shops

The methodology will be tested in different X-tendo target countries, as showed in the table below.

Table 1: Implementing and expert countries per features

	EPC databases	Building Logbooks	Enhanced Recommendations	Financing Options	One Stop Shops
Feature lead	*TU Wien*	*BPIE*	*TU Wien*	*ADENE*	*ADENE*
Austria, EAST			Expert		
Denmark, DEA	Implementer		Implementer	Implementer	Implementer
Estonia, TREA		Implementer			
Greece, CRES	Implementer	Implementer			
Italy, ENEA	Implementer				
Poland, NAPE			Implementer	Expert	
Portugal, ADENE		Expert / Implementer		Implementer	Expert
Romania, AAECR				Implementer	Implementer
UK, EST	Expert		Implementer		Implementer

2 EPC DATABASES

2.1 Introduction

EPC databases store EPCs and underlying data, making it an important tool that allows public authorities to source building stock information and check EPC's compliance. The implementation and improvement of EPC databases include aspects such as how to set up an EPC database, how to gather the data, how to establish the interoperability of different databases, and how to use data and extract relevant insights from it. Finally, ensuring the reliability and accuracy of the information stored in the database through quality assurance processes and data verification remains a key requirement common to all EPC schemes. Because of that, X-tendo's methodology focuses on defining and establishing routines and analyses for quality control of EPCs in the EPC Databases. The Figure 2 below presents the phases of an EPC issuing processes, where quality control routines can be applied to:

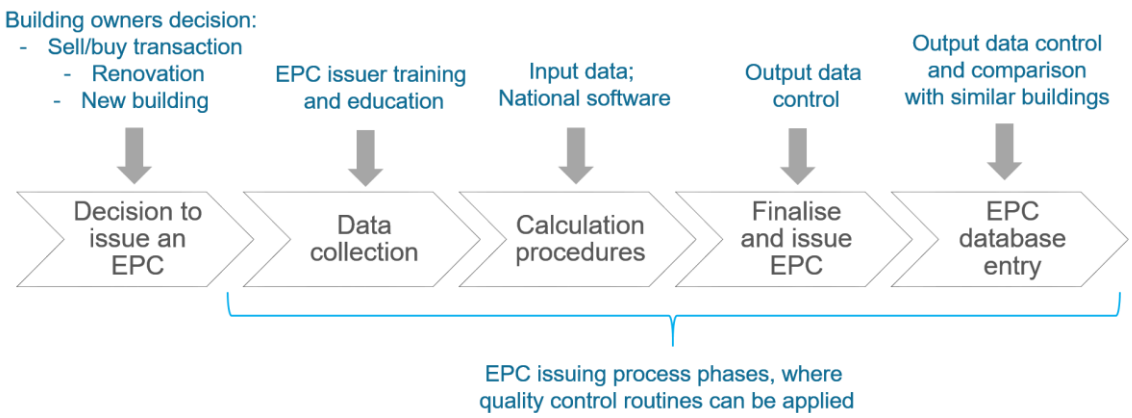

Figure 2: EPC issuing process phases and possible application of quality control routines

In X-tendo, we focus on the last step of the figure above, i.e. on the point where the EPC is fed into the EPC database and where quality control measures can be applied before finally accepting and storing it in the database.

2.2 Proposed methodology

Figure 3 below shows the proposed quality control method developed by the X-tendo project for EPC databases. In some cases, especially if there is an exchange between EPC database manager and EPC software developer (as it is the case in Denmark), step 1 a can be performed directly during the EPC issuing process. In the context of the project, the steps 1 to 3 described below are performed after the EPC has been issued, directly in the Database. Step 4 consists of describing how an analysis of the verification results can be done:

1) *First threshold value verification* requires all EPCs in the database to be automatically verified. At this stage, a **"broad" threshold value check** (broad range) is performed for a series of EPC parameters, for example whether U-values fulfil the requirement to be greater than (>) 0. The set of rules for this first step is explained in section 2.4.
2) *Second threshold value verification*. In this second stage, a more **"narrow" threshold value check** (narrow range) is performed for previously defined building archetypes.

