D2.2 - ALDREN Methodology note on energy rating procedure

September 2020

ALDREN ALliance for Deep RENovation in buildings

Implementing the European Common Voluntary Certification Scheme, as back-bone along the whole deep renovation process

Project resume:

The ALDREN objectives are to achieve higher renovation rates and better renovation quality by overcoming market barriers and preparing the ground for investment.

The excellence of the ALDREN solutions offered are:

1. a harmonized Energy performance rating based on the European Voluntary Certification Scheme (EVCS) verified by measurements to increase comparability, confidence and market uptake by standardized solutions (CEN / ISO);
2. associating low energy renovation with high quality indoor environments to trigger renovation and to promote health and comfort;
3. aligning market recognition of high quality with enhanced building value by financial tools and capacity building. Establishing business case for deep renovation to motivate private investment.

These solutions are integrated in a consistent, common way in a building passport to ensure the results and effective financing also in case of step-by-step renovation.

The ALDREN coordinate and support actions bring together in ALDREN Alliance the main stakeholders involved in building renovation to specify the needs of the non-residential building sector and to organize the pilot use of the ALDREN procedure.

The ALDREN actions are sound and credible. They answer a market request for common reliable tools by using the EVCS policy instrument (e.g. the EPBD Art. 11(9)) and by completing it to reach the needed holistic approach for deep renovation.

The implementation and dissemination of the ALDREN procedure uses existing channels of environmental scheme operators for the pilot phase, but also for further dissemination.

The ALDREN overarching outcome will be the infrastructure to enable market transformation by deep renovation driven by the business case and able to directly support the EU policies (EED, EPBD).

Coordinator:

- **CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT** — **France**

Participants:

- ENBEE — Slovakia
- INSTITUTO VALENCIANO DE LA EDIFICACION — Spain
- CERTIVEA — France
- REHVA — Belgium
- VERCO ADVISORY SERVICES LIMITED — United Kingdom
- DANMARKS TEKNISKE UNIVERSITET — Denmark
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Annex C to this report is a separate document

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Abbreviations

BACS	Building Automation and Control Systems
BES	Building Energy Simulation
CDD	Cooling Degree-Days
CEN	the European Committee for Standardization
CHP	Combined heat and power
CO	Cost optimal level of energy performance of buildings
DHW	Domestic hot water (system)
EP	energy performance
EPB	energy performance of buildings
EPB standards	EN and ISO standards for the energy performance of building calculation developed under the European Commission's Mandate M/480 to CEN
EPBD	Directive 2010/31/EU of the European Parliament and of the Council of May 19, 2010 on the Energy Performance of Buildings with amendments
EPC	Energy performance certificate
EVC	Common European Voluntary Certificate
EVCS	Common European Voluntary Certification Scheme
EX	existing building
GIA	Gross internal floor area
HDD	Heating Degree-Days
IEQ	Indoor Environmental Quality
NIA	Net internal floor area
NZEB	Nearly Zero-Energy Building
MS	Member State of the European Union
PEF	primary energy conversion factor
PV	photo-voltaic
RER	renewable energy ratio
RES	renewable energy sources
SRI	Smart Readiness Indicator
f_{Pnren}	non-renewable primary energy conversion factor
f_{Pren}	renewable primary energy conversion factor
f_{Ptot}	total primary energy conversion factor

1 Executive Summary

1.1 The context

Property owners need a harmonized assessment methodology and procedures to manage the large buildings stocks, possibly at the European scale. Benchmarking based on the energy performance certificates could be a core instrument for building energy management and for energy policies.

National energy performance certificates do not always consider innovative solutions and all technical systems in a harmonised way. The aim of ALDREN European Voluntary Certificate (EVC) is to provide tool for building owners, tenants, financial institutions and policy makers for comparable energy ratings at the European scale. Common European energy rating could also facilitate the adoption of a voluntary European certification scheme for non-residential buildings according to EPBD Article 11 (9).

Energy savings are not the main motivation of investors and owners of non-residential buildings towards deep renovation. Additional indicators are needed to link the energy performance with the IEQ, comfort, attractiveness and asset value.

1.2 The ALDREN solutions

The European Voluntary Certificate has been worked out to be integrated in the property managers' decision making process. ALDREN provides methodologies, procedures, indicators and template to ensure **comparability, transparency and reliability of EPCs** on a building stock scale and the European scale with the aims:

- To identify the building within a given **building stock** associated to a performance target,. At the building stock scale, the calculation methodology and the energy rating scale (classes from A-G) of the EVC may be used to assess, compare and identify in priority the buildings fitting for deep renovation (60% energy savings or NZEB level),
- To provide information for decision making process at the **building scale.** The rating scale may be used to **identify the "energy class transition"** needed to reach the deep renovation level and to **identify the renovation actions** required to achieve it.

Extension of energy performance by additional indicators, based on all ALDREN tasks, is proposed for methodological integration of the indictors in property managers' decision process presented in Annex B in the modular structure of EVC+. Annex C provides the full EVC+ template and a transparent description of the ALDREN calculation methodology and choices to support the development of Annex A of the overarching standard EN ISO 52000-1:2017 [7]. Annex C has been developed as a separate document.

1.3 Key points of the methodology

The main conclusions and achievements are:

- based on the calculation of several model buildings using simulation software with hourly calculation step close to the EPB standards (M 480), the **ALDREN scale** is proposed with the fixed reference values per building category and for three climates (Warm, Moderate, Cold) presented in Table 1. The scale is leading to the target, that is the **ALDREN NZEB,** defined in line with the Commission Recommendation [6]. These values take into account the technical potential for building improvement and renovation steps suitable for EU harmonised rating (see Annex A).

Offices

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**70**	**25**
Moderate	**130**	**46**
Cold	**170**	**60**

Hotels

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**200**	**70**
Moderate	**270**	**95**
Cold	**310**	**109**

Table 1 The reference values (REF) for ALDREN scale and ALDREN NZEB in kWh/(m^2.a) of non-renewable primary energy

- **The EVC template** has been worked out as a support for integration in decision making process. The link of energy efficiency with the asset valuation, indoor environmental quality and actual energy consumption is provided (see Annex B and Annex C).
- **The calculation methodology** in line with the EPB standards and performance indicators are defined in the protocol together with the ALDREN NZEB definition, which is based on the fulfilment of specific requirements for four criteria. The choices to support the development of Annex A of the overarching standard EN ISO 52000-1:2017 [7] are provided for a transparent description of the calculation methodology and assessment boundaries (see separate document Annex C).

Commission Recommendation (EU) 2016/1318 [6] on guidelines for the promotion of nearly zero-energy buildings has been taken as the main reference for definition of ALDREN nearly zero office buildings. The recommended values by the neZEH initiative [28] are the basis for the definition of the NZEB for hotels.

The study in Annex A, on testing the scale and reference points on the scale, shows that the proposed values for NZEB in three different climates can be achieved and the step-by-step renovation is visible by energy classes transition for each renovation step.

2 Main outcomes

2.1 Objectives

Harmonized assessment methodology and procedures will help property owners to manage the large buildings stocks, possibly at the European scale. Benchmarking is a core instrument for energy management and for financial instruments.

The revised EPBD [2] amended by Directive 2018/844 [3] aims to accelerate the cost-effective renovation of existing buildings and to promote smart technologies in buildings. The role of the **energy performance certificates** has been strengthened in the Directive 2018/844 by the recommendation to be improvements achieved assessed by comparing energy performance certificates issued before and after renovation. The Member States are asked to ensure that the national certificates are of good quality to provide reliable information. EPCs are assumed to be important tools for **green financing** on the way to 2050 EU targets.

National EPCs do not provide yet a direct **comparability** of energy performance ratings across the EU and do not consider in the same way the innovative solutions and all technical systems [36]. The aim of ALDREN European Voluntary Certificate (EVC) is to provide tool for building owner, tenant, financial institutions and policy makers for comparable energy ratings at the European scale. European voluntary certificate could facilitate the adoption of a voluntary European certification scheme for non-residential buildings according to EPBD Article 11 (9).

In addition, the ALDREN energy performance indicators ensure the **transparency and reliability** through:

- harmonized calculation methodology based on new EPB standards developed by CEN under Commission Mandate M/480, using hourly calculation step, local climate conditions and the national use patterns;
- consideration of the innovative solutions, technical systems and renewable energy used and produced in building in the same way;
- The main and additional numerical indicators, for the entire building's overall energy use and for the definition of targets (NZEB).

The energy performance indicators are adapted to facilitate the potential use of EVC as an energy module in wider voluntary environmental schemes including LEVEL(s) [24]. The needs of existing voluntary certification schemes were examined and taken into account.

ALDREN EVC provides a possible link with financial valuation, asset value and financial strategies to facilitate energy efficiency renovations and indicators to be collected in the building renovation passport.

2.2 Methodology

The review of relevant legislative documents, standards, studies for Commission and relevant H2020 projects was the basis for setting the EVC energy performance indicators and the reference values for the scale.

The definition of typical existing buildings was an important step in estimating the relative building targets for deep renovation that were examined and are presented in the study in Annex A.

The reference on the scale (upper limit of energy class "D") represents buildings that are approximately at the cost optimal level of minimum requirements calculated by Member States in 2013. The characteristics of typical existing buildings and buildings at the cost optimal level have been defined on the basis of overview of national reports from calculation of cost optimal level of energy performance in 2013 [22]. Member States had to define the typical existing reference buildings and report them to the Commission according to Regulation 244/2012 [4]. The review of national reports shows that the impact of deep renovation on energy savings can be higher in countries with the poor building stock quality. The deep renovation target expressed in % of energy savings is therefore not appropriate for achieving the full renovation potential.

Due to the differences in the types of indicators and the assessment boundaries, ALDREN could not directly take the cost optimal level of energy performance expressed as a numerical indicator of primary energy in kWh/(m².a) reported by Member States in 2013 [22] to setting the reference on the scale.

When calculating ALDREN model buildings using simulation software [49], only the properties of typical existing buildings, cost-optimal buildings and NZEB reported by Member States were used as input data in calculation to determine the reference values for the scale, not the results in energy use.

The NZEB is the main target of ALDREN renovation strategies and the scale has to reflect this target. The Commission Recommendation (EU) 2016/1318 on guidelines for the promotion of nearly zero-energy buildings [6] has been taken as the main reference for the definition of nearly zero office building.

The recommended values by the neZEH initiative [40] have been taken as the basis for the nearly zero hotel building. Hotels are complex buildings with many different potential use scenarios depending on the operation (annual, seasonal), climate and hotel category.

The challenge for hotels is how to define the “typical use of the building” for energy performance calculation required by the EPBD. The neZEH initiative [31] identified the categories based on geographical area (urban, rural, coastal, mountain) and according to the customer activities (business, Spa, resort, B&B). The need to take into account the specificities of hotel buildings in the calculation of energy performance was emphasized in their position paper [32] and confirmed by the study presented in Annex A.

The study by Triple E Consulting [20] on the market uptake of the EU voluntary certification scheme recommends that the “uptake would be increased if it is integrated into existing schemes or if it replaces mandatory schemes”. The ALDREN indicators are adapted to the needs of existing schemes analysed also using the questionnaire (DGNB, IVE, HQE).

The consultation with stakeholders and relevant outcomes from the study “Enabling the European Common Voluntary Certification scheme (VCS) for non-residential buildings” Service contract No. ENER/C3/2015-545/SID.710527 have been also taken into account.

2.3 Common Energy Performance Indicators, Rating and Scale

The options for the scale and reference value for benchmarking energy performance were tested on five model office buildings and three model hotel buildings of different sizes and properties located in three climates (Palermo, Bratislava, Helsinki). The proposed scale and reference values were also tested on real pilot buildings.

The calculation methodology is based on EN and ISO standards for the energy performance of buildings calculation developed under the European Commission’s Mandate M/480 to CEN. An hourly calculation step is required. For testing the scale, a simulation software fulfilling these conditions was used [49].

For the same building, it is possible to achieve different numerical values of energy performance indicator expressed in primary energy in kWh/m². The numerical value depends on the assessment boundaries for renewable energy, the type of primary energy (total, non-renewable), the consideration of on-site renewable energy production (export allowed or not), etc.

Annex A to EN ISO 52000-1 [7] is an empty template that can be filled in with the national or regional data and choices to describe the calculation methodology for assessment of energy performance of building. For EVC the choices are described in protocol in the structure of Annex A to EN ISO 52000-1 [7].

All potential indicators are reported in ALDREN EVC to fit the different schemes and choices by Member States and by existing voluntary schemes. Two indicators are benchmarked by energy class:

- non-renewable primary energy with export to grid counted (the main EP indicator).
- non-renewable primary energy with only auto-consumption of PV electricity produced on-site counted;

Following the recommendation by Directive 2018/844/EU the additional numerical indicators, are also calculated and reported in ALDREN EVC (the energy needs, overall energy use, delivered energy per carrier and per service, thermal comfort indicator ..).

The scale is in line with the new option in EN ISO 52003-1 [8]. It is a non-linear stepped scale with seven main classes (A-G) and with one reference point located at the upper limit of energy class “D”. This reference value is based approximately on the cost optimal level of minimum requirements calculated by Member States in 2013. Energy Class „A“ is the definition of ALDREN NZEB.

The reference value for the scale is proposed for office buildings and hotels based on the calculation of model buildings using simulation software with an hourly calculation step for 3 climates (Palermo, Bratislava, Helsinki). The climate data for a Typical Meteorological Year (TMY) for Europe, developed by European Commission, Joint Research Centre, have to be used.

The rules for allocation of rated building in one of the 3 climate zones (warm, moderate, cold) for the ALDREN rating have been set on the basis of heating degree-days (HDD) obtained from the Typical Meteorological Year (TMY) used for the calculation.

For testing the transition of energy classes and energy savings, three main levels of building quality were applied to model buildings:

- **Existing building** – initial stage, based on the description of typical national existing building in EU countries' 2013 cost-optimal reports [22],
- **Cost optimal level (2013)** – based on the EU countries' 2013 cost-optimal reports [22]. This level corresponds to the reference value on the scale (upper limit of energy class “D”). This can be also one of the initial states before renovation,
- **NZEB** – the target based on the properties for national definitions of NZEB [22].

Packaged solutions for deep renovation strategies were also tested on ALDREN model buildings, considering the appropriate sequence of renovation steps to avoid the lock-in effect and considering different pre-renovation states.

The main target of renovation steps is deep renovation defined by at least 60% primary energy savings or by achieving the NZEB level. Three partial renovation steps of the envelope and systems were applied on model buildings towards NZEB level.

ALDREN NZEB is defined by energy class “A” and by three additional requirements specified in the protocol.

The numerical value for ALDREN NZEB may not necessarily be in the compliance with the national definition of NZEB due to the different types of indicators, the different assessment boundaries and the calculation methodologies used at national level. Compliance with the national minimum requirements for existing buildings is not within the scope of ALDREN and must be ensured by the designer.

2.4 ALDREN European Voluntary Certificate

The harmonised European Voluntary certificate (EVC), compliant with the amended EPBD, is proposed in Annex B. The EVC improves the current practice at least by the following features:

- local climate is used for the energy performance calculation instead of one national or regional climate. The gap between calculated and actual energy consumption is reduced;
- common harmonised calculation methodology based on CEN EPB standards developed under M/480 that improves the level playing field for products and comparability of energy performance across EU;
- all options for indicators are reported making the EVC usable for most of national and existing voluntary certification schemes;
- hourly calculation step provides a more correct consideration of thermal comfort and correct estimation of some technologies e.g. PV auto-consumption, heat pumps;
- thermal comfort score from hourly calculation is reported together with the energy use to make visible the relation between the calculated energy use and the IEQ.
- additional indicators are reported (health & wellbeing, measured energy, financial valuation)
- recommendations for improvement of energy performance towards the NZEB are reported with link to the details in Renovation Roadmap to avoid the lock-in effect;
- the definition of ALDREN NZEB (green certificate) is based not only on one indicator for primary energy, but on the requirements for four indicators.

ALDREN EVC provides comparability at EU level and highlights high-performance buildings and the ratio of renewable sources used in building. It can be taken over by Member States (EPBD Art. 11), by the Commission for EPBD Art. 11(9) or by existing voluntary certification schemes as an energy module.

The EVC could be a parallel complementary option to national EPCs, as it provides comparability at the level of the EU building stock, while national mandatory certificates provide comparability with the national building stock.

The EVC template contains the main pages for reporting the energy performance indicators, recommendations for improvement and the optional pages for reporting the results from other tasks e.g. TAIL (Health and wellbeing indicator), economic valuation, smart readiness indicator (SRI), gap between measured and calculated energy performance and operational rating.

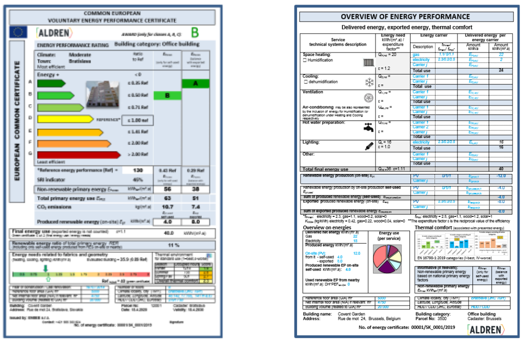


Figure 1 ALDREN EVC pages with the main energy performance indicators

Energy performance certificates shall include **recommendations for improvement** of energy performance of a building, unless there is no reasonable potential for such improvement compared to the energy performance requirements in force. The Directive 2018/844 recommends to be provided more detailed renovation strategies in an optional building renovation passport, complementary to the energy performance certificate. In ALDREN EVC the detailed renovation roadmap **RenoMap** developed in Task 2.6 (Deliverable 2.6) is used and referenced for detailed information.

2.5 Outcomes of the task

The ALDREN EVC rating protocol describes each step that a professional should follow when issuing an EVC. The steps were tested on ALDREN model buildings. The development and testing procedures are in Annex A "Study on energy performance indicators and targets for deep renovation" and in Annex B "Methodological integration of the EVC in ALDREN procedures".

The main conclusions and achievements are:

- the ALDREN scale is proposed with the fixed reference values for each building category and for **3 climates** (Warm, Moderate, Cold) based on the calculation of ALDREN model buildings using simulation software with an hourly calculation step (Figure 2). The analysis in Annex A justifies the need for 3 climates to take appropriately into account the technical potential for building improvement. A scale based on one fixed reference value for all climates could cause a lock-in effect as a full potential for improvement would not be exploited in some climates (Figure 3),
- The rules for allocation buildings to one of the 3 climate zones for ALDREN rating were set on the basis of the HDD obtained from a Typical meteorological year (TMY) developed by the European Commission (JRC) and used for energy calculation,
- The NZEB level on the scale is proposed in line with the Commission's Recommendation for NZEB and other sources,
- **Reference values** on the scale were defined and tested on several model buildings in 3 climates, including the energy class transition in case of step-by-step renovation. The results show that the scale is suitable for harmonised EU rating. The buildings pre-renovation stages and targets suitable for deep renovation have been identified (Annex A)
- Simulation on ALDREN model buildings confirms that the proposed **scale shape** based on **one reference point,** which is located on the upper limit of energy class "D" in line with the new option in EN ISO 52003-1 [8], has sufficient sensitivity to allow visibility of the individual renovation steps. One reference point on the scale limits also the uncertainty of the old approach to the scale, which uses the average building stock level as one of two reference points.
- The **template for European Voluntary Certificate** has been worked out and is reported in Annex B as a proposal for integration in decision-making process (Task 2.1). It provides a clear link to a more detailed renovation roadmap (RenoMap) with recommendations for improvement (Task 2.6) and to the indicators developed in Task 2.3, Task 2.4 and Task 2.5, which also provides a financial valuation of recommended improvement measures and a link to asset valuation.
- **The numerical reference values** on the scale expressed in non-renewable primary energy in kWh/(m^2.a) are presented in Figure 2 with a graphical expression in Figure 3.