The verification rules are set for different building *archetypes* that are defined by clustering different parameters and their sub-groups (building type, building construction year, climate zone etc.). Also this step is being done automatically. The methodology used to define archetypes and threshold values are explained in section 2.5.

3) *EPC flagging* according to the identified faults, notification of the inconsistencies, and indication of EPCs that will require manual checks. The EPC is flagged according to the severity and number of inconsistencies, and receives a final scoring. The calculation of this final scoring is explained in section 2.6. The flagging contributes to a targeted selection of the EPCs, that have to be manually audited. However, the manual check is not included in the present X-tendo methodology.
4) *EPC database analysis*: the methodology will deal with how to assess and analyse EPC databases based on the results from the verification checks. The results from an EPC database quality control process can also serve as feedback loop, on how to improve education programs for energy auditors and other professionals responsible for issuing EPCs. The main objective is to prevent that commonly made mistakes are repeated, and less faulty EPCs are logged in the database.

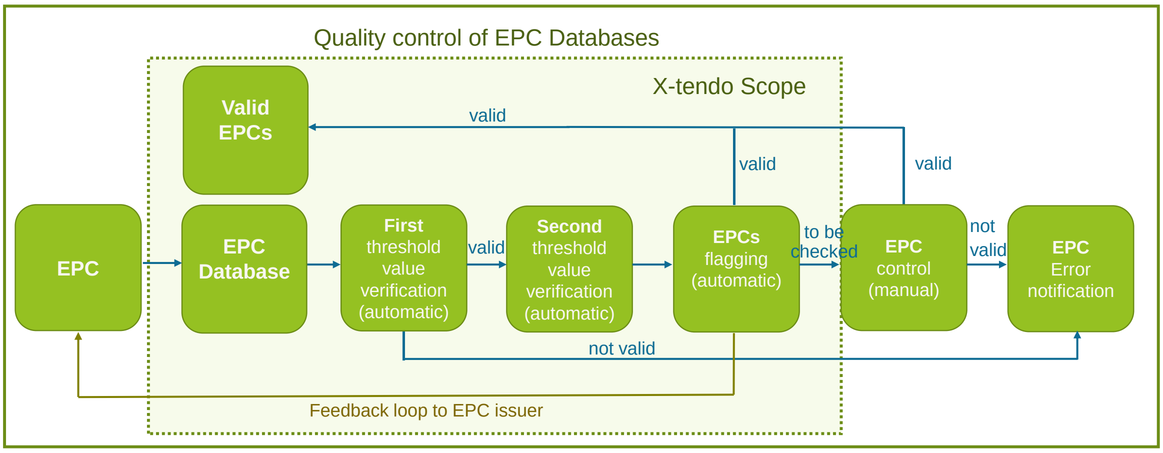

Figure 3: Outline of the proposed quality assurance method

2.3 Implementation of the proposed methodology

The steps 1 to 3 (as described in the chapter 2.2) will be implemented as programming code in Python Language. The programming code consists of an interface through a DAO between the national EPC databases and the core code. The data source from which the building data is gathered, is not assumed to be uniform among countries, therefore an Abstract DAO base class specifies a common interface which should be implemented for each country. The AbstractDAO deals as interface between the "country specific" database and the core code that performs the constraints checks. The implementing class is the ideal place to handle database transactions and other persistence-related tasks. The Figure 4 below presents how the DAO interface and the code happens.