- The data to be collected in the building renovation passport are set out in Annex B.

Offices		
Climate zone	ALDREN REF	ALDREN NZEB
Warm	**70**	**25**
Moderate	**130**	**46**
Cold	**170**	**60**

Hotels		
Climate zone	ALDREN REF	ALDREN NZEB
Warm	**200**	**70**
Moderate	**270**	**95**
Cold	**310**	**109**

Figure 2 Reference values (REF) for ALDREN scale and NZEB in kWh/(m^2.a) of non-renewable primary energy

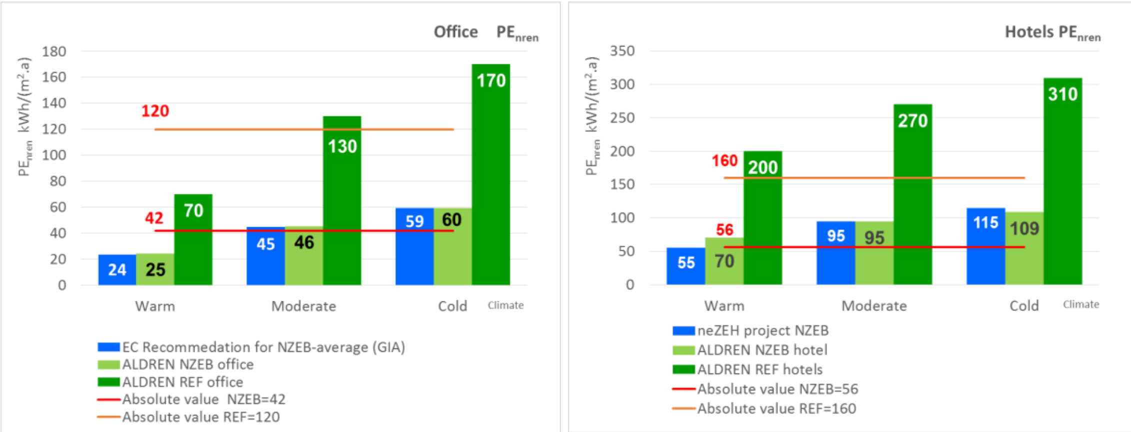


Figure 3 Comparison of one fixed reference value and ALDREN climate depending reference values

3 Overview of protocol development

The aim of this part of the report is to provide the overview of the procedures and assumptions for the development of the protocol that allow to produce an European voluntary certificate (EVC).

The aim of the Study in Annex A and Annex B is to provide the detailed justification and verification of the proposed choices for energy performance indicators and targets for deep renovation of existing buildings and a proposal for methodological integration of indicators into property managers' decision-making process, among the various criteria of building assets evaluation (including the attractiveness and technical state) (T2.1)

At the building stock level, the calculation methodology and the EVC rating scale (classes from A-G) were used to assess, compare and prioritize buildings suitable for deep renovation (60% of energy savings or NZEB level).

At building level, the indicators are set, verified and used to assess energy performance of buildings, identify the necessary "energy class transition" and the related renovation actions to achieve the target.

The definition of existing buildings' forms the baseline for impact assessment of relative energy performance targets for deep renovation and for step-by-step renovation.

3.1 Description of the current status

Relevant documents on indicators, benchmark and targets for energy performance rating were analysed with a focus on office buildings and hotels.

Based on an overview of the various sources dealing with existing building stock across the EU, the EU countries' 2013 cost-optimal reports [22] have been identified as the most relevant source for setting a common comparable reference. The advantage is the common structure of EU countries' 2013 cost-optimal reports and a common methodology based on EU legislation [4].

The reports from cost-optimal level of energy performance calculation by EU countries have also been assessed by the European Commission (Ecofys [21]) and were the basis for the definition of a typical existing building and of the building at the CO level (2013) for:

- setting baseline for the relative ALDREN targets for deep renovation (typical existing building),
- setting and verification of the ALDREN reference value on the scale (cost optimal level 2013).

Review of EU countries' 2013 reports on cost-optimal level calculation

The EPBD Article 4(1) [2] requires Member States to ensure that the minimum energy performance requirements for buildings are set with a view to achieving cost-optimal levels. Article 5 of the EPBD requires Member States to calculate the cost-optimal levels of minimum energy performance requirements for buildings and building elements using the comparative methodology framework published in the Commission Delegated Regulation No. 244/2012 [4]. The Guidelines [5] accompany the comparative methodology framework .

MSs shall report to the Commission all input data and assumptions used for the calculations and the results of the calculations.

The national reports from cost-optimal level calculation are documents that provide results based on a common framework, but also take into account national specificities of the building stock and traditions.

The report from Assessment of cost-optimal calculations by Ecofys [23] recalls that the "Technical assessment of national/regional calculation methodologies for the energy performance of buildings" (Service contract No. ENER/C3/2013-425/SI2.679523) [35] provides information on the level of compliance of Member States' calculation methodologies with Annex I of the EPBD. The conclusion is that more than half of the methodologies lack some aspects required in Annex I of the EPBD. The main issue is a reliability of the primary energy calculation. In some Member States, primary energy is not used as an EP indicator and not all technical systems are addressed.

Due to the incomparability of national calculation methodologies, the numerical indicators, which are expressed in primary energy derived from the EU countries' 2013 reports on the calculation of the cost-optimal level, cannot be used directly as a reference for ALDREN scale and rating.

To set the reference on the ALDREN scale, only information on individual **components and systems** for typical existing buildings and for cost-optimal level was used as input for ALDREN model buildings**,** from which numerical values expressed in primary energy were calculated.

3.2 Definition of existing building

The correct definition of existing buildings is important as a baseline for estimating deep renovation targets (60% savings) and for assessing impact of energy saving measures and related investments.

The aim of the review of EU countries' 2013 reports on the calculation of the cost-optimal level was to define the existing reference building as the baseline for the benchmarks.

Commission Delegated Regulation No. 244/2012 Annex I [4], requires Member States to establish at least two typical existing reference buildings for each category of building that are undergoing major renovation. Reference buildings can be established on the basis of subcategories of buildings (e.g. differentiated by size, age, cost structure, construction material, use pattern or climatic zone), which take into account the characteristics of the national building stock.

The reporting templates are set out in Annex III which Member States may use to report to the Commission on reference buildings representing the national building stock .

The EU countries' 2013 reports provided ALDREN with relevant information to define the characteristics of typical existing buildings and of their cost-optimal levels. The reports used come from: Austria, the Czech Republic, Denmark, Estonia, Finland, Germany, Ireland, Italy, Poland, Slovakia, Spain and the United Kingdom .

The impact of deep renovation at the building stock level depends on the specifics of the national building stock. A review of national reports shows that the energy performance of existing buildings varies between countries, and the impact of deep renovation could be much higher in countries with the poor quality of existing buildings.

The cost-optimal level of energy performance expressed as a numeric indicator of primary energy in kWh/(m².a) is not directly comparable between countries due to the following main differences:

- Reference building geometry (size, floor height)
- Calculation methodology (compliance with the EPBD Annex I, calculation step)
- Services included (only EPBD, also non-EPBD)
- Indoor set-point temperature (varies from 17 °C ÷ 21 °C)
- Type of primary energy (total, non-renewable, renewable)
- Primary energy factors (differs for the same carrier e.g. for electricity)
- Balance of energy use and energy production (export of PV electricity or only auto-consumption is counted)

The differences in the national typical existing office buildings defined by the Member States are presented in Figure 4. Table 2 shows the variability of important parameters derived from EU countries' 2013 reports [22] that influence the numerical indicator.

Due to these differences only the properties of components for existing buildings and for a cost-optimal level were taken over and applied to ALDREN model buildings for setting and testing the reference values for benchmark on the scale.

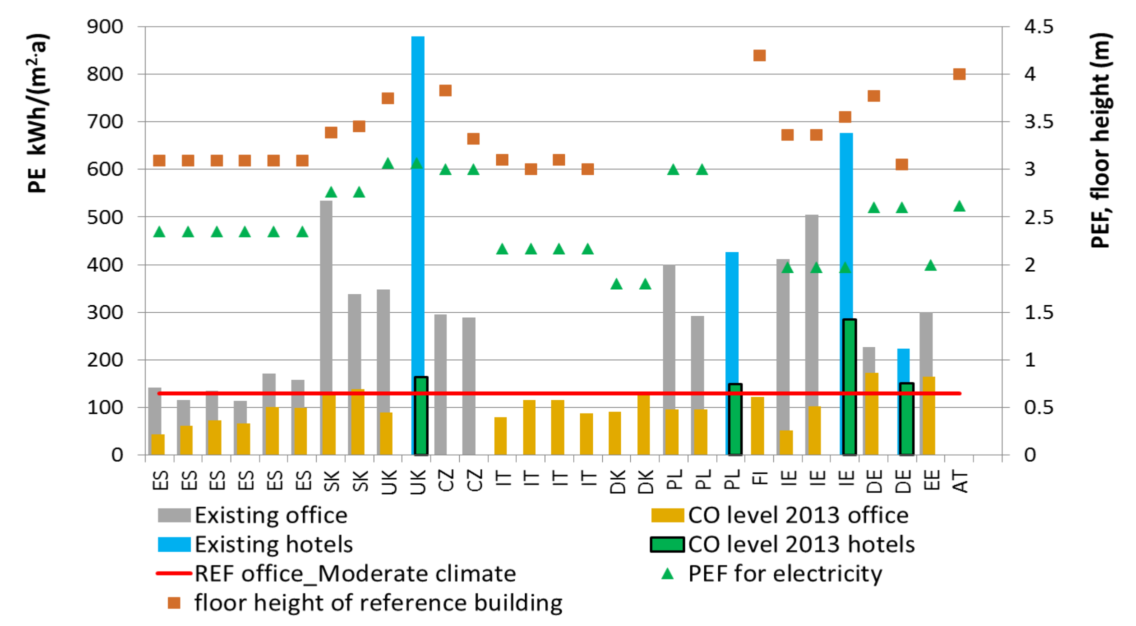


Figure 4 Review of EU countries' 2013 cost-optimal reports

Table 2 Typical existing buildings from EU countries' 2013 cost-optimal reports [22]

Parameter	**Category**	**Min**	**Max**	**Average[1]**
Floor area (m²)	Office building	283	13 360	2 806
	Hotels	1903	15 200	5 522
Floor height of reference building (m)	Office building	3.00	4.20	3.34
	Hotels	3.55	3.55	3.55
Shape factor S/V (1/m)		0.16	0.60	0.38
Heating degree-days HDD (K.day)		400	4 270	2 960
Cooling degree-days CDD (K.day)		26	637	281
Internal temperature for heating (°C)		17	21	20
Internal temperature for cooling (°C)		25	26	26
PEF for electricity (-)		1.80	3.07	2.44
Primary energy (kWh/(m².a)) Office buildings	Existing	**113**	**535**	**281**
	CO (2013)	43	172	101
Primary energy (kWh/(m².a)) Hotels	Existing	**223**	**880**	**552**
	CO (2013)	149	284	186

[1] Average of available data and selected countries

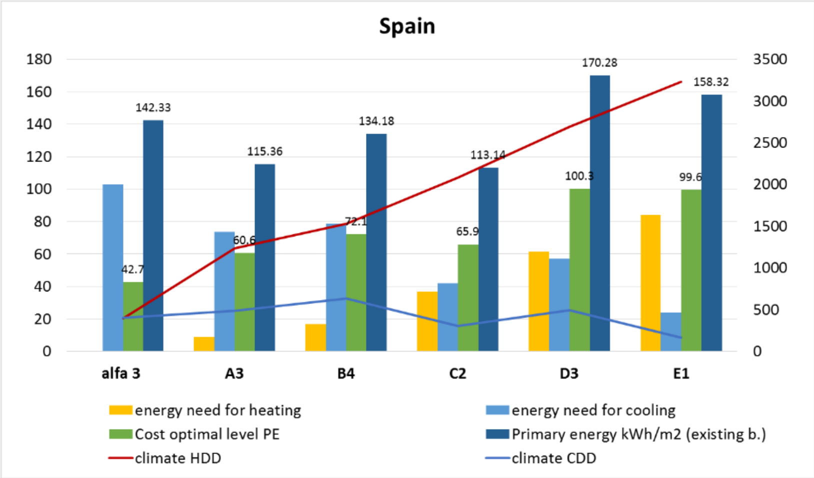


Figure 5 Example of cost-optimal level of energy performance for office buildings in Spain [22]

3.3 Numerical indicators of energy performance and targets

Article 2.4 of the EPBD [2] states that "energy performance of a building means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting."

Article 9, 3a) of the EPBD requires the national plans for NZEB to include, inter alia, Member State's detailed application in practice of the NZEB definition including a numerical indicator of primary energy use expressed in kWh/m^2 per year.

The JRC [21] has identified some points in these definitions that need clarification in terms of effective and uniform policy implementation (e.g. boundary, energy uses, balance, renewables). An open issue is related to the target expressed as a numerical indicator of primary energy use in kWh/(m^2.a), as required by Annex I of the EPBD [2].

Member States have the flexibility to define the type of primary energy (total, non-renewable) and the time step for calculation of primary energy and compensation by renewable energy production. Example of metrics used is in Figure 6.

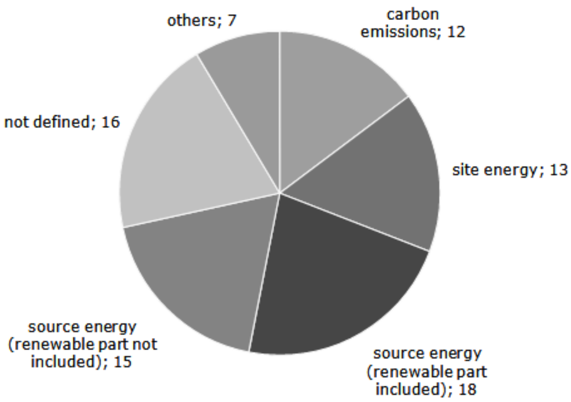


Figure 5. Overview on chosen metrics of the known 75 international balance methodologies. In some cases more than one metric is considered. Source University of Wuppertal

Figure 6 Alternatives in balance methodologies Source: Hermelink et al. [27]

All the different numerical indicators of primary energy use expressed in kWh/m^2 per year for the same ALDREN model building presented in the Figure 7 fulfil the definition of indicator for the NZEB in the EPBD [2]. It is up to decision by Member State, which is taken as an energy performance indicator.

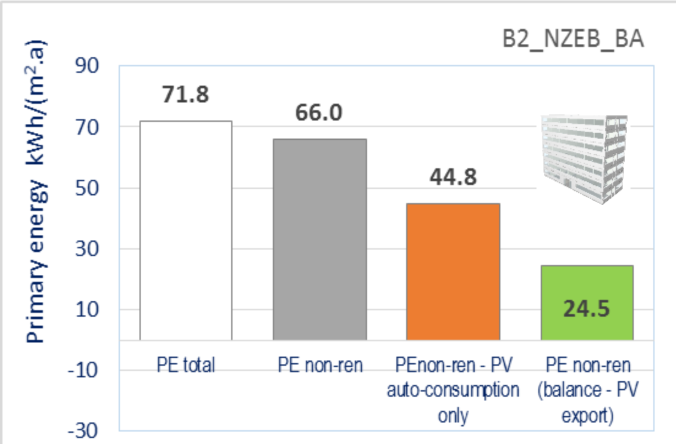


Figure 7 Alternatives of numeric indicator of primary energy use expressed in kWh/m2 per year for the same building

The definition of NZEB in Article 2.2 of the EPBD says "... the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced **on-site or nearby**".

Article 2.6 of the EPBD defines 'energy from renewable sources', which means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases;

The specification of on-site or nearby and off-site renewable energy sources is needed for calculation of ratio of renewable sources.

EN ISO 52000-1:2017 [7] defines **nearby** the building site as the local or district level (e.g., district heating or cooling). **On-site** means the premises and the parcel of land on which the building(s) is located, and the building itself, with a strong link between the energy source and the specific building. **Distant** to the building site is defined as neither on-site nor nearby.

Practical implementation of system boundary for RES considered in building's assessment are described by Hermelink et al. in [27]:

- on-site renewables: PV on roofs of parking lots,
- nearby renewables: systems close-by financed by owner or user,
- off-site renewables: biomass, purchased green power from power contracts or wind turbines, fossil and biomass by CHPPs, imported or exported heat and cold.

Hermelink et al. [27] describe different approaches to the system boundary for RES by certification schemes and consideration in calculation:

"**Minergie-A** only allows production of renewable energy by systems that are installed on or in the building itself. In implementing this may lead either to a combination of solar thermal collectors with wood boilers (plus PV for any other compensation) or to all-electric houses with a heat pump and PV".

The EPC standard from the Netherlands contains district heating, PV, wind turbines within a range of 10 km, if they are financed by the project owner.

The approach of the Plusenergiesiedlung in Freiburg ("Plusenergiehaus©") enables the balance on the settlement level (row houses with a positive energy balance compensate buildings with a negative balance).

The Norwegian "Powerhouse accounts exported energy only if it has at least the same quality (=exergy) of energy delivered to the building. That means exported heat can only balance imported heat, but not contribute to balance electricity. Electricity export, instead, can balance all other carriers.

In the "EffizienzhausPlus" (formerly "Plus-Energie-Haus-Standard") definition of The Federal Ministry of Transport, Building and Urban Development in Germany, the site on which the house is built must be recognized as a balance boundary. In extension to the balance boundary of EnEV (immediate spatial context of the building), the sum of the generated energy from renewable sources on site of the evaluated building is creditable ("on-site generation").

The Austrian definition of "Plusenergiehaus" from the research programme "Haus der Zukunft plus" defines that the yearly primary energy demand has to be below on-site energy production from renewable sources where on-site production means production within the system boundaries of the house in the "immediate vicinity".

Commission Recommendation (EU) 2016/1318 [6] on guidelines for the promotion of nearly zero-energy buildings refers to the EPBD definition of the **energy performance** as '…the amount of energy needed to meet the energy demand associated with a typical use of the building which includes, inter alia, energy used for heating, cooling, ventilation, domestic hot water and lighting'. Recommendation [6] refers to Commission Delegated Regulation (EU) No 244/2012 [4] and its accompanying guidelines [5] on how to calculate the energy performance of a building.

Stakeholders (i.e. financial institutions, building owners) need to have confidence in the results of the EVC in order to reduce the risks of investments related to the energy efficiency of buildings while there are many uncertainties in current approaches.

The aim of ALDREN project is to increase the transparency, comparability and reliability of energy performance assessment in the EU non-residential real estate market through clear indicators based on a new set of EPB standards, hourly calculation step and the climate of the building location.

The ALDREN indicators will also follow the indicators proposed for the EVCS presented to stakeholders during the 1st VCS workshop (2016-01-14) in the frame of the study **"**Enabling the European Common Voluntary Certification scheme (VCS) for non-residential buildings" (Service contract No.. ENER/C3/2015-545/SID.710527). The proposed indicators were: building energy needs, total primary energy, non-renewable primary energy balance taking into account exported energy, CO_2 metric. It was recommended that the indicator with the compensation allowed only within the same time step is needed in order to favour auto-consumption and energy storage of produced PV electricity. Additional indicators are informative to identify the partial performance.

3.4 Consultation with existing voluntary certification schemes

Market study by Triple E Consulting [20] recommends for market uptake of the EU voluntary certification scheme "a modular scheme addressing energy first and complemented by other modules on different sustainability issues later on, or to combine these modules with existing schemes, thereby allowing existing scheme operators to use part of the new EU voluntary scheme. Uptake would be increased if it was integrated into existing schemes or if it replaces other mandatory schemes".

The questionnaire has been developed on the indicators used, which was sent to existing voluntary certification schemes with responses received from DGNB, IVE BES and HQE. The indicators used in the existing schemes and their content and assessment boundaries were investigated, also in personal exchanges.

The main objective of the questionnaire is to find common features between the EVC and existing voluntary certification schemes and potentially adapt ALDREN indicators. This could facilitate the integration of ALDREN´s energy module into an existing certification scheme e.g. by using the ALDREN´s energy module at the international level instead of national mandatory energy performance certificates.

The questions were structured as far as possible in line with the templates in Annex A to EN ISO 52000-1 [7]. The description of choices for the ALDREN calculation methodology was provided in the first column.

The most important questions and proposal for adaptation of ALDREN indicators to existing voluntary certification schemes are presented in Table 3.

Table 3 Description of calculation of indicators based on Annex A to EN ISO 52000-1 and proposal for adaptation of ALDREN methodology to existing voluntary certification schemes (VCS)

	Question	**Certification Scheme**				Decision / adaptation of ***ALDREN EVC indicators***
		ALDREN EVC	**VCS 1**	**VCS 2**	**VCS 3**	
2	***Principle and procedure to be implemented for the presence of the systems if system is not present (Tab. B.19)***					
	Principle "Assumed system" (default system calculated in case of not present system if conditioning is needed (e.g. building without cooling but needing cooling)	yes	no	no	no	Principle "Presence of system" with additional information about thermal comfort (T-score) reported with EP added in EVC first page
	Principle "Presence of system" (calculation of system only in case of presence of system). This can cause better rating but lower thermal comfort.	no	yes	yes	yes	
	Change of reference value (benchmark, scale) in case of no systeme presence	no	Yes Reference building	no	no	
5	***Type of metric for the building size - reference floor area (Tab. B.21):***					
	Gross floor area (from external dimensions)	no		no	no	Net internal floor area (NIA) has been added as information in EVC
	Total internal floor area gross floor area with excluded external walls = GIA - RICS definition of gross internal floor area)	yes	no	yes	yes	
	Net floor area (internal dimensions without walls, all conditioned or partly conditioned spaces included)	no	yes	yes	yes	
	Net useful floor area (internal dimensions without walls, only useful spaces are included, e.g. only offices without staircases, corridors, ...)	no	no	yes	no	
6	***Services included in the main energy performance indicator (Tab. B.18)***					
	Heating	yes	yes	yes	yes	In some schemes the Auxiliary energy is reported separately
	Domestic hot water preparation	yes	yes	yes	yes	
	Cooling	yes	yes	yes	yes	
	Mechanical ventilation	yes	yes	yes	yes	
	Humidification	yes	yes	yes	yes	
	Dehumidification	yes	yes	yes	yes	
	Lighting	yes	yes	yes	yes	
	Auxiliary energy	yes	yes	no	yes	
	Embodied energy	no	yes	no	yes	
	Transport (lifts, escalators)	no	no	yes	yes	
	External lighting	no	no	no	yes	
	Appliances	no	no	yes	yes	
9	***Renewable energy taken into account for indicator of energy performance - perimeter choice (Tab. B.24)***					
	On-site produced renewable energy	yes	yes	yes	yes	
	Nearby produced renewable energy (e.g. local district heating)	yes	yes	yes	yes	
	Distant - including off-site (e.g. renewable in primary energy factor for electricity)	yes	no	yes	yes	
10	***Renewable energy production - export, connection to grid (Tab. B.17 — k_{exp}-factor)***					
	Full export of produced renewable energy and not used in building is counted in balance	yes	no	no	yes	Two indicators are reported:

	Counted temporary exported energy and used in different time only up to level of building energy use.	no	Yes (only up to auxiliary)	no	no	PEnren with export PEneren with auto-consumption of produced PV electricity
	Exported energy is not included in balance. Only produced energy from RES and consumed in building in the same calculation step (e.g. hour) is taken into account (auto-consumption). Electricity storage system is needed to take into account not consumed energy in the same calculation step	no	no	no	yes	
15	***Verification of energy performance after construction***					
	Required obligatory	no		no	no	Optional page in EVC for corrected measured energy
	Optional	yes		yes	yes	
	Other, please specify		Existing is monitored			
16	***Primary energy factors for calculation of primary energy use for the main indicator in different countries (energy carrier delivered from distant) (Tab. B.16)***					
	The same primary energy factors are used for all countries	yes	no	no	no	The calculation of PEF for each country based on the Eurostat Energy balance sheets DATA [26] is an option. PEFs from EN ISO 52000-1:2017 were used for the scale testing and for pilot buildings.
	Electricity	2.3	National (included in ref. building)	no	2.58	
	Natural gas / fossil fuels	1.1		no	1	
	Bio fuels, solid	0.2		no	0	
	Solar energy , Wind, geo, aero, hydro	0		no	0	
	District heating	0.7-1.3		no		
	The national primary energy factors are used (e.g. official for mandatory energy performance certificates)	no	yes	yes	yes	
	Different primary energy factors are used per country but are not the same as the official national primary energy factors.	no	no	no	no	
18	***Building use (occupancy, operation schedule) for calculation of energy performance (Tab. B.2)***					
	The standard use of buildings defined by our certification scheme	yes	no	no	no	Task T2.3 provides protocol for EP assessment for real use.
	The real use of buildings based on design	no	no	no	yes	
	The real use of buildings based on measurements	no	no	no	yes	
	National standard use patterns (e.g. used for mandatory EPC)	yes	yes	yes	no	
19	***Climate for calculation of energy performance***					
	Climate of building location	yes	no	yes	yes	
	National standard climate (for mandatory EPC)	no	yes	yes	yes	
20	***Would it be possible to take over the energy performance from ALDREN in your certification scheme for some cases (e.g. at the international level, for renovated buildings without dynamic simulation available)?***		yes	*Yes, as an option*	*Partly, under some conditions*	

The BREEAM voluntary certification scheme is using an indicator composed of 3 values: energy need (heating and cooling demand), total primary energy, CO_2 emissions.

An important answer from existing certification schemes DGNB, IVE BES and HQE is that it would be possible to take over the energy performance from ALDREN in full, partly or under some conditions.

3.5 Energy performance targets towards NZEB

The NZEB level is the main goal of ALDREN renovation strategies. The NZEB level on the scale has to be close to the national or EU definition of NZEB.

Offices have a clear standard use, which varies slightly according to the tradition of using buildings across the EU. The energy performance targets for office buildings are well described in national regulations and were taken into account in the inputs to the calculation of model buildings for testing the ALDREN scale and targets.

The Commission Recommendation (EU) 2016/1318 on guidelines for the promotion of nearly zero-energy buildings [6] provides a recommendation for numerical indicators for definition of NZEB for 4 climates according to the study by Ecofys [27]:

- Mediterranean as Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo)
- Continental as Zone 3: Budapest (others: Bratislava, Ljubljana, Milan, Vienna)
- Oceanic as Zone 4: Paris (others: Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Macon, Nancy, Prague, Warszawa)
- Nordic as Zone 5: Stockholm (Helsinki, Riga, Gdansk, Tovarene).

The Commission recommendation [6] provides the general principles and factors that Member States are encouraged to take into account when drawing up the definition of NZEB to be applied at national level in line with the EPBD [2]. It says that there can be no uniform level of ambition for NZEB across the EU. Flexibility is needed to take into account the impact of climatic conditions on heating and cooling needs and on the cost-effectiveness of packages for energy efficiency and renewable energy sources measures.

The terms ‘nearly zero’ or ‘very low amount’ of energy introduced by the EPBD indicate the scope and limits of the discretion of Member States. NZEB definitions should aim at a nearly neutral energy balance [6].

Recommendation underlines, with the reference to the new set of EPB standards developed under the Commission's mandate M/480 to CEN, that setting numerical benchmarks for NZEB primary energy indicators, at EU level, is most useful when the values to be compared result from transparent calculation methodologies.

Today, there are differences between national calculation methodologies and some technical systems are not fully taken into account [35].

The Recommendation emphasizes the fact that **energy need** is the starting point for the calculation of primary energy, and therefore a very low level of energy need for heating and cooling is an essential condition for nearly zero primary energy buildings. Very low energy needs are also a precondition for achieving a significant share of energy from renewable energy sources and nearly zero primary energy.

The recommended values for energy performance of the NZEB are given in Section 4.1 in the ranges for the different EU climate zones reported in Table 4. Values in kWh/(m^2.a) are expressed for useful floor area.

Table 4 Numerical indicators in Commission recommendation [6] for the NZEB definition

Climate	Commission recommendation (EU) 2016/1318 [6]			Average Net non-renewable primary energy use kWh/(m^2.a)
	Net non-renewable primary energy use kWh/(m^2.a)	On-site renewable sources kWh/(m^2.a)	Total primary energy use kWh/(m^2.a)	
Mediterranean	20-30	60	80-90	**25.0**
Oceanic	40-55	45	85-100	**47.5**
Continental	40-55	45	85-100	**47.5**
Nordic	55-70	30	85-100	**62.5**

The EPB standard EN ISO 52000-1 [7] does not recommends in Annex H “Proposal of indicators for the assessment of Nearly Zero-Energy Buildings (NZEB)” to use only one requirement for NZEB definition, e.g. the numerical indicator of primary energy.

The Ecofys study [27] also recommends not to take primary energy as the only basis for setting benchmarks for nearly zero-energy buildings, and strongly recommends always adding energy need for heating, cooling and domestic hot water preparation as well as the energy use for lighting.

Based on the cost-optimality calculation in 2013, Ecofys [27] recommends following ranges of values for energy needs (the sum of heating and cooling) for offices the different climate zones (new buildings, financial perspective):

- Zone 1: 15-45 kWh/(m^2.a)
- Zone 3: 15-45 kWh/(m^2.a)
- Zone 4: 30-45 kWh/(m^2.a)
- Zone 5: 15-30 kWh/(m^2.a)

According to the Ecofys study [27], energy needs in non-residential buildings are strongly affected by the availability of daylight at a certain latitude. The Norwegian standard NS 3071:2012 “Criteria for passive houses and low energy buildings. Non-residential buildings” sets a maximum value of 12,5 kWh/(m^2.a) for energy use for lighting. A range between 6 and 10 kWh/(m^2.a) is considered adequate for zones with higher daylight availability.

Based on these sources and taking into account the currently available technologies and the evolution of the prices of innovative solutions, the energy needs for heating, cooling and lighting reported in Table 5 can be used for ALDREN NZEB as a reference related to building envelope and geometry. Energy needs for lighting mean the energy use that takes into account the requirements and available daylight.

Table 5 Energy needs related to building fabrics and geometry proposed for benchmark as a reference target for ALDREN NZEB level for offices

ALDREN climate zone	Energy needs in kWh/(m^2.a) for GIA floor area		
	Heating and cooling	Lighting	Proposal for target value for ALDREN NZEB for offices
South	30	8	38
Moderate	30	10	40
Cold/Nordic	30	12	42

Hotels

Hotels are complex buildings with many different scenarios of potential use depending on the operation (annual, seasonal), climate and hotel category.

The challenge for hotels is how to define a “typical building use” for calculation of energy performance and benchmarks as asked by the EPBD.

The neZEH initiative [30] identified 4 main categories according to the geographical area in which the hotel is located:

- Urban;
- Rural: rural side areas, available in all climate zones;
- Coastal: hotels on see shores, available in all climate zones;
- Mountain: hotels in the mountains, available in all climate zones, due to the high altitude this is a category, where the cold climatic aspects can be taken into account.

Moreover, the neZEH initiative [31] identified 4 types of hotels according to customer needs and the main characteristics of hotels activities:

- Business hotels;
- Spa/ Wellness hotels;
- Resort hotels;
- Hotels B&B.

According to Buso et al [39] the available consistent national NZEB definitions allow to set benchmark values for nearly zero hotels in four climate zones presented in Figure 8. However, a comparison with existing buildings has shown that the real primary energy consumption of existing hotels is on average by factor 4 higher compared to the neZEH benchmark values.

Table 5. Summary of the requirements for nearly zero energy hotels in Europe.

Zone	EP [kWh/m²·a]	Energy uses	RES [%]
Zone 1	55	Heating, cooling, domestic hot water, HVAC aux, lighting	50
Zone 2	60		35
Zone 3	95		35
Zone 4	115		25

Figure 8 Recommended values for NZEB hotels by the neZEH initiative
(Source: Rehva article jan/2014 [40])

The zones considered are: Zone 1 (Mediterranean Europe), Zone 2 (Eastern Central Europe), Zone 3 (Western Central Europe) and Zone 4 (Northern Europe).

In France, the basic numerical indicator for definition of NZEB hotel building is 100 kWh/(m^2.a) for night part and 150 kWh/(m^2.a) for day part that is 1.43 times more (night part) or 2.14 times more than for offices (70 kWh/(m^2.a)) [29].

In Croatia, the numerical indicator for definition of NZEB hotel is 90 kWh/(m^2.a) for inland and 70 kWh/(m^2.a) for costal hotels. It is 2.57 times more than for inland offices (35 kWh/(m^2.a)) and 2.8 times more than for costal offices (25 kWh/(m^2.a)) [29].

The numerical indicator expressed in non-renewable primary energy use for the definition of NZEB hotels in Slovakia [18] is 82 kWh/(m^2.a) that is 1.34 times more than in the case of offices (61 kWh/(m^2.a)). The energy uses for definition of NZEB are:

Heating:	Offices = 28 kWh/(m^2.a)	Hotels = 36 kWh/(m^2.a)
Lighting:	Offices = 15 kWh/(m^2.a)	Hotels = 12 kWh/(m^2.a)
DHW:	Offices = 4 kWh/(m^2.a)	Hotels = 32 kWh/(m^2.a)
Cooling, ventilation:	Offices = 16 kWh/(m^2.a)	Hotels = 14 kWh/(m^2.a)

The neZEH Nearly Zero Energy Hotels initiative [32] identified problems with benchmark of hotel buildings expressed in their position paper as follows:

The national NZEB definitions do not sufficiently recognize the specificities of the accommodation industry. They should focus on the specific building characteristics, typical uses and operating models, as hotels cannot be considered as typical non-residential buildings….

The specificities of the type o hotel building will be taken into account when developing methodologies for calculating energy performance and defining numerical values.

Occupancy rates cannot be standardised for the different types of hotels identified by neZEH initiative and there are some specific technologies (e.g. control systems for unoccupied rooms), that could lead to improvement of energy performance in hotels, but they are taken into account in calculation is not clear.

According to Buso [39] all the referenced studies show that the actual energy use in hotels is deeply affected by hotel size and age, category, number of rooms, occupancy, opening period, customers' profiles, location, climate zone, as well as services and guests' activities. A statistical overview of energy consumption indicators in 184 Hilton and Scandic hotels shows a big difference in total energy use (from 129.3 to 859.2 for Hilton and from 123.7 to 567.2 for Scandic), based on data source (P. Bohdanowicz & Martinac 2007).

Experience with numerical indicators and potential for reduction of primary energy use in hotels from neZEH project are given in Figure 9.

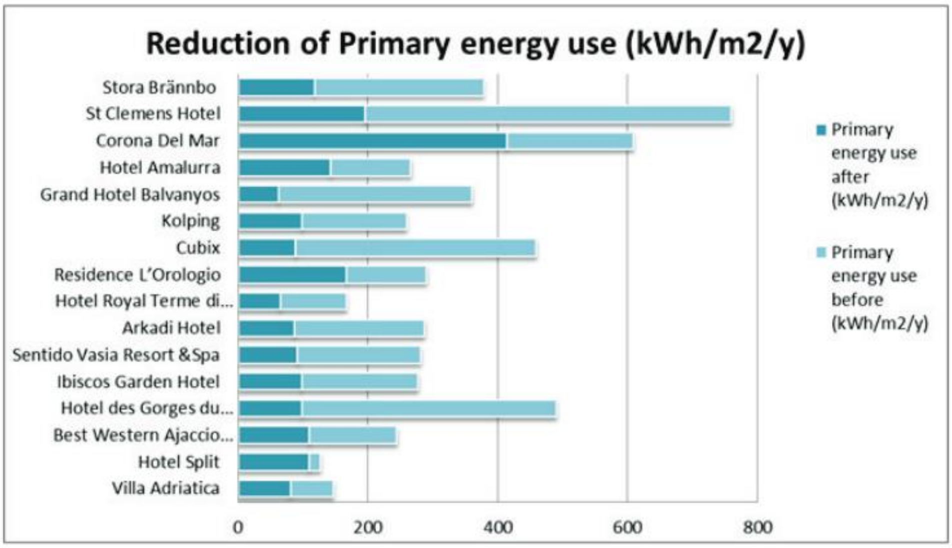


Diagram 1 Reduction of primary energy use in each neZEH pilot hotel after the renovation

Figure 9 Results from neZEH project [30]

3.6 Typical technologies and solutions for existing buildings and NZEB

According to the EPBD definition of NZEB, the renewable energy sources play an important role in the NZEB concept, starting with the principle of energy efficiency first. The definition of NZEB should take into account that not all RESs are feasible or cost-effective in all climates and for all building categories. Ecofys [27] provides a summary of the distribution of different renewable energy technologies in different climates in Europe (Figure 10).