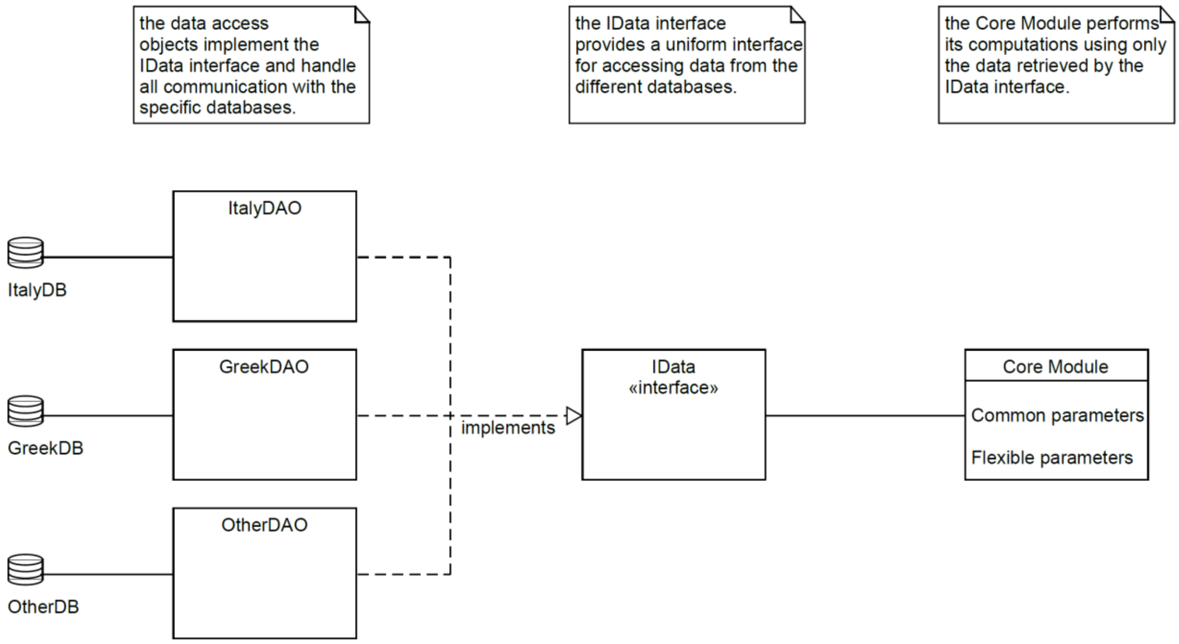

Figure 4: DAO Interface between countries' EPC database and X-tendo core code

The core code performs the verifications based on the rules set for first and second value check. Because of the country specific singularities, there will be developed a model for each country (Italy and Greece). Each code will be tested by the X-tendo implementing partners by running it on their own EPC database. Together with the programming code, a user handbook and a code documentation will be provided with relevant information as input data, explanations and guidelines how to use the code[1].

Below it is described how the developed method will be applied in the different X-tendo implementing countries Denmark, Greece and Italy:

- **Denmark** will implement and test the concept for an automatized EPC database analysis, linking the results with a feedback loop on how to improve education programs for energy auditors and other professionals responsible for issuing EPCs;
- **Greece and Italy** will implement and test the first and second verification checks as well as the EPC flagging;

2.4 Setting the rules for the first verification check

In the first check, the value of EPC parameters available in the EPC database are verified. Therefore, it is necessary to define which EPC parameter should be checked and which rules should be applied. The main objective of this verification check is to perform a **"broad" threshold value check** (broad range). Exemplary rules are "*U-value external wall not empty*

[1] The programming code will be part of the project deliverable "Tools/ IT-Components and related documentation of the proposed calculation and data handling procedures to be tested in WP5" (Project deliverable D4.5)

or greater than 0" and "*Surface area external wall not empty or greater than 0"*. In this first check also the dependence between parameters and their values can be specified. For example, the parameter value *heating degree days* has to be in a specific range depending on the parameter *climate zone*.

In the X-tendo project, the rules[2] for the first check were determined in a country specific manner. For Italy, a total of 50 rules were specified. For Greece, a total of 45 rules were specified (available in ANNEX I – Rules first threshold check (per country)). In the future, these rules can be extended. In Denmark, about 350 rules have already been implemented before the start of the X-tendo project.

2.5 Setting the rules for the second verification check

To define the rules for the second verification check, the following process steps were followed: (1) the definition of EPC parameters that should be checked, (2) the identification of the building parameters and their sub-groups to define building cluster, and (3) a statistical analysis of the actual EPC database to define the threshold values of parameters defined in (1) per building cluster (2). Each of these parts are explained below:

1. Define the EPC parameters

Both X-tendo implementing partners Greece and Italy defined the EPC parameters that should be checked in the second verification. Example of chosen parameters are final energy consumption for heating and final energy consumption for cooling. For Greece 15 parameters were defined, and for Italy 11 (ANNEX III – Parameters second threshold check (per country)).