Table 2. Summary of the distribution of different renewable energy technologies in Europe

Renewable Energy Technologies	Northern Europe	Eastern Europe	Western Europe	Southern Europe
Solar Thermal Systems	Need for more sophisticated systems. Higher abatement costs than in moderate climates. Small market size.	Installed systems present low capacity. The market is underdeveloped.	The installed systems present high capacity. The market is large and well developed.	Great potential due to high radiation levels; most suitable for less sophisticated Solar Domestic Hot Water preparation (SDHW); and high efficiency compact low-cost thermal storage systems. Large still growing market.
Photovoltaic Systems	Actually still low efficiency and high costs due to low radiation levels. Small market size.	The market is underdeveloped.	The systems have a high efficiency. The market is large and well developed.	Great potential due to high radiation levels and short payback times. Medium size, still growing market.
Heat Pumps	Due to cold climate, lower system efficiency. However, systems have a very good market penetration	Main challenge for increasing use: difficult license procedures. However: growing market.	Mainly used in heating mode, air conditioning rarely required. The market is large and it is still growing.	Reversible systems are economically attractive in this climate. Combisystems have the biggest potential for market growth. Medium size still growing market.
Biomass and Pellets	Main producers and consumers in Europe. Large market size, has been well developed in recent years and is still growing	The market is in an initial development stage.	The market is large, well developed and it is still growing.	Scarce raw materials; buildings just have a relatively low heat demand due to the warm climate. Still quite small market but with considerable growing potential. In areas with low air movement, particulate emissions by direct burning may cause limitations.

Figure 10 The summary of the distribution of different renewable energy technologies in Europe (Source Ecofys Towards NZEB [27])

Questionnaires on typical solutions

The Questionnaire was completed by consortium partners (Slovakia, France, Spain) on typical technologies in their country installed in old existing buildings and on the best technologies available and marketed for renovation solutions leading to NZEB level specifically for offices and hotels.

Some comparisons based on the questionnaire are shown in Figure 11 and Tables 6 and 7 below.

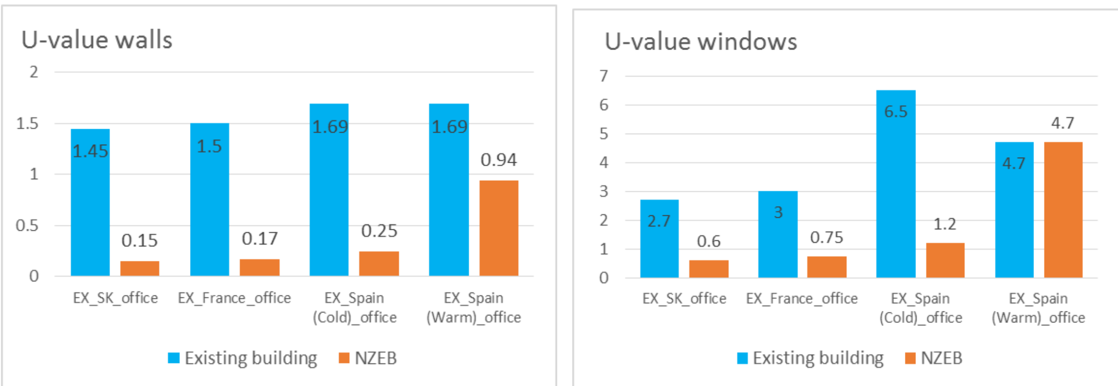


Figure 11 Typical U-values for existing buildings and NZEB requirement

Table 6 Typical solutions for heating systems in Slovakia, France, and Spain for office buildings

System	Existing buildings				NZEB			
	SK	FR	**Spain (Cold)**	**Spain (Warm)**	SK	FR	**Spain (Cold)**	**Spain (Warm)**
Heating systems								
Type of emission system	radiators	radiators, electric heaters	radiators, electric heaters	radiators, electric heaters	air-conditioning	air-conditioning, fan coils	air-conditioning, fan coils, low temperature emissor	air-conditioning, fan coils, low temperature emissor
Type of distribution network	insulated	not insulated tubes	not insulated tubes	not insulated tubes	insulated	insulated	insulated	insulated
Heating + hot water preparation?	yes	no	no	no	yes	yes	yes	yes
Type of heat generator	standard gas boiler	standard gas boiler, electric heaters	standard gas boiler, electric heaters	standard gas boiler, electric heaters	heat pump	heat pump, district heating system	heat pump, district heating system	heat pump, district heating system
RES	no	no	no	no	yes	yes	yes	yes
Fuel type, energy carrier	gas	gas, electricity	electricity, gas oil	electricity, gas oil	gas, electricity	electricity, district heating sources	electricity, district heating sources	electricity, district heating sources

Table 7 Typical solutions for cooling systems in Slovakia, France, and Spain

System	Existing buildings				NZEB			
	SK	FR	**Spain (Cold)**	**Spain (Warm)**	SK	FR	**Spain (Cold)**	**Spain (Warm)**
Cooling systems								
Type of emission system	no cooling, or air-conditioning diffusers	no cooling or air conditioning diffusers	air conditioning independent units or centralized service	air conditioning independent units or centralized service	VRV system, multi-split type air conditioner, fan coils	air-conditioning diffusers, fan coils, underfloor cooling system	air-conditioning diffusers, fan coils, underfloor cooling system	air-conditioning diffusers, fan coils, underfloor cooling system
Type of distribution system	no or by air - low pressure air-conditioning, non-insulated tubes	no cooling, direct air emission	no cooling, direct air emission	no cooling, direct air emission	central air-conditioning, insulated tubes under ceiling	central air-conditioning, insulated tubes under ceiling	central air-conditioning, insulated tubes under ceiling	central air-conditioning, insulated tubes under ceiling
Type of cold generator	no or local systems for individual rooms	no cooling or electric air conditioners	electric air condition units	electric air condition units	heat pump, central compressor	heat pump, central compressor, district cooling	heat pump, central compressor, district cooling	heat pump, central compressor, district cooling
RES	no	no	no	no	yes	yes/no	yes/no	yes/no

4 PROTOCOL FOR ALDREN EUROPEAN VOLUNTARY CERTIFICATE

4 Protocol for ALDREN European Voluntary Certificate

The aim of this section is to provide a protocol for step-by-step procedure for rating the energy performance of building from data collection to issuance of a European Voluntary Certificate (EVC) based on the ALDREN methodology described in this report and its Annexes.

The stages from decision making, design and construction work to the final stage after building renovation are identified and it is highlighted when the calculation of energy performance and issue EVC is recommended.

The proposed procedures are also based on experience from the pilot phase and consultation with stakeholders.

4.1 Input Data collection

The initial phase in ALDREN Task 2.2 procedures is data collection. The recommended procedures refer to the steps and checklist recommended in EN 16247-2:2014 Energy audits – Part 2: Buildings.

Energy audit is one of the important sources of information on specific building, if they are available. For a correct analysis of an existing building, the main input parameters should not only be collected but, consequently evaluated.

Data collection is an important first step in the energy audit process, as described in Annex A in EN 16247-2 [20]. It is an integral part of a loop covering the steps in Table 8, which are recommended to be applied in a similar way applied to energy performance certification.

Table 8 Input data collection according to EN 16247-2 – Annex A [16]

Step	Description
Initial data collection	✓ request for expected/needed data, ✓ review of the available data, ✓ preliminary data analysis,
Fieldwork (on-site visit/inspection)	✓ comparison of available data to the on-site situation, ✓ evaluation of individual building technical services, ✓ technical state of the building constructions and technical systems and evaluation of their performance, (e.g. building defect, moulds, …) ✓ identification of the data gaps and differences between planned/designed/as-built/operational state of the building and its technical systems, ✓ definition of potential energy efficiency improvement opportunities and related constraints and restrictions)
Analysis	✓ evaluation of energy saving potential, ✓ definition of proposed technical and economically feasible measures/interventions ✓ their interactions and impact

4.2 Steps towards energy rating and ALDREN European Voluntary Certificate – protocol for ALDREN methodology

In the whole process of building renovation four time points are important to ensure the final quality of the renovation design and the quality of implementation during construction works.

When the procedures for ALDREN energy performance and rating should be applied in the different stages of the renovation works are presented in Figure 12.

Besides issuing EVC before renovation (Stage 2) and after renovation (Stage 5), also the consultancy during a detailed design development, including the calculation for design solution (Stage 3), and consultancy during the construction works (Stage 4) are important for the final quality of renovation.

This is based on practical experience, because it is too late to calculate energy performance after renovation (nothing can be changed). Changes may be needed in designed technologies and elements during construction works, especially for large non-residential buildings, where the process from design to construction can take several years and the available technologies will change intime. All changes during the renovation works should be consulted with an ALDREN consultant.

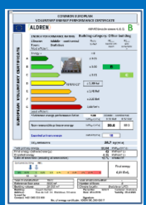
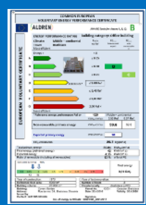
Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Decision (Set requirements)	**Develop design**	**Detailed Design**	**Works**	**In use** (After renovation)
BUILDING				
in use before renovation	in use before renovation	in use before renovation	Under construction / renovation (in-use or empty)	in use after renovation
ALDREN ACTION / TASK T2.2				
	✓ **Calculation of EP - before renovation**	✓ **Calculation of EP for designed solution**	✓ **Supervision of construction works and consultancy on changes needed (recalculation)**	✓ **Calculation of EP after renovation**
ALDREN OUTCOME				
	✓ **EVC before renovation** 	✓ **Design rating** - predicted EP and energy class for designed solution **- part of design documentation**	✓ **Supervision of construction works → quality of final result assurance**	✓ **EVC after renovation** 

Figure 12 Procedures for ALDREN energy performance and rating in different stages of renovation works

The proposed ALDREN methodology for energy rating and European Voluntary Certificate has ambition to be:

Consistent, codified	Realistic	Clear	International	Reliable
Link to existing European standards, and Regulations where possible	Close to the real EP (local climate, national use patterns)	Simple, close to daily work of energy consultants, designers, experts	Performed by international expert at EU level able to work with European standards	Unambiguous result, clear inputs and choices

The overall methodology of the energy performance rating protocol is described step by step in Table 9.

The following symbols are used in column "ALDREN":

✓ ALDREN methodology (new methodology proposed by ALDREN)

☐ Empty cell means that the general procedures should be used by expert (out of scope of ALDREN) either based on daily practice of expert or defined in other sources, e.g. standard data collection, EP calculation using CEN standards, etc.

Table 9 Protocol with steps towards ALDREN energy rating and Energy Performance Certificate

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Building context and general information			
Building type		**Step 1** **Building type** according to permit for use / current use / intended use. Current operation and use	• Information from owner • On-site measurements
Location / Climate		**Step 2** **Location of building** *Example:* **Helsinki (HEL)**  60.1699° N, 24.9384° E	• Latitude, longitude, altitude
Typical meteorological year (TMY) for EP calculation	✓	**Step 3** Selection of the nearest TMY for hourly energy calculation using JRC TMY Generator based on the latitude and longitude (Step 2) The typology, altitude, orography has to be taken into account when selecting the nearest building location. The datasets are in formats directly usable with the main building simulation software (e.g. EnergyPlus, TRNSYS, IDA-ICE). The JRC TMY Generator produces TMY that takes into account also altitude. https://e3p.jrc.ec.europa.eu/articles/typical-meteorological-year-tmy	• JRC TMY Generator reference year - find nearest location from available https://re.jrc.ec.europa.eu/pvg_tools/en/#TMY
Climate zone for setting the reference on	✓	**Step 4** **Heating degree-days (HDD) calculation** - Identify the external temperature in hourly step (8760 h) in reference year used for calculation	• **ALDREN methodology** Eurostat: HDD and

<table>
<tr><th>Subject</th><th>ALDREN</th><th>Steps / actions / explanation / examples</th><th>Source of data / information</th></tr>
<tr><td>the scale</td><td>✓</td><td>(TMY) / or results from calculation
- Calculate HDD applying to the hourly external temperature in TMY used for calculation the rules set by Eurostat (JRC) for mean air temperature of day.
- If $T_m \leq 15°C$ Then [HDD = $\sum_i(18°C - T_{im})$] Else [HDD = 0] where T_{im} is the mean air temperature of day i.

The calculation of HDD relies on the base temperature, defined as the lowest daily mean air temperature not leading to indoor heating. The value of the base temperature depends in principle on several factors associated with the building and the surrounding environment. By using a general climatological approach, the base temperature is set to a constant value of 15°C in the HDD calculation.

Step 5 Allocate building to zone based on HDD (Step 5).
<table>
<tr><th>Zone</th><th></th><th>HDD</th></tr>
<tr><td>Zone 1</td><td>Warm/Mediterranean</td><td>≤ 1200</td></tr>
<tr><td>Zone 2</td><td>Moderate</td><td>1201 - 4000</td></tr>
<tr><td>Zone 3</td><td>Cold/Nordic</td><td>> 4000</td></tr>
</table>

Example (model buildings):
<table>
<tr><th>Town</th><th>HDD from reference year used for calculation of EP ti=18°C, base temperature 15°C – starting heating)</th><th>Zone</th><th>Zone</th></tr>
<tr><td>Palermo</td><td>864 K.day</td><td>Zone 1</td><td>Warm/Mediterranean</td></tr>
<tr><td>Bratislava</td><td>3040 K.day</td><td>Zone 2</td><td>Moderate</td></tr>
<tr><td>Helsinki</td><td>4128 K.day</td><td>Zone 3</td><td>Cold/Nordic</td></tr>
</table>
</td><td>CDD are derived from meteorological observations of air temperature, interpolated to regular grids at 25 km resolution for Europe.

https://ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.htm

To be check on pilots the division to zones</td></tr>
<tr><td>Primary energy conversion factors (PEF)</td><td></td><td>Step 6 Definition of PEF for delivered energy carriers
• Common PEFs based on CEN standards allow
• compare buildings quality
• consistent comparison of systems (biomass, gas, electricity)
• possibility to calculate RER according to CEN standards as all types of PEF are available (for total, non-ren, ren primary energy)
• PEF for district heating can be based on the local value if it is reported by heat producer. Calculation is possible using EN 15316-4-5:2017. The default value 0,7 can be used for CHP if no information is provided by district heat producer.
• Example of values in Table B.16, EN ISO 52000:2017</td><td>• ALDREN methodology
• CEN standard M480 EN ISO 52000-1: 2017, Annex B, Table B.16</td></tr>
</table>

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information

Table B.16 — Weighting factors (based on gross or net calorific value)
(See 7.3.5, 9.5.1, 9.6.2, 9.6.5 and 9.6.6.3)

	Energy carrier		f_{Pnren}	f_{Pren}	f_{Ptot}	K_{CO2e} (g/kW h)
	Delivered from distant					
1	Fossil fuels	Solid	1,1	0	1,1	360
2		Liquid	1,1	0	1,1	290
3		Gaseous	1,1	0	1,1	220
4	Bio fuels	Solid	0,2	1	1,2	40
5		Liquid	0,5	1	1,5	70
6		Gaseous	0,4	1	1,4	100
7	Electricity c)		2,3	0,2	2,5	420
	Delivered from nearby					
8	District heating a)		1,3	0	1,3	260
9	District cooling		1,3	0	1,3	260
	Delivered from on-site					
10	Solar	PV electricity	0	1	1	0
11		Thermal	0	1	1	0
12	Wind		0	1	1	0
13	Environment	Geo-, aero-, hydrothermal	0	1	1	0
	Exported					
14	Electricity b) c)	To the grid	2,3	0,2	2,5	420
15		To non EPB uses	2,3	0,2	2,5	420

a) Default value based on a natural gas boiler. Specific values are calculated according to M3-8.5.

Building data collection (audit and inspection)

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Services included	✓	**Step 7** **Definition of building utilities**: • **Office building** Energy uses: Heating, domestic hot water, cooling, mechanical ventilation, lighting • **Hotel: Hosting functions only** (guests' rooms, reception hall, offices, bar, restaurant, sitting rooms, meeting rooms) Energy uses: Heating, domestic hot water, cooling, mechanical ventilation, lighting, **Not included**: **non-hosting functions** (kitchen, laundry, swimming pool, spa, technical rooms, sauna, gym)	• **ALDREN methodology** • On-site Inspection
Building geometry		**Step 8** **Data collection about geometry**, areas of the thermal envelope, building volume Vb (based on GIA according to Step 9 and total heigh of building based on "overall internal dimensions"), distribution into zones.	• Previous design • Current design • On-site Measurements • E.g. IFC building modelling
Reference floor area	✓	**Step 9** **Reference floor area** (A_b) for energy performance indicator in kWh/(m².a) is a **Gross internal area (GIA),** that means the floor area contained within the building measured to the internal face of the external walls ignoring the internal partitions (using "overall internal dimensions"). **The external walls define the heat exchange envelope** of building so that the reference floor area is coherent with the calculation of the thermal losses. The rules and examples in the International Property Measurement Standards (IPMS) as developed by the International Property Measurement Standards Coalition (IPMSC) for Office buildings, IPMS 2 can be used for specific cases, while the spaces outside the considered thermal envelope for the thermal losses' calculation are excluded (e.g. unheated basement with garage). https://ipmsc.org/standards/office/ [47]	• **ALDREN methodology**, IPMS • Previous or current design documentation • On-site Measurements

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Envelope components		**Step 10 Definition of building envelope** U-value, areas of the thermal envelope Walls, Roof, Ceiling above basement/ground floor, windows -Windows-average g-value of glazing Total energy transmittance (g-value), Correction g-value, Frame reduction factor, Shading factor … Thermal bridges Type of construction: Light, medium, heavy, weight construction, Internal heat capacity See all input data needed in relevant CEN standards M480	• On-site Inspection • Previous design • Current design • Product data • Measurement • Default data in CEN standards M480
Air Tightness, Infiltration rate		**Step 11** Definition of air tightness based on installed products characteristics or infiltration rate obtained by on-site measurements.	• On-site Inspection • Previous design • Current design • Product data • Measurement • Default data CEN standards M480
Energy systems description		**Step 12** Definition of energy systems • Heating • Cooling • Air-conditioning • Ventilation • DHW • Lighting • Other services • Energy production - electricity • Energy production – thermal • Emission and distribution systems • Individual or collective metering • Thermostat types • Smart metering systems See all input data needed in relevant CEN standards M480. **Only installed systems are included in the calculation of energy.**	• On-site Inspection • Previous/current design • Product data (Ecodesign) • Measurement • Default data CEN standards M480
Standard indoor and outdoor conditions			
Building occupancy and use		**Step 13** Set occupancy and uses scenarios depending on building category: Occupancy: • Usage times, daily use (beginning, end of use), daily operating time, days of use, non-usage days Temperature set points for each usage time • Set point temperature - heating • Set back temperature - heating • Set point temperature - cooling • Set back temperature – cooling Internal gains • Energy gains • Humidity inflow	• National input data for EP calculation (standard use) • EN 16798:2018 Scope: This standard specifies occupancy schedules to be used in standard energy calculations.