2. Definition of building cluster

A building archetype is defined by the combination of different building parameters and their sub-groups. For example: the building parameter *building use* has following sub-groups *residential*, *office*, *school etc.* The building parameter *climate zone* might have following sub-groups *subtropical temperate and hot temperate.* An exemplary archetype that consists of sub-groups from building use, construction period and climate zone is: *residential-until 1910- subtropical* (ANNEX II – Cluster parameters (per country)).

3. Define the threshold values for the parameters defined in *step 1*, for each cluster defined in *step 2*

In this final step, the threshold values were defined. The definition of these values were based on statistical analysis of the current EPC databases. For each EPC parameter and each building cluster defined (previously described in steps 1 and 2), different percentiles (80-99%) were extracted from the actual database. The chosen appropriate percentile (for example, 99%) define the threshold values.

[2] These rules are also implemented in the project deliverable "Tools/ IT-Components and related documentation of the proposed calculation and data handling procedures to be tested in WP5" (Project deliverable D4.5), which is a programming code in Python.

The X-tendo implementing partners Greece and Italy defined both the different building parameters as their sub-groups, allowing that country specific definition of building archetypes according to their building stock's and their country's characteristics. For Greece 324 archetypes were defined, and for Italy 240 – delivered from the information in (ANNEX II – Cluster parameters (per country) .

2.6 EPC flagging

Setting a scoring to classify the whole EPC, based on the final scoring

An EPC could be classified as risky if:
(1) At least one of the parameters is "very risky".
(2) At least 3 parameters "risky"
(3) Etc.

The final rules for the flagging of EPCs will be determined during the testing on the real EPC databases. This part will be revised in the next version of this document, which will be ready by August 2022.

2.7 Analysis of EPC inconsistencies

In Denmark, the Danish Energy Agency has already implemented standardised rules[3] to verify the EPCs in the database and to identify potentially risky EPCs, to be manually checked, similar to the verifications checks specified in the steps 1 and 2 above. While issuing the EPC in Denmark, the energy auditor can receive automatically generated warnings, according to the input values entered in the software. This serves as base information for a risk based control, when selecting EPCs for control. Another option is to assess the EPCs (in the Database), and verify if specific rules are violated. Below, a process to provide standardised evaluation of warnings and inconsistences is described, as well as results from a demonstrative example applied to the Danish EPC Database. Through this evaluation it is possible to identify which rules are violated frequently, the severity and the main explanations to the violations. This evaluation allows improvements in different areas: 1) setting the validation rules; 2) specification of calculation procedures and tools to specify a parameter value or 3) education materials for energy auditors and consultants, who issue EPCs.

The main objective of these evaluation is to verify, how consistent the EPCs input data are, when compared to threshold values. The steps followed in this evaluation are:

1. **Selection of the building element**: the first step is to choose the building elements/and or components that will be evaluated, as windows, roofs, external walls, etc;
2. **Specify the characteristics of these building elements**: in this step, the characteristics are specified, for example: according to the building construction period;

[3] More details about how these rules are set in the Danish case can found in the report "Description of implementing partners' user needs and detailed technical specifications regarding features on handling and user of EPC data".

3. **Selection of the EPC parameters and their rules**: for each building element and/or component, the representative EPC parameters and the threshold value, as well as, the rule should be defined. The differentiation according to the historical development of the building code standards might also be taken into account;
4. **Database extraction**: after all the definitions above have been made, the information can be extracted from the database. This activity allows the identification of the number of EPCs per defined category, the number of violation per rules, and consequently the percentage of faulty EPCs.