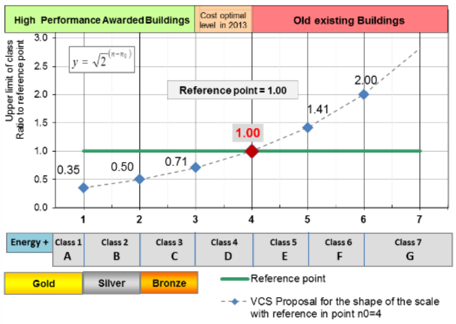
<table>
<tr><th>Subject</th><th>ALDREN</th><th>Steps / actions / explanation / examples</th><th>Source of data / information</th></tr>
<tr><td></td><td></td><td>FprEN 16798-1:2016 (E)

Office, Landscaped
Parameters and set points
<table>
<tr><th></th><th>Parameter</th><th>Value</th><th>Unit</th></tr>
<tr><td>Operation time</td><td>Hour at day, START</td><td>7</td><td>hour</td></tr>
<tr><td></td><td>Hour at day, END</td><td>18</td><td>hour</td></tr>
<tr><td></td><td>Breaks, inside range</td><td>0</td><td>hours</td></tr>
<tr><td></td><td>days/week</td><td>5</td><td>days</td></tr>
<tr><td></td><td>hours/day</td><td>11</td><td>hours</td></tr>
<tr><td></td><td>hours/year</td><td>2868</td><td>hours</td></tr>
<tr><td>Internal gains</td><td>Occupants</td><td>17</td><td>m2/pers</td></tr>
<tr><td></td><td>Occupants (Total)</td><td>7,0</td><td>W/m²</td></tr>
<tr><td></td><td>Occupants (Dry)</td><td>4,7</td><td>W/m²</td></tr>
<tr><td></td><td>Appliances</td><td>12</td><td>W/m²</td></tr>
<tr><td></td><td>Lighting</td><td></td><td></td></tr>
<tr><td></td><td>Moisture production</td><td>3,53</td><td>g/(m2, h)</td></tr>
<tr><td></td><td>CO_2 production</td><td>1,10</td><td>l/(m2, h)</td></tr>
<tr><td>Set points</td><td>Min T,op in unoccupied hours</td><td>16</td><td>°C</td></tr>
<tr><td></td><td>Max T,op in unoccupied hours</td><td>32</td><td>°C</td></tr>
<tr><td></td><td>Min T,op</td><td>20</td><td>°C</td></tr>
<tr><td></td><td>Max T,op</td><td>26</td><td>°C</td></tr>
<tr><td></td><td>Ventilation rate (min.)</td><td>0,8</td><td>l/(s m²)</td></tr>
<tr><td></td><td>Ventilation rate for CO_2 emission</td><td>0,53</td><td>l/(s m²)</td></tr>
<tr><td></td><td>Max CO_2 concentration (above outdoor)</td><td>500</td><td>ppm</td></tr>
<tr><td></td><td>Min. relative humidity</td><td>25</td><td>%</td></tr>
<tr><td></td><td>Max. relative humidity</td><td>60</td><td>%</td></tr>
</table>
Usage schedule
<table>
<tr><th></th><th colspan="6">Energy calculation</th></tr>
<tr><th></th><th colspan="3">Weekdays</th><th colspan="3">Weekends</th></tr>
<tr><th>h</th><th>Occupants</th><th>Appliances</th><th>Lighting</th><th>Occupants</th><th>Appliances</th><th>Lighting</th></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>5</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>6</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>7</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>8</td><td>0,2</td><td>0,2</td><td>0,2</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>9</td><td>0,6</td><td>0,6</td><td>0,6</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>10</td><td>0,6</td><td>0,6</td><td>0,6</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>11</td><td>0,7</td><td>0,7</td><td>0,7</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>12</td><td>0,7</td><td>0,7</td><td>0,7</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>13</td><td>0,4</td><td>0,4</td><td>0,4</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>14</td><td>0,6</td><td>0,6</td><td>0,6</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>15</td><td>0,7</td><td>0,7</td><td>0,7</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>16</td><td>0,7</td><td>0,7</td><td>0,7</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Set point temperatures should be national in limits given by EN 16798-1:2018: indoor temperatures limits (max, min)
• Min T_{op} heating/winter = 20 °C,
• Max T_{op} cooling/summer = 26°C
• Min Top unoccupied = 16 °C
• Max Top unoccupied = 32°C
Hot water needs (national standard use)</td><td>• CEN standards M480 EN ISO 52000-1</td></tr>
<tr><td>Systems operation, controls</td><td></td><td>Step 14 Completing inputs on building system operation with national standard use or standards
• Ventilation rate and operating time
• Infiltration rate
• Lighting operating time
• Heating and cooling seasons</td><td>• National input data for EP calculation (standard use)
• CEN standards M/480</td></tr>
<tr><td>Climate data</td><td></td><td>Step 15 Hourly climate data in the required format depending on software based on CEN standards or other compliant with CEN standards: TMY, see step 3</td><td>• Climate data TMY – see step 3</td></tr>
<tr><th colspan="4">Building Energy Performance Simulation</th></tr>
<tr><td>Modelling of building geometry</td><td></td><td>Step 16 Modelling building geometry in software or dedicated 3D graphic modeller.</td><td>• Step 8-9</td></tr>
<tr><td>Building envelop modelling</td><td></td><td>Step 17 Modelling building envelop components, walls, windows, roof, ceiling characteristics, air tightness, etc.</td><td>• Step 10-11</td></tr>
<tr><td>Building systems modelling</td><td></td><td>Step 18 Modelling building systems features and operation settings.
• Heating
• Cooling
• Air-conditioning
• Ventilation
• DHW
• Lighting
• Other services
• Energy production - electricity
• Energy production – thermal</td><td>• Step 12</td></tr>
<tr><td>Modelling of building indoor and outdoor</td><td></td><td>Step 19 Modelling building systems features and systems operation settings.
• Heating</td><td>• Step 13-14-15</td></tr>
</table>

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
conditions		• Cooling • Air-conditioning • Ventilation	
Outcomes from calculation		**Step 20** Annual final energy use per energy carrier	• software outputs
Energy performance indicators calculation			
Primary energy calculation		**Step 21** **Delivered energy** Per service and per energy carrier Sum per energy carrier	• CEN standards M480 –hourly step • Software tool
		Step 22 **Renewable energy generation** electricity generation by PV panels heat generation by biomass heat generation by heat pumps heat generation by solar **Step 23** electricity generation by wind (small size **turbines)**	• CEN standards M480 – hourly step • Software tool
		Step 24 **Renewable energy auto-consumption** Auto consumed - electricity generated by PV panels Auto consumed - heat generation by biomass Auto consumed - heat generation by heat pumps Auto consumed - heat generation by solar **Step 25** Auto consumed - electricity generation by wind (small size turbines)	• CEN standards M480 – hourly step • Software tool
		Step 26 **Renewable energy export** Export - electricity generation by PV panels Export - heat generation by biomass Export - heat generation by heat pumps **Step 27** Export - heat generation by solar	• CEN standards M480 – hourly step • Software tool
		Step 28 **Main EP indicator** – non-renewable primary energy balance (with export of produced renewable energy counted) **EP indicator** – non-renewable primary energy (only the auto-consumption of energy produced from renewable sources by the building is counted)	• CEN standards M480 – hourly step • Software tool
		Step 29 **Additional indicators** Energy needs (heating, cooling, ventilation, hot water, lighting) Energy needs related to building fabrics and geometry (heating, cooling, lighting) Total primary energy Energy use Exported energy/primary energy CO_2 emission Energy use for space heating Energy use for cooling Energy use for air-conditioning Energy use for ventilation Energy use for DHW Energy use for lighting Energy from RES production - electricity	• CEN standards M480 – hourly step, • software outputs

<table>
<tr><th>Subject</th><th>ALDREN</th><th>Steps / actions / explanation / examples</th><th>Source of data / information</th></tr>
<tr><td></td><td></td><td>Energy from RES production - thermal
Energy from RES export - electricity
Energy from RES export – thermal
Expenditure factors for each service and for overall final energy. The expenditure factor reported on the first page should be calculated based on all services.</td><td></td></tr>
<tr><td></td><td></td><td>Step 30 Ratio of renewable
According to EN ISO 52000-1 (3 types of primary energy factors are needed - non-ren, ren, total) –</td><td>CEN standards M480 – EN ISO 52000-1</td></tr>
<tr><td colspan="4">Energy rating – energy class</td></tr>
<tr><td>Reference point on the scale</td><td>✓</td><td>Step 31 Reference energy performance (non-ren. primary energy). Select the reference point based on the climate zone and building category.
The following tables present the reference values for offices and hotels buildings

Offices
<table>
<tr><th>Climate zone</th><th>ALDREN REF</th><th>ALDREN NZEB</th></tr>
<tr><td>Warm</td><td>70</td><td>25</td></tr>
<tr><td>Moderate</td><td>130</td><td>46</td></tr>
<tr><td>Cold</td><td>170</td><td>60</td></tr>
</table>
Hotels
<table>
<tr><th>Climate zone</th><th>ALDREN REF</th><th>ALDREN NZEB</th></tr>
<tr><td>Warm</td><td>200</td><td>70</td></tr>
<tr><td>Moderate</td><td>270</td><td>95</td></tr>
<tr><td>Cold</td><td>310</td><td>109</td></tr>
</table></td><td>ALDREN methodology
Step 1-2-4</td></tr>
<tr><td>Energy rating scale</td><td>✓</td><td>Step 32 Definition of energy scale based on the reference point and energy class estimation

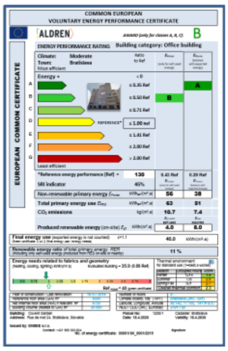
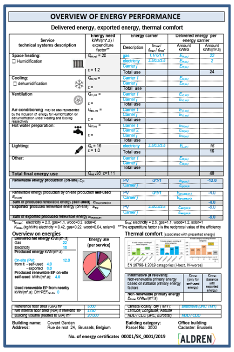
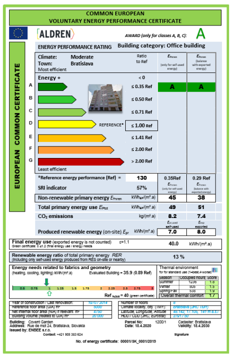
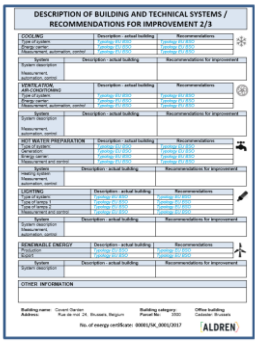
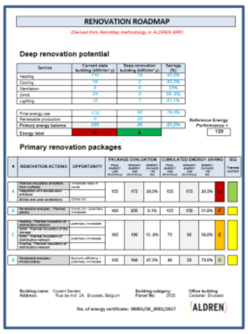
The scale allows the determination of EVC energy class. The scale is non-linear stepped scale with 7 main classes (A-G) based on one reference point (Step 28) located on the upper limit of class “D”.


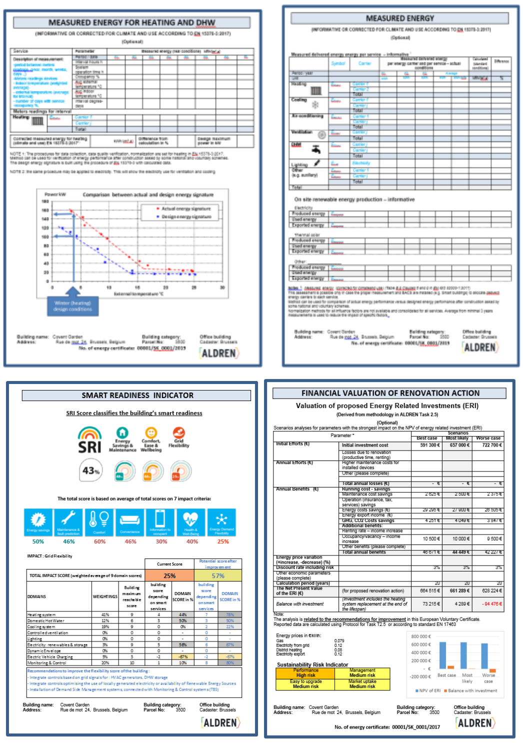
<table>
<tr><th>Class</th><th>Energy classes</th></tr>
<tr><td>Energy +</td><td>EP < 0</td></tr>
<tr><td>A</td><td>0 Ref ≤ EP ≤ 0,35 Ref</td></tr>
<tr><td>B</td><td>0.35 Ref < EP ≤ 0.50 Ref</td></tr>
<tr><td>C</td><td>0.50 Ref < EP ≤ 0.71 Ref</td></tr>
<tr><td>D</td><td>0.71 Ref < EP ≤ 1.00 Ref</td></tr>
<tr><td>E</td><td>1.00 Ref < EP ≤ 1.41 Ref</td></tr>
<tr><td>F</td><td>1.41 Ref < EP ≤ 2.00 Ref</td></tr>
<tr><td>G</td><td>2.00 Ref < EP</td></tr>
</table></td><td>ALDREN methodology
CEN standards M480 – EN 52003-1
Step 28</td></tr>
</table>

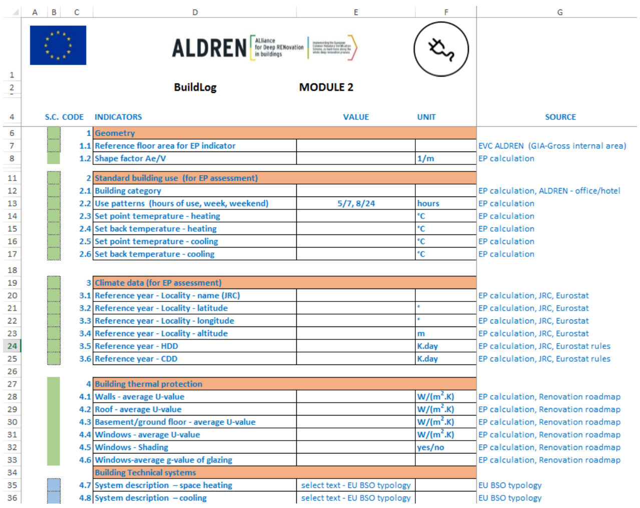
Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Energy class	✓	**Step 33 Determination of energy class for actual state building** Indicators for energy rating and scale are: - Main EP indicator – with export counted - EP indicator – without export counted - Ratio to reference **The ALDREN NZEB (Green certificate)** is achieved if: - Energy class „A" is achieved for the main indicator - Overall thermal comfort score and thermal comfort score for each season is lower or equal to 2.0 (**Step 34-35-36**) - requirements on energy needs (sum heating, cooling, lighting) are lower than the values in **Table 5** (≤ 40 kWh/(m^2.a) for moderate climate) - The expenditure factor for final energy ε ≤ 1.2 (final energy use /energy needs). The expenditure factor ε is the reciprocal value of the efficiency. **Award energy classes** are: A-gold, B-silver, C-bronze	• **ALDREN methodology** • CEN standards M480

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
		Thermal comfort score	
	✓	The energy use of the building can be lower without some systems installed (e.g., cooling) due to a good design exploiting passive solutions. To avoid a better energy rating due to a poorer indoor environment, the thermal comfort score has to be reported together with the energy performance indicators in order to show the level of indoor thermal comfort for calculated energy performance (**Step 12**). ALDREN NZEB (green certificate) cannot be achieved even if building is in energy class "A" if the thermal comfort score is outside a certain range. Note: The presence of the system or not can be addressed in the national certification schemes by the approach of reference building or by the different requirements for buildings with and without cooling. ALDREN proposes the scale based on the same absolute values with and without cooling in order to be technology neutral and to support passive solutions. **Step 34** Extraction of the hourly operative temperature from the output from energy calculation. **Step 35** Operative temperature analysis based on categories of spaces and intervals according to EN ISO 16798. The % of occupation hours outside the intervals has to be estimated. **Step 36** Calculation of **thermal comfort score** based on ALDREN methodology (see Table 9)	• **ALDREN methodology (See full methodology in Table 9)** • software outputs from energy calculation (hourly operative temperatures) • EN 16798:2018

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Recommendations for improvement of energy performance			
Renovation roadmap	✓	**Step 37** **Recommendations for improvement, if possible, based on the outcomes from ALDREN Renovation Roadmap** (Task 2.6) - Renovation roadmap towards NZEB that includes: • Definition of the building renovation potential. • Energy savings and indicators related to cost and well-being. • Recommendations for elementary renovation actions associated with the main building components. • Renovation packages. Evaluation of energy class, cost and IEQ indicators. • Description of proposed measures in EVC (**pages 4-5**) **Step 38** Calculation of **energy , energy class and energy savings after realisation of proposed renovation** action towards ALDREN NZEB **Step 39** Calculation of **thermal comfort score after realisation of proposed renovation action** towards ALDREN NZEB	• **ALDREN methodology** • Task 2.6.3 – Renovation roadmap methodology
Measured energy			
		Step 40 Optional pages in EVC – Measured energy reporting (recommendation in EPBD Art. 11(1) for non-residential buildings). Assessment of energy performance based on measured energy is possible only in case the proper measurement and BACS are installed (e.g. link to SRI). Inputs needed: - Allocation of measured delivered energy to carriers and services. - External climate conditions and internal temperature (measured or set-point temperature) - Occupancy. The procedures for data collection, data quality verification, normalization are set for heating and DHW in **EN 15378-3:2017**.	CEN standards M480 Method for energy signature and normalisation in EN 15378-3:2017
	✓	**Step 41** Procedures for optional page in EVC – Measured energy for heating and DHW according to EN 15378-3:2017: - Normalization for most influencing factors, - normalisation from yearly measurement or from short term measurement - average from min 3 years measurements - Energy signature (based on calculation vs. measurement) according to EN 15378-3.	