The Table 2 below shows the results obtained from a case study in Denmark, following the steps described above. In this exemplary table, linear thermal transmittance, windows and roofs are chosen, and represented by the parameters y- and U-values. The table also shows that the threshold values varies due to the evaluation of the Danish building code standards that have become more restrictive over the time. The parameters are classified according to different construction periods and use codes. The use codes, in Denmark, represent different building uses, for example: single family house (120) and multifamily house (140). The last column shows the results obtained.

Table 2: Evaluation of EPC inconsistencies, example from Denmark

Building element	Constructin period and user codes	Parameter, Rule and Threshold value	Total numbers of EPCs with year and usecode conditions	Number of violations	Percentage Violation
Linear thermal transmittance	Before year 1973	y > 0,80 W/m·K	8611	33	0%
	Year 1973-2000	y > 0,70 W/m·K	3122	141	5%
	Year 2001-2006	y > 0,60 W/m·K	321	18	6%
	After year 2006	y > 0,40 W/m·K	3047	72	2%
Windows	Year 1972	U > 2,8 W/m^2·K (1972)	330	71	22%
	Year 1973-2000	U > 2,8 W/m^2·K (1973-1994) U > 1,9 W/m^2·K (1995-2000)	3140	464	15%
	Year 2001-2006	U > 1,9 W/m^2·K (2001-2006)	324	61	19%
	After year 2006	U > 1,9 W/m^2·K (2007) U > 1,5 W/m^2·K (2008-)	3055	256	8%
Roofs	Year 1960-1972 and usecodes 110, 120, 130, 131 and 132	U > 0,43 W/m^2·K (1960-1972)	2750	641	23%
	Year 1973-2000 and usecodes 110, 120, 130, 131 and 132	U > 0,43 W/m^2·K (1973-1979) U > 0,30 W/m^2·K (1980-1994) U > 0,20 W/m^2·K (1995-2000)	2914	698	24%
	Year 2001-2006 and usecodes 110, 120, 130, 131 and 132	U > 0,20 W/m^2·K	286	78	27%
	After year 2006 and usecodes 110, 120, 130, 131 and 132	U > 0,20 W/m^2·K	2637	42	2%

The main conclusions to be led from this analysis done during the X-tendo project is that the higher percentage of violations occurs by the roof. After analysing it with the X-tendo implementing partner DEA, different reasons for that were identified: over the past 20 years, the documentation of the buildings have increased rapidly. Also, digitalisation has been playing an important role, as it enabled that building drawings from the building's planning phase could be saved and used in future activities. This also means, that for the buildings constructed before this period, there is still a lack of documentation, as for example ceiling and roof drawings. Consequently, energy auditors and consultants have to estimate the U-value of the roof. Then, two possible error sources are identified, one is the wrong estimation made by the energy auditor and the other is that in fact the building does not comply with the regulation requirements. In terms of feedback loop, on how to improve education programs for energy auditors and other professionals, the present analysis indicates that education programs should focus on methods of how to accurately estimate U-values for the roofs or how to handle with the appropriated tools for that.

Secondary results (showed in the Table 3) from this analysis were some inconsistencies in the EPCs, by identifying double entries or empty parameter values. However, they are numerically not significant and also not relevant for the main objective of this demonstration.

Table 3: Secondary identified inconsistencies, example from Denmark

Linear thermal loss	
EPCs in same category	15101
Doubles	17
EPCs without linear thermal loss	70
	15154
Windows	
EPCs in same category	15171
Doubles	19
EPCs without windows	2
	15154
Roof	
EPCs in same category	15145
Doubles	19
EPCs without roof	28
	15154

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[1] DIN V 18599-2, 2011. Teil2_ Nutzenergiebedarf für Heizen und Kühlen von Gebäudezonen.pdf.

[2] DIN V 18599-9, 2011. 2011_Teil 9_ End- und Primärenergiebedarf von stromproduzierenden Anlagen.pdf.

[3] Invert/EE-Lab [WWW Document], 2021. URL https://invert.at/ (accessed 6.28.20).

[4] ÖNORM B 8110-4:2011 07 15 - Lesesaal - Austrian Standards [WWW Document], 2011. URL https://lesesaal.austrian-standards.at/action/de/private/details/396775/OENORM_B_8110-4_2011_07_15 (accessed 4.6.21).