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
EVC template – 2 pages with the main indicators			
EVC template	✓	**Step 42** Fill the templates based on results obtained in previous steps  COMMON EUROPEAN VOLUNTARY ENERGY PERFORMANCE CERTIFICATE  OVERVIEW OF ENERGY PERFORMANCE NZEB:  COMMON EUROPEAN VOLUNTARY ENERGY PERFORMANCE CERTIFICATE	• **ALDREN methodology (See the full EVC template in Annex C to this report)**
EVC template – 4 pages about recommendations for improvement of EP			
EVC template	✓	**Step 43** Fill the templates for description of building, technical systems, recommendations for improvement and energy savings.  DESCRIPTION OF BUILDING AND TECHNICAL SYSTEMS / RECOMMENDATIONS FOR IMPROVEMENT 1/3  DESCRIPTION OF BUILDING AND TECHNICAL SYSTEMS / RECOMMENDATIONS FOR IMPROVEMENT 2/3  DESCRIPTION OF BUILDING AND TECHNICAL SYSTEMS / RECOMMENDATIONS FOR IMPROVEMENT 3/3  RENOVATION ROADMAP	• **ALDREN methodology (See the full EVC template in Annex C to this report)**

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
EVC template – optional pages			
EVC template	✓	**Step 44** Fill the template for all optional pages based on results obtained in previous steps and on the results from other tasks (Task 2.3, Task 2.4, Task 2.5). Examples (see the full EVC template in Annex C to this report) 	• **ALDREN methodology (See the full EVC template in Annex C to this report)**

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Data collection – integration of EP indicators in the building passport (Task 2.6)			
	✓	**Step 45** List of data from EVC to be collected and included in Building Renovation Passport 	• **ALDREN methodology** **(See Annex B2 in this report)**

BuildLog MODULE 2

	S.C. CODE	INDICATORS	VALUE	UNIT	SOURCE
6	1	Geometry			
7	1.1	Reference floor area for EP indicator			EVC ALDREN (GIA-Gross internal area)
8	1.2	Shape factor Ae/V		1/m	EP calculation
11	2	Standard building use (for EP assessment)			
12	2.1	Building category			EP calculation, ALDREN - office/hotel
13	2.2	Use patterns (hours of use, week, weekend)	5/7, 8/24	hours	EP calculation
14	2.3	Set point temeprature - heating		°C	EP calculation
15	2.4	Set back temperature - heating		°C	EP calculation
16	2.5	Set point temeprature - cooling		°C	EP calculation
17	2.6	Set back temperature - cooling		°C	EP calculation
18					
19	3	Climate data (for EP assessment)			
20	3.1	Reference year - Locality - name (JRC)			EP calculation, JRC, Eurostat
21	3.2	Reference year - Locality - latitude		°	EP calculation, JRC, Eurostat
22	3.3	Reference year - Locality - longitude		°	EP calculation, JRC, Eurostat
23	3.4	Reference year - Locality - altitude		m	EP calculation, JRC, Eurostat
24	3.5	Reference year - HDD		K.day	EP calculation, JRC, Eurostat rules
25	3.6	Reference year - CDD		K.day	EP calculation, JRC, Eurostat rules
26					
27	4	Building thermal protection			
28	4.1	Walls - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
29	4.2	Roof - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
30	4.3	Basement/ground floor - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
31	4.4	Windows - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
32	4.5	Windows - Shading		yes/no	EP calculation, Renovation roadmap
33	4.6	Windows-average g-value of glazing			EP calculation, Renovation roadmap
34		Building Technical systems			
35	4.7	System description – space heating	select text - EU BSO typology		EU BSO typology
36	4.8	System description – cooling	select text - EU BSO typology		EU BSO typology

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
Integration of EP indicators in asset evaluation (Task 2.5)			
	✓	**Step 46** Energy savings – the difference between the current state and the recommended state after renovation to the NZEB level is the **direct benefit** as an input in the value of energy related investment (NPV) calculation**.** Energy savings can be expressed in kWh, kWh/m^2 or in % of savings. The energy savings have to be calculated per energy carrier (delivered energy). The real energy prices per energy carrier at the site should be used for energy costs calculation taking into account the fixed and variable part of energy price. Financial indicators should be calculated using the methodology in Task 2.5.	• **ALDREN methodology** **(See Annex B3 in this report)**

Example

Moderate (Bratislava) €/m2

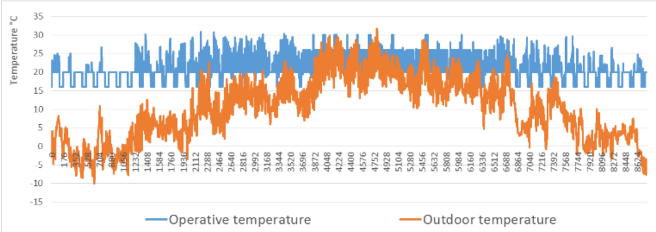
Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	7.36	7.59	6.99	4.86	4.32	4.32	7.59
EX-CO (2013)	6.91	7.06	6.47	4.04	3.84	3.84	7.06
CO-NZEB	0.45	0.53	0.51	0.82	0.48	0.48	0.53

Energy cost savings (PV auto-consum	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	9.04	9.25	8.44	5.90	4.92	5.36	8.97
EX(no PV)-CO (2013) (PV auto)	8.45	8.57	7.76	4.99	4.44	4.87	8.29
CO (no PV)-NZEB(PV auto)	2.13	2.19	1.96	1.86	1.09	1.52	1.91

FINAL ENERGY (PV auto)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	91%	91%	90%	86%	82%	85%	90%
EX-CO (2013)	62%	61%	61%	47%	50%	50%	61%
CO-NZEB (PV auto)	76%	76%	74%	73%	64%	69%	74%

Table 10 Protocol for calculating the Thermal Comfort Score for simulated energy performance

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information
The Thermal Comfort Score for Simulated Energy Performance			
Thermal comfort score for simulated energy performance to be reported with energy class	✓	The absence of a system (e.g., cooling) could lead to better energy performance with poorer IEQ. Improving IEQ by installing the system (e.g., cooling) could lead to poorer energy performance. Passive solutions leading to low energy consumption while ensuring a good thermal comfort need to be rewarded. Therefore, a thermal comfort score is introduced to be reported together with the energy performance indicators and the energy class. This will make it possible to compare the energy performance of building (e.g., before and after renovation) with regard to IEQ. In order to link the indoor conditions with the energy class, the thermal comfort is evaluated under the same standard conditions assumed in the calculation model for energy performance assessment. The calculated thermal comfort score is dedicated for comparing buildings (e.g. before renovation and after renovation) and it is not linked to a specific use or a specific room of the building. **To evaluate the actual IEQ of the building, the TAIL rating (Task 2.4.) provides specific information based on measurements.**	• **ALDREN methodology** • EN 16798-1: 2019

<table>
<tr><th>Subject</th><th>ALDREN</th><th>Steps / actions / explanation / examples</th><th>Source of data / information</th></tr>
<tr><td></td><td></td><td>
The calculation should be performed in the following steps:
Step 1 Extraction of hourly external temperature (TMY) and internal operative temperature of the zone from energy simulation (8760 h).
Example:


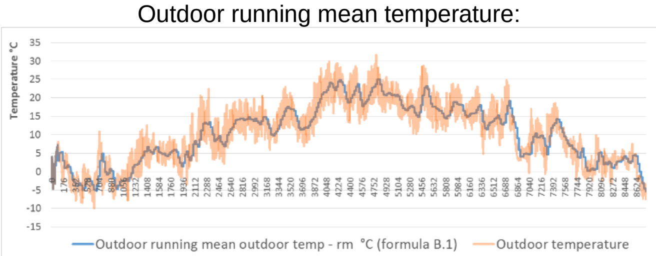
</td><td></td></tr>
<tr><td></td><td>✓</td><td>
Step 2 Assign the hours during occupancy to 3 seasonal periods of the year based on the outdoor running mean temperature Θ_{rm} calculated from the previous 3 days according to formula B.1 in EN ISO 16798-1:2019 (<u>corrected formula</u>):

$$\Theta_{rm} = \frac{1}{(1 + \alpha + \alpha^2)} \cdot (\Theta_{ed-1} + \alpha \cdot \Theta_{ed-2} + \alpha^2 \Theta_{ed-3})$$

Winter (heating) season is considered with Θ_{rm} equal or less 10 °C.
Summer (cooling) season is considered with Θ_{rm} equal or more 15 °C.
The spring/fall (between heating and cooling) seasons is considered with Θ_{rm} between 10 and 15 °C.

Example:
Distribution of occupancy hours into 3 seasons:

<table>
<tr><td>Winter (heating)</td><td>Summer (cooling)</td><td>Spring/fall (between heating and cooling)</td><td>Total hours during occupancy</td></tr>
<tr><td>2018</td><td>738</td><td>501</td><td>2457</td></tr>
</table>

Outdoor running mean temperature:


Note:
The division into heating, cooling and intermediate season between heating and cooling is based on the clothing, which refers to the outdoor running mean temperature. The operation schedules of technical systems are not taken into account for division into seasons (heating, cooling, between heating and cooling).
</td><td>

ALDREN methodology
EN 16798-1: 2019

</td></tr>
<tr><td></td><td>✓</td><td>
Step 3 For each season, divide the hours during occupancy into IEQ categories based on the hourly operative temperature of the zone.
The temperature intervals for the categories of indoor environment for heating, cooling and for between the heating and cooling season are defined in EN ISO
</td><td>

ALDREN methodology
EN 16798-1: 2019

</td></tr>
</table>

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information

16798-1:2019, Tab. B.5.

Table 3 – Categories of indoor environmental quality

Category	Level of expectation	Explanation
IEQ_{I}	High	May be selected for occupants with special needs (children, elderly, handicapped).
IEQ_{II}	Medium	The normal level used for design and operation.
IEQ_{III}	Moderate	Will still provide an acceptable environment. Some risk of reduced performance of the occupants.
IEQ_{IV}	Low	Should only be used for a short time of the year or in spaces with very short time of occupancy.

Source: IEQ categories in EN ISO 16798:2019

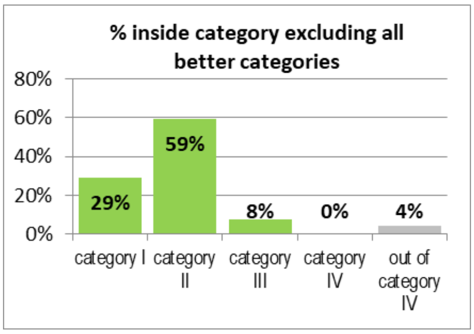
For each season and for each IEQ category, calculate the % of occupancy hours **outside the temperature interval** and inside the interval excluding all better categories.

Use the following formulas to calculate the **% inside the category** excluding all better categories:

(100-IEQ I,%out)
(IEQ I,%out – IEQ II,%out)
(IEQ II,%out – IEQ III,%out)
(IEQ III,%out – IEQ IV,%out)
IEQIV,%out

Example**:**

Distribution of occupancy hours during the **winter (heating) season** into IEQ categories:



✓ **Step 4** For each season, calculate **the thermal comfort score** based on the % of occupancy hours outside the intervals for the IEQ categories according to EN ISO 16798-1:2019, using the following formulas (Bjarne Olesen):

((100-IEQI,%out)*1 +
(IEQI,%out - IEQII,%out)*2 +
(IEQII,%out - IEQIII,%out)*3 +
(IEQIII,%out - IEQIV,%out) *4 +
(IEQIV,%out*5)) /100

Subject	ALDREN	Steps / actions / explanation / examples	Source of data / information

Example:

Estimation of the score for **winter** (**heating) season**:

Category	Weight	% of hours out of category	% inside category, except for all better categories
IEQ $_{I}$	1	71%	29%
IEQ $_{II}$	2	12.0%	59%
IEQ $_{III}$	3	4.4%	8%
IEQ $_{IV}$	4	4%	0%
out of IEQ $_{IV}$	5		**4%**
		Score	**1.9**

✓ **Step 5** Calculate the thermal comfort score **for each season.**

- **ALDREN methodology**

✓ **Step 6** Calculate the **overall thermal comfort score** as a weighted average using the hours during occupancy for each season period as a weighting factor.

In the case of division of building in more zones, repeat the **Steps** for each zone.

The overall thermal comfort score of multiple zones is estimated as the weighted average of the scores of each zone using the floor area or volume of the zone as a weighting factor.

✓ **Step 7** Example of **reporting** the Thermal comfort score for simulated energy performance in the EVC template:

Thermal environment

for standard use (1=best, 4-worse)

Season	Occupied hours	Score
Winter	1218	1.9
Summer	738	2.8
Spring/Fall	501	2.7
Overall thermal comfort		**2.3**

The scale

≤ 2
>2.0 ≤ 2.5
>2.5 ≤ 3
>3

✓ **Step 8** The required thermal comfort score for **ALDREN NZEB** must be less or equal to 2.0 for each season, in addition to the other requirements set for ALDREN NZEB (see Table 8, **Step 33**).

5 CONCLUSIONS

5 Conclusions

5.1 Conclusions from setting and testing the scale and reference

Details of the assumptions and inputs for simulation of model buildings, analysis and results of the scale setting and testing including the reference values estimation are given in Annex A.

Scale shape

The scale for office buildings is designed as a non-linear stepped scale with 7 main classes (A-G) based on one reference point located at the upper limit of class “D” (option 2 in the EPB standard [8]). The reference is based on the approximately cost-optimal level of minimum energy performance requirements calculated by Member States in 2013 [22]. Energy Class „A“ is the definition of ALDREN NZEB.

Based on the results of the study in Annex A, it is not possible to achieve the NZEB level (35% of energy performance of reference) in hotel buildings due to the large part of DHW in the energy use of building at 100% occupancy throughout the year. The average occupancy of hotels has to be taken into account.

The position of the energy class for the reference point (Ref) on the scale can potentially be changed from the position n_0 = 4 (class D) for offices to position n_0 = 3 (class C) for hotels. Two different scales as presented in Table 11 and Figure 13.

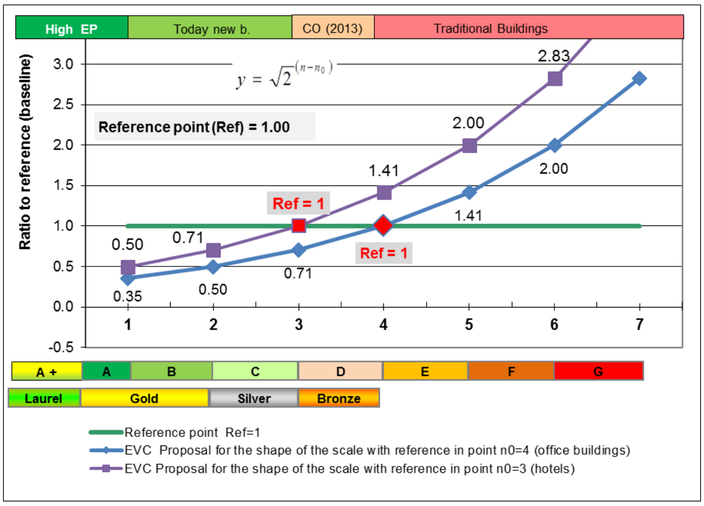


Figure 13 Two types of ALDREN scale, based on reference point located at the upper limit of class “D” or “C”

Table 11 Energy performance classes as the ratio of assessed building (EP) to the reference (Ref) for two different Ref positions

Ref = energy class C

Class	Energy classes
A+	EP< 0
A	0 < EP ≤ 0.5 Ref
B	0.5 Ref < EP ≤ 0.71 Ref
C	0.71 Ref < EP ≤ **1.00 Ref**
D	1.00 Ref < EP ≤ 1.41 Ref
E	1.41 Ref < EP ≤ 2.00 Ref
F	2.00 Ref < EP ≤ 2.83 Ref
G	2.83 Ref < EP

Ref = energy class D

Class	Energy classes
A+	EP< 0
A	0 < EP ≤ 0.35 Ref
B	0.35 Ref < EP ≤ 0.50 Ref
C	0.50 Ref < EP ≤ 0.71 Ref
D	0.71 Ref < EP ≤ **1.00 Ref**
E	1.00 Ref < EP ≤ 1.41 Ref
F	1.41 Ref < EP ≤ 2.00 Ref
G	2.00 Ref < EP

The reference on the scale

The absolute reference values per building category for all climates are not recommended, as the potential for technical improvement to the NZEB level may be lost. The costs efficiency is usually the time specific value. New solutions and new prices for innovative solutions evolve over time, and prices often push down stricter energy performance requirements for buildings.

The national numerical indicators for definition of NZEB take into account the climate. In case the fixed values for all climates are used, the ALDREN NZEB nay be far from the national definition of NZEB in some climates.

Therefore, **absolute reference values per building category and for three climates,** presented in Table 12, are proposed for the ALDREN methodology based on an extensive simulation of the model buildings described in Annex A. The NZEB level derived from the reference values are:

- for offices in line with the Commission Recommendation (EU) 2016/1318 on guidelines for the promotion of nearly zero-energy buildings [6]
- for hotels in line with the recommendation of the neZEH project.[40]

Table 12   Proposal for reference point and NZEB level on the scale for ALDREN EVC

Offices

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**70**	**25**
Moderate	**130**	**46**
Cold	**170**	**60**

Hotels

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**200**	**70**
Moderate	**270**	**95**
Cold	**310**	**109**

Comparison of fixed reference values for all climates and proposed reference values (cost-optimal level 2013) and the NZEB level based on calculated model buildings for three climates are shown in Figure 14.

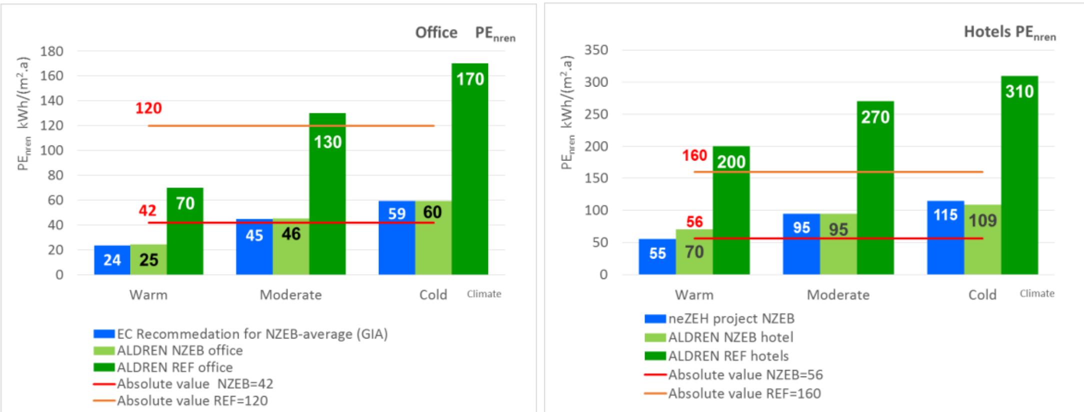


Figure 14   Comparison of fixed reference value for all climates and ALDREN reference values for three climates

The ALDREN NZEB is achieved if:

- Energy class „A“ for the main indicator expressed in primary energy is achieved
- Thermal comfort is ensured (Step 34-35-36 in the Protocol)
- Requirements on energy needs (heating, cooling, lighting) are fulfilled with values 38 kWh/(m².a) for warm climate, 40 kWh/(m².a) for moderate climate and 42 kWh/(m².a) for Cold/Nordic climate (Table 5).

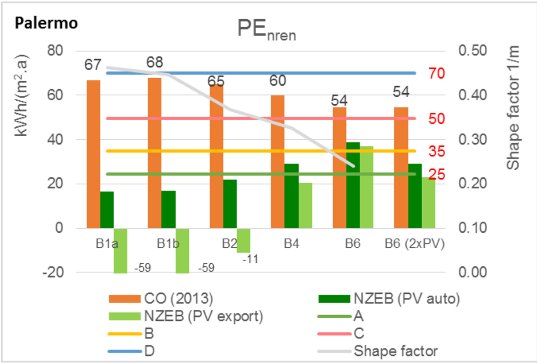
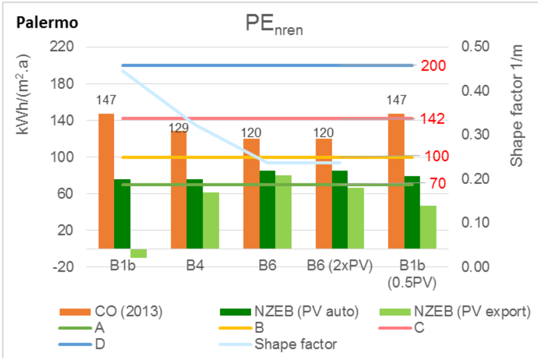
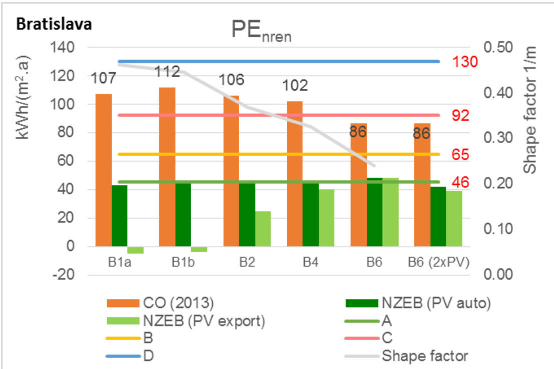
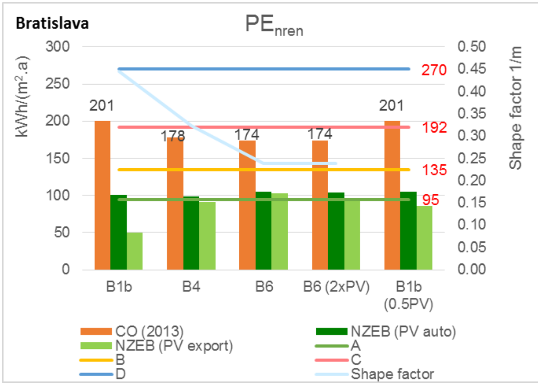
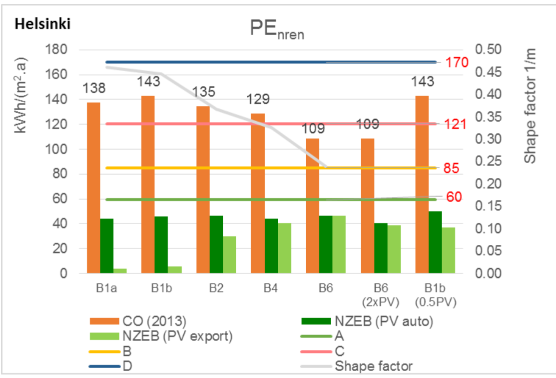
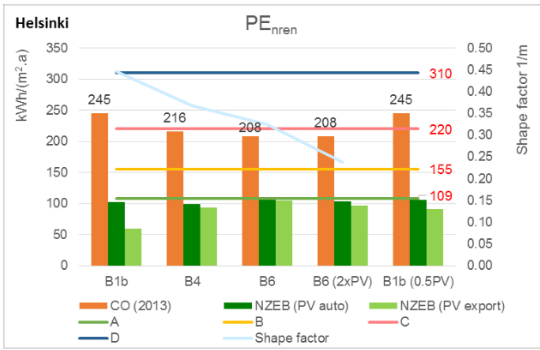
Based on the analysis of various sources, the proposal for the distribution of a specific building location in 3 climatic zones for the ALDREN procedure for EVC rating and scale, is based on heating degree-days (HDD) according to Table 13.

Table 13 Proposal for allocation of building to climate zone for ALDREN procedure

ALDREN climate zone		HDD from reference year used for calculation of EP (t_i =18 °C, base temperature 15 °C) in K.day
Zone 1	Warm	≤ 1200
Zone 2	Moderate	1201 - 4000
Zone 3	Cold	> 4000

The reference values on the scale were tested in Annex A on several model buildings in 3 climates including and the energy class transition in case of step-by-step renovation. The results from detailed simulation using hourly calculation step show that:

- Buildings with properties close to CO level (2013) are mostly in class “D” for office buildings. In the case of hotel buildings, it is mostly energy class “C” (Figure 15).
- The NZEB office building can only be achieved with the export of renewable energy (PV electricity) in a warm and moderate climate. In cold climates, the NZEB can also be achieved with PV auto-consumption only counted, as the export could not be cost-efficient in the cold climates (Figure 16-17).
- The scale is suitable to provide sufficient resolution to present and identify the relative building targets for step-by-step renovation towards NZEB level.

EP indicators and energy classes achieved on the scale for **office buildings**	EP indicators and energy classes achieved on the scale for **hotel buildings**
	
	
	

Note:

CO(2013) level of building and systems properties close to cost-optimal level defined by MS in 2013

NZEB level of building and systems properties close to national definitions of NZEB or best practices

Figure 15 Results from scale testing for office and hotel buildings in 3 climates

Climate: Warm (Palermo) **Reference (Ref)** 70

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	G	G	G	F	F	F	G
	CO (2013)	D	D	D	D	D	D	D
	NZEB	D	D	D	D	D	D	D
PE_{nren} (PV auto-consumption only)	EX	F	F	G	E	F	E	G
	CO (2013)	B	B	B	C	C	B	C
	NZEB	A	A	A	B	C	B	A
PE_{nren} (balance - PV export))	EX	D	D	F	E	F	E	F
	CO (2013)	A+	A+	A	B	C	B	A
	NZEB	A+	A+	A+	A	C	A	A+

Climate: Moderate (Bratislava) **Reference (Ref) =** 130

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	G	G	F	F	E	E	G
	CO (2013)	D	D	D	D	C	C	D
	NZEB	C	C	C	B	B	B	C
PE_{nren} (PV auto-consump	EX	F	F	F	E	E	E	F
	CO (2013)	C	C	C	C	C	C	D
	NZEB	A	A	A	A	B	A	B
PE_{nren} (balance - PV expo	EX	F	F	F	E	E	E	F
	CO (2013)	A	A	B	C	C	C	C
	NZEB	A+	A+	A	A	B	A	A

Climate: Cold (Helsinki) **Reference (Ref)** 170

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	E	E	D	D	D	E
	CO (2013)	D	D	D	D	C	C	D
	NZEB	B	B	B	A	A	A	B
PE_{nren} (PV auto-consumption only	EX	E	E	E	D	D	D	E
	CO (2013)	C	D	C	C	C	C	D
	NZEB	A	A	A	A	A	A	A
PE_{nren} (balance - PV export))	EX	D	E	E	D	D	D	E
	CO (2013)	B	B	C	C	C	C	C
	NZEB	A	A	A	A	A	A	A

EX	level of building and systems properties close to typical existing building
CO(2013)	level of building and systems properties close to cost-optimal level defined by MSs in 2013
NZEB	level of building and systems properties close to national definitions of NZEB or best practices

Figure 16 Results from scale testing for office buildings located in 3 climates

Climate:	Warm (Palermo)	Reference (Ref)	200			
		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	D	D	D	E
	CO (2013)	D	C	C	C	D
	NZEB	C	B	B	B	C
		B1b	B4	B6	B6	B6
PE_{nren} (PV auto-consumption only)	EX	D	D	D	D	E
	CO (2013)	C	C	C	C	C
	NZEB	B	B	B	B	B
PE_{nren} (balance - PV export))	EX	C	D	D	C	D
	CO (2013)	A	B	C	B	B
	NZEB	A+	A	B	A	A

Climate:	Moderate (Bratislava)	Reference (Ref) =	270			
		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	D	D	D	E
	CO (2013)	D	C	C	C	D
	NZEB	B	B	B	B	B
PE_{nren} (PV auto-consumption o	EX	E	D	D	D	E
	CO (2013)	C	C	C	C	C
	NZEB	B	B	B	B	B
PE_{nren} (balance - PV export))	EX	E	D	D	D	E
	CO (2013)	B	C	C	C	C
	NZEB	A	A	B	A	A

Climate:	Cold (Helsinki)	Reference (Ref)	310			
		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	D	D	C	C	D
	CO (2013)	D	C	C	C	D
	NZEB	B	B	B	B	B
PE_{nren} (PV auto-consumption only	EX	D	C	C	C	D
	CO (2013)	D	C	C	C	D
	NZEB	A	A	A	A	A
PE_{nren} (balance - PV export))	EX	D	C	C	C	D
	CO (2013)	C	C	C	C	C
	NZEB	A	A	A	A	A

EX	level of building and systems properties close to typical existing building
CO(2013)	level of building and systems properties close to cost-optimal level defined by MS in 2013
NZEB	level of building and systems properties close to national definitions of NZEB or best practices

Figure 17 Results from scale testing for hotel buildings in 3 climates

Identification of relative building targets for step-by-step renovation towards the NZEB

The results of simulation of step-by step renovation towards NZEB for two model buildings are shown in Figures 55 to 57 in Annex A, chapter A6, together with the energy classes' transition. The conclusions for model buildings are:

- Energy classes transition on the scale and the reference fit to the expected renovation steps and the changes of energy classes by each renovation step are visible;
- Renovation **from an existing building to the NZEB level**, even without PV, achieves the deep renovation targets (60% savings);

- The impact of improving the building envelope is higher for smaller building, but deep renovation (60% savings) cannot be achieved by improving the building envelope alone;

- By improvement of an old **existing building to a cost-optimal level (2013),** the level close to the limit of 60% is achieved for small building, but it is not enough for larger building (only 46% savings are achieved). The risk of a lock-in effect is evident, as the renovation to the cost-optimal level (2013) would prevent building for several years from further improvement to the NZEB level (Figures 55-56 in Annex A);

- **Step 1** as a pre-renovation state (replaced windows only) is often the case for current situation in building stock. The improvement from Step 1 to the properties of NZEB even without PV can be considered as a deep renovation with savings of more than 60%;

- **The cost-optimal level (2013)** as a pre-renovation state with PV is presented in Figure 57 in Annex A. Savings of 60% can be achieved for some buildings with oversized PV, but not for all buildings. Cost-effectiveness must be examined in the case of renovation from CO level (2013) to NZEB level. Lock-in effect by renovation to cost optimal level in 2013 is evident.

5.2 Conclusions on the methodological integration of the EVC into ALDREN procedures

Integration of the EVC into ALDREN procedures proposed in Annex B is divided in 3 topics:

- Integration of indictors into the property managers' decision process, among the various criteria of building assets evaluation (including the attractiveness and technical state) (Task 2.1) - **Template for ALDREN European Voluntary Certificate (Annex B, B1);**

- Integration of EP indicators in the building passport (Task 2.6) – **Data to be collected from EVC (Annex B, B2);**

- Integration of EP indicators in the asset evaluation (Task 2.5) – **benefits based on energy savings, attractiveness and technical state (Annex B, B3).**

Template for ALDREN European Voluntary Certificate (Annex B, B1)

Proposal for template of the harmonised European Voluntary Certificate in Annex B1 can stand alone, can be included in other certification scheme or may be overtaken by the Commission (EPBD Art. 11(9) [2]). EVC could be complementary to national mandatory EPCs, as it provides comparability at the level of EU building stock, while national mandatory certificates provide comparability with the national building stock. The EVC indicators are also included in ALDREN Building Renovation Passport (Task 2.6)

The European Voluntary Certificate (EVC), compliant with the amended EPBD, improves the current practice by at least following features:

- The local climate is used to calculate energy performance, instead of one climate for the whole country or region. The gap between the calculated and the actual energy consumption is reduced;

- An hourly step is used for energy performance calculation. The hourly step provides a more correct consideration of indoor comfort and a correct estimate of the impact of some technologies e.g. PV electricity auto-consumed in the building, heat pumps;

- A common harmonised calculation methodology based on the new CEN standards developed under M/480, that improves the level playing field for products across EU and comparability of energy performance EU wide;
- Additional indicators are reported that makes the EVC applicable for national and existing voluntary certification schemes;
- Thermal comfort score is reported together with energy use to make visible the relation between the indoor thermal environment and the energy presented in energy class (e.g. to compare building with and without a cooling system);
- A typology for describing systems in line with common EU databases (e.g. EU Building Stock Observatory).

The EVC contains 2 main pages with energy performance indicators, pages with recommendations for improvement and optional pages with reporting on measured energy, which is recommended in EPBD Art. 11(1) for non-residential buildings.

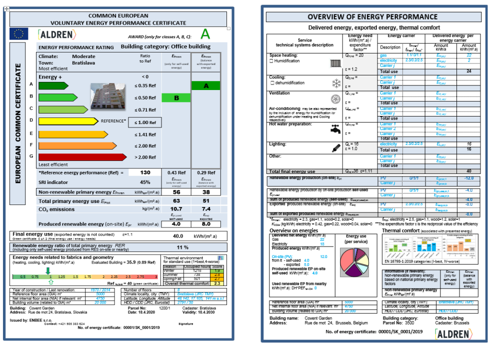


Figure 18 ALDREN EVC pages with the main EP indicators

The energy performance certificate contains, in line with EPBD Art. 11, the **recommendations for improvement** of energy performance of a building, unless there is no reasonable potential for such an improvement compared to the energy performance requirements in force. The ALDREN procedures recommend the development of a detailed renovation roadmap (**RenoMap**) for step-by-step renovation actions and in case it is developed, the recommendations in the EVC should refer to it.

EP indicators in the building passport (Task 2.6) (Annex B, B2)

The aim of integration of EP indicators in the building passport in Annex B2 is to collect all relevant information in one place in order to provide owners, building mangers, designers, energy auditors and energy assessors with a set of information during building lifespan and decision making tool in renovation roadmap. The typology of building components and systems should be based on common EU databases (EU Building Stock Observatory).

EP indicators in asset valuation (Task 2.5) (Annex B, B3)

Task 2.5 presents economic benefits due to the deep renovation of existing commercial non-residential buildings (offices, hotels) including attractiveness and technical state in order to motivate building owner towards investment in deep renovation.

The income approach based on Net present value (NPV) can explicitly demonstrate the benefits for building owner resulting from deep renovation that integrates several aspects during the commercialisation of buildings such as building technical quality / obsolescence of the building, energy performance and Health & Wellbeing (attractiveness for occupants).

The inputs in NPV calculation are:

- all future cash flows (incomes, costs), net income during the calculation period → **also influenced by energy costs, maintenance and replacement cost for building technical systems (heating, cooling, DHW, ventilation, lighting)**
- discount rate (with risk) → **also influenced by attractiveness and technical state of systems**
- final value for subsequent resale (value at the end of the calculation period) → **also influenced by the attractiveness and technical condition of the systems.**

The inputs from energy performance calculation that can be used directly for NPV method (energy and cost savings) are presented in Figure 19 and Figure 20.

The main findings from investigation on model buildings are:

- It is more difficult to achieve 60% savings for larger buildings (envelope has less impact);
- It is difficult to achieve 60% savings for hotel buildings, even with PV installed;
- Renovation of a building from the CO(2013) level to ALDREN NZEB does not achieve 60% savings if PV is not installed.

In Helsinki, the existing buildings are very close to the CO(2013) level. So even if there are energy savings in final energy, there could negative savings in terms of primary energy and costs savings due to transition from gas to electricity.

In case the ALDREN RenoMap (Task 2.6.3) is not developed for building, it is recommended to perform a **global costs analysis** for various options how to get to NZEB level based on EPB standard EN 15459-1:2017 [14] and based on Regulation 244/2012 [4] for a big investment in deep renovation.

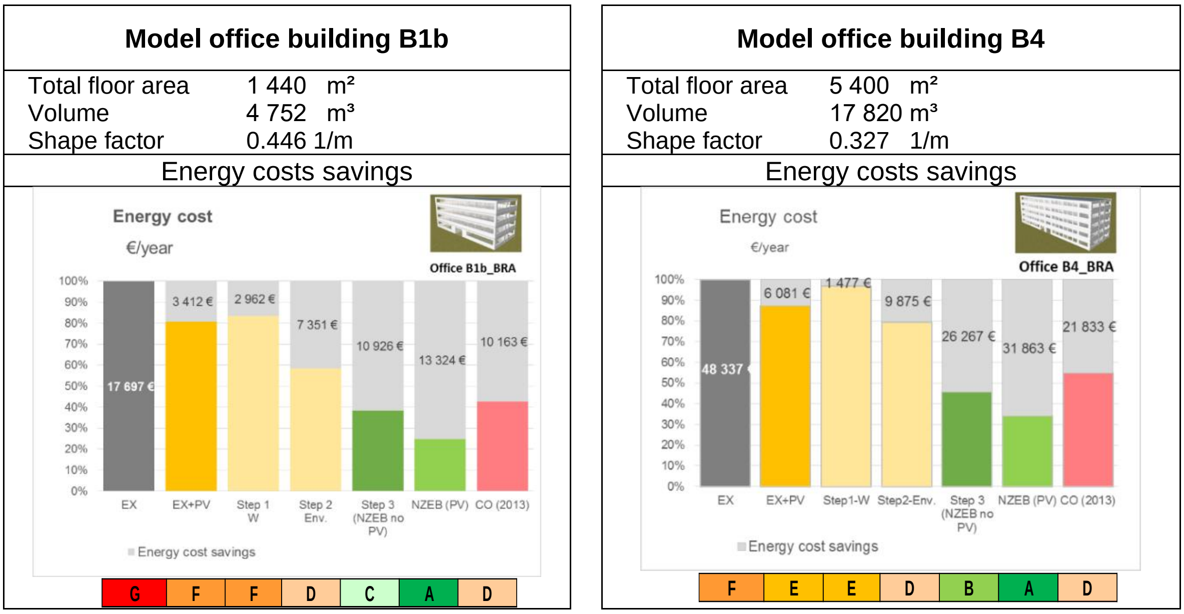


Figure 19 Example of direct energy costs savings for step-by-step renovation

Savings **Moderate (Bratislava)**

PRIMARY ENERGY nren (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	75%	75%	74%	68%	66%	66%	75%
EX-CO	60%	60%	59%	46%	48%	48%	60%
CO-NZEB	**37%**	**39%**	**38%**	**42%**	**34%**	**34%**	**39%**

PRIMARY ENERGY (PV auto consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	84%	84%	83%	76%	71%	75%	83%
EX-CO (PV auto)	68%	68%	66%	53%	54%	57%	66%
CO (no PV)-NZEB(PV auto)	**60%**	**60%**	**58%**	**56%**	**44%**	**52%**	**57%**

PRIMARY ENERGY (PV export)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	102%	101%	91%	79%	71%	77%	88%
EX-CO (PV export)	87%	86%	75%	56%	54%	59%	73%
CO (no PV)-NZEB(PV export)	**105%**	**104%**	**77%**	**61%**	**44%**	**55%**	**71%**

FINAL ENERGY (PV auto)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	91%	91%	90%	86%	82%	85%	90%
EX-CO (2013)	62%	61%	61%	47%	50%	50%	61%
CO-NZEB (PV auto)	76%	76%	74%	73%	64%	69%	74%

Moderate (Bratislava) € total

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	10 596	10 926	17 602	26 267	51 322	51 322	10 926
EX-CO (2013)	9 949	10 163	16 312	21 833	45 597	45 597	10 163
CO-NZEB	648	762	1 291	4 434	5 724	5 724	762

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	13 022	13 324	21 261	31 863	58 494	63 649	12 910
EX(no PV)-CO (2013) (PV auto)	12 168	12 345	19 561	26 960	52 769	57 804	11 936
CO (no PV)-NZEB(PV auto)	3 073	3 161	4 949	10 030	12 897	18 052	2 747

Moderate (Bratislava) %

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	61%	62%	61%	54%	53%	53%	62%
EX-CO (2013)	58%	57%	56%	45%	47%	47%	57%
CO-NZEB	9%	10%	10%	17%	11%	11%	10%

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	75%	75%	73%	66%	60%	65%	73%
EX(no PV)-CO (2013) (PV auto)	70%	70%	67%	56%	54%	59%	67%
CO (no PV)-NZEB(PV auto)	42%	42%	39%	38%	25%	35%	36%

Moderate (Bratislava) €/m2

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	7.4	7.6	7.0	4.9	4.3	4.3	7.6
EX-CO (2013)	6.9	7.1	6.5	4.0	3.8	3.8	7.1
CO-NZEB	0.4	0.5	0.5	0.8	0.5	0.5	0.5

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	9.0	9.3	8.4	5.9	4.9	5.4	9.0
EX(no PV)-CO (2013) (PV auto)	8.5	8.6	7.8	5.0	4.4	4.9	8.3
CO (no PV)-NZEB(PV auto)	2.1	2.2	2.0	1.9	1.1	1.5	1.9

Figure 20 Example of direct energy and costs savings – office building in Bratislava

ANNEX A

Annex A Study on energy performance indicators and targets for deep renovation - Testing of the EVC rating scale

A1 Assessment methodology of the energy performance of buildings

The methodological components that have been used for testing the rating scale are presented in this first part of Annex A. They relate to the calculation standards and assumptions on which the study is based.