ANNEX I – RULES FIRST THRESHOLD CHECK (PER COUNTRY)

Greece

Variable Name	Rule
Climate zone	In the range [1;4]
U-value external wall	Greater than 0
U-value roof	Greater than 0
U-value door	Greater than 0
U-value floor against ground	Greater than 0
Surface area external wall	Greater than 0
Surface area roof	Greater than 0
Surface area door	Greater than 0
Surface area floor against ground	Greater than 0
Surface area window	Greater than 0
Window glazing U-value	Greater than 0
Window g-Value	Greater than 0
Sun protection (Shading)	Greater than 0
Heat Efficiency	Greater than 0
Cooling Efficiency	Greater than 0
Lighting	Greater than 0
Building use	In the range [1;60]
Reason	In the range [1;19] or Equals 99
Suggestions	If the energy class is C or worse, at least one suggestion is required
Primary Energy For Heating	Greater than 0
Primary Energy For Cooling	Greater than 0
Primary Energy For Lighting	Greater than 0
Primary Energy Consumption	Smaller than 5000
Reference Building Primary Energy Consumption	Smaller than 5000
CO2 emmissions	Greater than 0
Gross building area	Greater than 0
Useful building area	Greater than 0 and less than or equal to Gross building area
Useful building volume	Greater than 0

Heated area	Greater than 0 and less than or equal to Gross building area
Cooled area	Greater than 0 and less than or equal to Gross building area
Heating days	In the range [1;364]
Climate region	In the range [1;4]
Windows orientation	In the range [1;359]
Ventilation system type	Is not null
Mechanical ventilation system exists	In the range [0;1]
Heating energy source	Element of ["LPG", "Natural Gas", "Electricity", "Heating Diesel oil", "Transport Diesel oil", "Distrinct Heating (PPC)", "Distrinct Heating (Renewable)", "Biomass", "Standardized Biomass"]
Reference heating energy needs	Greater than 0
Building's heating energy needs	Greater than 0
Domestic hot water energy needs	Greater than 0
Useful heating energy (dhw)	Greater than 0
Useful electricity demand	Greater than 0
Primary energy demand	Greater than 0
Carbon dioxid emission	Greater than 0

Italy

Variable Name	**Rule**
Cadatral identification of buildig ID	Is not null
User profile (name or code)	In the range [0;14]
Statistical code of the Region	In the string range [01;22]
Regional ID of the EPC	Is not null
Heated area	Greater than 0
Cooled area	Greater than 0
Heated bruto-volume	Greater than 0
Cooled bruto-volume	Greater than 0
Building envelope area (heat loss area)	Greater than 0
Compactness (based on heat loss area)	Greater than 0
Heat degree days	Complex table-based check
Climate region	Complex table-based check

Yie-value periodic thermal transmittance	Greater than 0
Equivalent solar Area/net heated area Ratio	Greater than or equal to 0
Mechanical ventilation system exists	Boolean value
Building structure	In the range [0;14]
Heating energy sources	In the range [0;15] if Space heating service exists
Cooling energy sources	In the range [0;15] if Space heating service exists
Energy demand for each energy source	Greater than 0
EPhnd,lim -> indicator	Greater than 0
Building's heating energy needs	Greater than 0
Reference Global primary energy demand (not renewable)	Greater than 0
Global primary energy demand (not renewable)	Greater than or equal to 0
Global primary energy demand (renewable)	Greater than or equal to 0
Global carbon dioxid emission	Greater than 0
Exported eletrical energy (for example: PV)	Greater than or equal to 0 or null
Primary energy demand (not renewable)	Complex table-based check
Space heating service exists	True
Heating primary energy demand (not renewable)	Greater than or equal to 0
Heating primary energy demand (renewable)	Greater than or equal to 0
Heating system efficiency	Greater than 0
Space cooling service exists	Boolean value
Cooling primary energy demand (not renewable)	If Space cooling service exists then Greater than or equal to 0
Cooling primary energy demand (renewable)	If Space cooling service exists then Greater than or equal to 0
Cooling system efficiency	If Space cooling service exists then Greater than to 0
DHW service exists	True if user profile equals 0 or 2
DHW primary energy demand (not renewable)	If DHW service exists then Greater than or equal to 0
DHW primary energy demand (renewable)	If DHW service exists then Greater than or equal to 0
DHW system efficiency	If DHW service exists then Greater than 0
Mech Vent primary energy demand (not renewable)	If Mechanical_Ventilation System Exists then Greater than or equal to 0

Mech Vent primary energy demand (renewable)	If Mechanical_Ventilation System Exists then Greater than or equal to 0
Mech Vent system efficiency	If Mechanical_Ventilation System Exists then Greater than 0
Lightning is considered	Boolean value
Lighting primary energy demand (not renewable)	If Lightning is considered then Greater than or equal to 0
Lighting primary energy demand (renewable)	If Lightning is considered then Greater than or equal to 0
Lighting system efficiency	If Lightning is considered then Greater than 0
Transport systems are considered/exist	Boolean value
Transport primary energy demand (not renewable)	If Transport systems are considered then Greater than or equal to 0
Transport primary energy demand (renewable)	If Transport systems are considered then Greater than or equal to 0
Transport system efficiency	If Transport systems are considered then Greater than 0

ANNEX II – CLUSTER PARAMETERS (PER COUNTRY)

Greece

Building uses

Residential single family houses
Residential multifamily houses
Hotels of continuous yearly operation
Hotels of intermittent operation – summer
Primary education schools
Secondary education schools
Higher education buildings
Hospitals
Offices

Climate zones

A
B
C
D

Construction period

1	Before 1980	no any insulation regulations in force
2	1980-2010	1st Building Insulation Regulation
3	2010-todate	2010-Transposition of EPBD & 1st Energy Performance Regulation

Renovation period

1	No renovation
2	2010-2017
3	after 2017

Italy

Building uses

1	Residential
2	Office buildings
3	Commercial buildings
4	Buildings for industrial and craft activities
5	Other not residential

Building constructions period

1	Before 1945
2	1945-1976
3	1977-1991
4	1992-2005
5	2006-2015
6	From 2016

Climate zone

1	A+B (<= 900 HDD)
2	C (901<=HDD<=1400)
3	D (1401<=HDD<=2100)
4	E (2101<=HDD<=3000)
5	F (HDD>= 3001)

ANNEX III – PARAMETERS SECOND THRESHOLD CHECK (PER COUNTRY)

Greece

Envelope characteristics	**Unit / comment**
U-value external wall	W/m2K
U-value roof	W/m2K
U-value floor against ground	W/m2K
U-value floor on pilotis	W/m2K
U-value windows	W/m2K
Energy consumption class	
Total Primary Energy Consumption	kWh/m2
HVAC Systems Data	
Heating System Efficiency	SCOP
Cooling System Efficiency	SEER
Mechanical Ventilation system (air supply)	m3/h
Solar Collector Area	m2
Energy Consumption Indicators	
Total final Energy Consumption	kWh/m2
Energy Consumption for Heating (final)	kWh/m2
Energy Consumption for Cooling (final)	kWh/m2
Energy Consumption for Lighting ** (final)	kWh/m2
Energy Consumption for DHW (final	kWh/m2

** only for non-residential

Italy

Building characteristics	**Unit / comments**
compactness	1/m
yie-value periodic thermal transmittance	W/m2K
Equivalent solar Area/net heated area Ratio	[-]
Specific energy demand indicators	
building's heating energy needs	kWh/m²a
Global primary energy demand (not renewable)	kWh/m²a
Global primary energy demand (renewable)	kWh/m²a
Global carbon dioxid emission	kg/m²a
Specific energy demand indicators	
Heating primary energy demand (not renewable)	kWh/m²a
DHW primary energy demand (not renewable)	kWh/m²a
Dimensionless energy indicators	
Heating primary energy demand (not renewable)/building's heating energy needs ratio	[-]
Reachable global primary energy demand (not renewable)/ Global primary energy demand (not renewable) ratio	[-]

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