The calculations were performed using a set of new EPB standards developed under mandate M480 and using the informative default options in Annex B reported in each of the EPB standards. In case the option in Annex B is not followed, this is described in the ALDREN methodology.

Terms and definitions of indicators and parameters are in line with the EPB standards.

A1.1 Energy performance indicators for the EVC rating

Indicators for EVC were presented to stakeholders during 1st VCS workshop (2016-01-14) [36] in the frame of the study **"**Enabling the European Common Voluntary Certification scheme (VCS) for non-residential buildings" (Service contract No. ENER/C3/2015-545/SID.710527). The proposed indicators are: building energy needs, total primary energy, non-renewable primary energy balance taking into account exported energy and the CO_2 emissions. The indicator with the compensation allowed only within the same time step is needed in order to favour auto-consumption of produced renewable energy and storage. The indicator for the main rating on the scale is expressed in the non-renewable primary energy balance with counted export of produced energy from renewable sources. Other indicators are informative to identify the partial performance.

Ratio of renewable sources calculated according to EN ISO 52000-1 [7] is reported for information and is based on the energy used within the building (auto-consumption) delivered from on-site and nearby, as stated in the EPBD.

The indicators were adapted to the needs of existing certification schemes.

Table 14 Energy uses included in the energy performance indicator

Services included in the EP indicator:	***ALDREN***
o Heating	✓
o Cooling / Air-conditioning	✓
o Mechanical ventilation	✓
o Domestic hot water preparation	✓
o Lighting	✓
o Auxiliary energy	✓
o Embodied energy	
o Lifts	
o External lighting	
o Appliances	

The main indicators used for energy performance rating (energy class) are:

- Non-renewable primary energy (PE_{nren}) balance with allowed export of energy produced energy from RES – **the main indicator**,
- Non-renewable primary energy (PE_{nren}) with only auto-consumption of produced energy from RES counted (no export allowed).

The additional indicators reported in the EVC are:

- The entire building's overall energy use,
- Total PE,
- Delivered energy per energy carrier,
- CO_2 emissions,
- Renewable energy production, auto-consumption and export,
- Ratio of renewable energy,
- Energy needs per service,
- Final energy,
- Wellbeing indicator – thermal comfort score,
- Measured energy – normalised (optional, only if applicable, e.g. smart buildings, BACS installed),
- Smart readiness indicator (SRI).

The main decisions about indicators, assessment boundary and perimeters after consultation with existing certification schemes are:

- Hourly calculation and balance period,
- Only EPBD services are included,
- National standard use patterns (e.g. used for mandatory EPC),
- Local climate conditions (JRC TMY),
- Rating (energy class) for both options with auto-consumed renewable energy production and with export allowed,
- Principle of assessment of present system only, in line with existing voluntary certification schemes. This could cause better rating but lower thermal comfort. Therefore an additional information about the thermal comfort (T-score) has to be reported together with the energy performance. CEN option (Annex B of EN ISO 52000-1), based on calculation of energy use with the assumed system would lead to the result far from the reality.
- Total energy needs for heating, cooling and lighting are reported as the characteristic of the envelope and geometry,
- The PEFs according to EN ISO 52000-1:2017 [7] were used for scale testing and for pilot buildings. The calculation of primary energy factor (PEF) for each country based on the Eurostat data is proposed as the best solution for the future. The national PEF for district heating can be used if calculated based on EPB standards,
- Reference floor area for indicators is gross internal floor area (GIA) according to RICS definition [46] adapted to energy performance (see Table 8). The net internal floor area (NIA) is also reported for potential recalculation by existing certification schemes,
- Ratio of renewable sources based on the energy used within the building delivered from on-site and nearby

A1.2 Reference floor area

The reference floor area is used for normalization of the energy performance and for expression in kWh/(m^2.a). EN ISO 52000-1:2017 [7] proposes in Annex B Table B.21 the Useful floor area as the reference floor area. EN ISO 52000-1:2017 Table B.22 specifies the space categories contributing to the reference size.

The ALDREN reference area is defined in line with the RICS definition for the **Gross internal area** (GIA) [47].

The reference floor area (Ab) for energy performance indicator in kWh/(m².a) is a Gross Internal Area (GIA), that means the floor area contained within the building measured to the internal face of the external walls ignoring the internal partitions (using "overall internal dimensions"). **The external walls define the heat exchange envelope of building** so that the reference floor area is coherent with the calculation of the thermal losses.

The rules and examples in the International Property Measurement Standards (IPMS) as developed by the International Property Measurement Standards Coalition (IPMSC) for Office buildings, IPMS 2 can be used for specific cases, while the spaces outside the considered thermal envelope for the thermal losses calculation are excluded (e.g. unheated basement with garage). https://ipmsc.org/standards/office/ [48]

The Net internal area (NIA) is also reported in EVC, based on the investigation of the needs of existing voluntary certification schemes.

The options for reference floor area based on the RICS Global Code of measuring practice [47] are:

Types of floor area	ALDREN indicators
○ **Gross floor area** (GFA) - The total floor area contained within the building measured to the external face of the external walls.	
○ **Gross internal area** (GIA) **-** The floor area contained within the building measured to the internal face of the external walls. GIA excludes the thickness of perimeter walls, but includes the thickness of all internal walls	✓
○ **Net internal area** (NIA) (or usable floor area UFA) **-** The NIA is the GIA less the floor areas taken up by lobbies, enclosed machinery rooms on the roof, stairs and escalators, mechanical and electrical services, lifts, columns, toilet areas (other than in domestic property), ducts, and risers.	

A1.3 Primary energy factors and CO_2 emission coefficients

The primary energy factors are used as the weighting factors for different energy carriers for calculation of the global indicators expressed in non-renewable primary energy.

According to the Commission recommendation (EU) 2016/1318 [6] for NZEB definition, the primary energy use must be calculated using primary energy factors specific to each energy carrier (e.g. electricity, heating oil, biomass, district heating and cooling). The Commission Delegated Regulation (EU) No. 244/2012 [4] and its accompanying guidelines [5] are referenced that recommend using the same primary energy factor (2.5) for delivered and for exported electricity.

The Commission recommendation (EU) 2016/1318 [6] also says that “In many cases, on-site renewable energy will not be sufficient to bring energy needs close to zero, without further energy efficiency measures or a significant decrease of primary energy factors for off-site renewable energy sources. Therefore, higher and more demanding requirements for highly efficient NZEB will also drive an increased use of on-building renewables and should result in adaptation of primary energy factors for off-site energy carriers, taking their renewable energy content into account.”

The Commission recommendation (EU) 2016/1318 [6] for NZEB definition supposes an evolution of primary energy factors in time, based on the off-site renewable energy sources to fulfil requirements on NZEB.

The advantages and disadvantages of application of different types of PEFs in ALDREN procedures for voluntary energy performance certificate are described in Table 15.

Table 15 Comparison of alternatives for primary energy factors and CO_2 emission coefficients

Alt.	Approach	Advantages of approach	Disadvantages
1	National PEF and CO_2 emission coefficients	✓ Link to national values	– No transparency today [1] – Not all types of PEF are available for calculation of the ratio of renewable energy (tot, nren, ren) – Need to adapt EU benchmark and the EU reference point to national PEFs (the energy classes at the national level are directly adapted to national PEF or by reference building)
2	Fixed common EU values (e.g. based on Annex B of EN ISO 52000-1:2017)	✓ Neutralisation of PEF allows to compare the quality of buildings and allows consistent comparison of technical systems (biomass, gas, electricity)	– The national PEFs were used for the national calculation of cost-optimal level of minimum requirements.
3	Calculation of PEF and CO_2 emission coefficient for each country based on the Eurostat data [25]	✓ transparent, consistent ✓ related to real country energy balance ✓ in line with Commission recommendation (EU) 2016/1318 [6] ensuring evolution in time ✓ if will become available at the European level, the hourly data is possible to use	– rules for calculation of PEF from Eurostat data [26] should be set, approach should be harmonised at EU level and with other projects (discussion started with H2020 project HybridGeotabs[2])

The primary energy factors for district heating systems have to be calculated according to CEN standard EN 15316-4-5:2017 [13]. The value for district heating and cooling is specific for each heat producer and should be provided by the district heating company. A default value of PEF=0,7 is recommended for production using combined heat and power (CHP), if no information is provided by district heating producer.

The fixed values according to Table 16, based on Annex B of EN ISO 52000-1:2017 [7], are used for the scale testing in Annex A to this study.

Table 16 Primary energy factors and CO_2 coefficients used for scale testing, based on EN ISO 52000-1

Type of factor / energy carrier	Gas	Combustible	Coal	Wood	Electricity
$PEF_{nren,}$ f_{pnren}	1.1	1.1	1.1	0.2	2.3
$PEF_{tot,}$ f_{ptot}	1.1	1.1	1.1	1.2	2.5
CO_2 K_{CO2e} (g/kWh)	220	360	360	40	420
PEF non-ren **exported** f_{pnren}	1.1	1.1	1.1	0.2	2.3
CO_2 - **exported** K_{CO2e} (g/kWh)	220	360	360	40	420

[1] New CEN standard is under development in CEN/TC 371/WG 1 “Energy performance of buildings — Determination and reporting of Primary Energy Factors (PEF) and CO2 emission coefficient –General Principles, Module M1-7” that could bring transparency in national primary energy factors

[2] http://www.hybridgeotabs.eu/

A1.4. Calculation methodology

The technical assessment of national calculation methodologies shows that not all Member states have a calculation compliant with the EPBD Annex I [35]. Several methodologies do either not cover all building categories or all technical systems. Lacks occur often in systems relevant for the non-residential building sector. More than half of the methodologies lack some aspects required by the EPBD Annex I, such as natural lighting and ventilation, RES solutions (wind, biofuel, CHP, district cooling), the correction of measured energy when used as energy performance indicator.

The ALDREN protocol for energy performance assessment is based on the latest CEN/ISO standards published in 2017 (M/480). It promotes a detailed energy calculation of the assessed building with an hourly time step. As software based on new set of CEN standards is not available, any software based on hourly step can be used as long as the software used produces the results that are consistent with CEN/ISO standards published in 2017 (M/480).

COMETh is the building physics model used in the French regulation RT2012 [17]. It is based on an energy balance calculation applied on homogenous thermal zones.

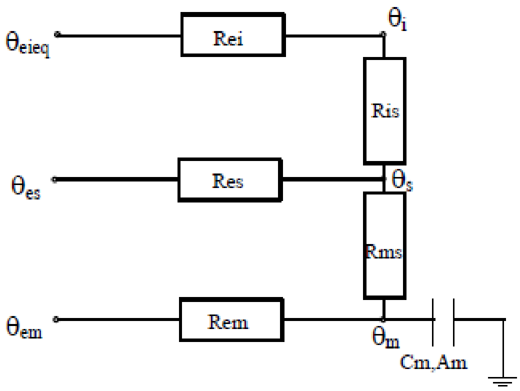


Figure 21 5RC network thermal model [17]

The main inputs of the model are the building envelope features, HVAC systems settings, climate data, uses and occupancy scenarios. Cooling and heating needs are calculated with the thermal model considering outdoor and indoor set-point temperatures. From these requested needs HVAC system operation is simulated at each time step. Distribution losses and systems efficiencies are considered providing the final energy consumption. COMETh is based on ISO 13790 standard and has been validated by a comparison with EN 15265 standard. Comparisons have also been made with reference software according to ASHRAE 140 standard [41].

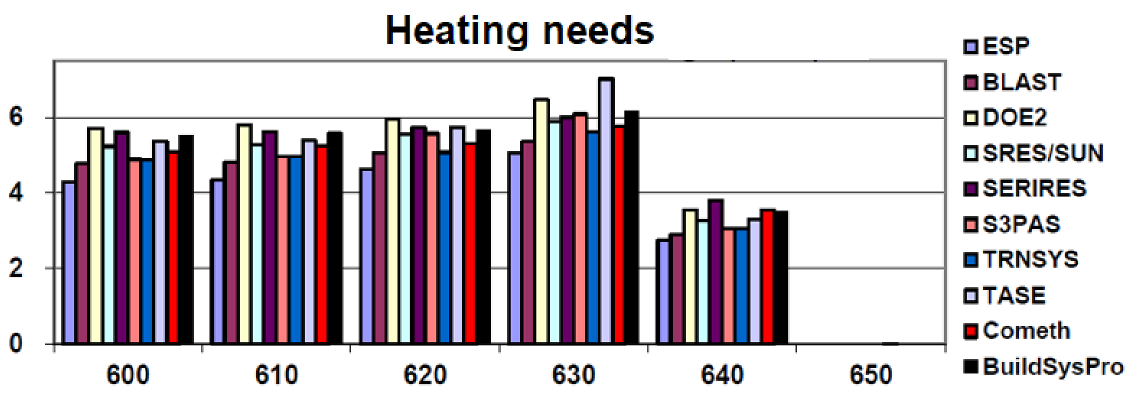


Figure 22 Validation of COMETh according to ASHRAE140 standard [41]

COMETh follows ALDREN's expectations concerning BES software which are related to hourly step calculations and consistency with EN standards.

A1.5 Climate data in the EVC

The testing study was conducted in three different locations: Bratislava (BRA), Palermo (PAL) and Helsinki (HEL). The required data were typical meteorological year (TMY), depicting typical conditions. They characterize average conditions but still representing consistent dynamic variations. They are commonly shaped by considering median months among a range of actual years' data and assemble with a mathematical process.

There are different formats of climate data used in different applications and software. These files are composed of hourly data including outdoor temperature, direct normal irradiation, diffuse irradiation, humidity, wind velocity and direction.

The reference years used for calculation of energy performance in ALDREN study is from the Joint Research Centre (JRC[3]). Data were selected based on the latitude and longitude. Downloaded .csv files were transformed to .ray files needed by the used BES software COMETh.

Meteorological data for hourly calculation

The European Commission, the Joint Research Centre, has developed climate data for Europe that should be used for the EVCS and ALDREN energy calculation.

A typical meteorological year (TMY) developed by JRC is defined as "a set of meteorological data with data values for every hour in a year for a given geographical location. The data are selected from hourly data over a longer time period (usually 10 years or more). For each month of the typical meteorological year the data have been selected from the year that was considered the most "typical" for that month. For example, January might be from 2007, February from 2012 and so on".

The sources of data are described in TMY Generator[4]. The source for solar radiation data is a satellite-derived solar radiation database, other climatic parameters are from other climate databases, possibly corrected for elevation (e.g., temperature). These data are combined to produce typical meteorological years for the exact location.

Several data will be provided for the selected location: elevation (in meters above sea level), average temperature (in °C), Heating Degree Days (HDD, using 15° as a base temperature) and Cooling Degree Days (CDD, using 24° as a base temperature).

The output in the .epw format needed for EnergyPlus or a generic .csv format can be chosen. The datasets are in formats directly usable with the main building energy simulation software (e.g. EnergyPlus, TRNSYS, IDA-ICE).

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[3] http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

[4] https://re.jrc.ec.europa.eu/pvg_tools/en/#TMY

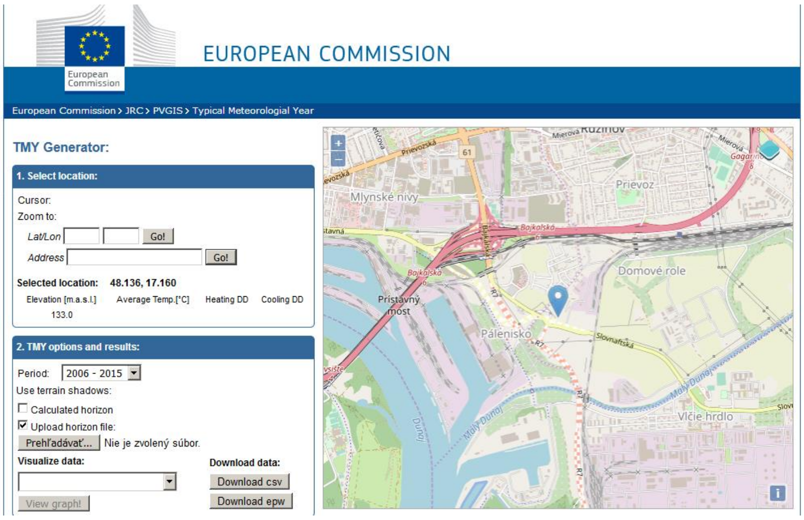


Figure 23 TMY Generator developed by the Joint Research Centre (Source: JRC)

The locations used for scale testing are based on the JRC Typical Meteorological Year (TMY) for these three sites:

Bratislava (BRA)	**Palermo (PAL)**	**Helsinki (HEL)**
 48.1486° N, 17.1077° E	 38.1157° N, 13.3615° E	 60.1699° N, 24.9384° E

Figure 24 Latitude and longitude used for climate data (TMY) extraction

Assignment of the assessed building to the climate zone

Climate zones based on administrative division are not suitable for the energy performance of buildings.

Heating degree days (HDD) are designed to describe the heating energy needs. Cooling degree days (CDD) are designed to describe the cooling (air-conditioning) needs of buildings. The heating degree days are often used for division into climate zones (e.g. Italy).

Eurostat provides HDD and CDD derived from meteorological observations of air temperature, interpolated into regular grids with a resolution of 25 km for Europe [19]. Data is available since January 1974. The data collection process is established and managed by the Joint Research Centre. The extract from the database with the Average Heating Degree Days for EU Member States is in Table 17 and Figure 25.

Table 17 Average Heating Degree Days in EU countries by Eurostat [19]

Country	Average Heating Degree Days (1974-2017) (θ=18°C)
Malta	556
Cyprus	788
Portugal	1271
Greece	1720
Spain	1861
Italy	2063
France	2498
Croatia	2509
Bulgaria	2659
Belgium	2822
Hungary	2860
Ireland	2864
Netherlands	2869
Slovenia	3042
Luxembourg	3070
United Kingdom	3121
Romania	3146
Germany	3202
European Union - 28 countries	3222
Slovakia	3390
Denmark	3449
Czechia	3501
Poland	3561
Austria	3715
Lithuania	4056
Latvia	4229
Estonia	4405
Sweden	5353
Finland	5778
Min	556
Max	5778

The analysis of different sources (Eurostat [19], Ecofys [27], Commission Recommendation for NZEB [6], national climate zones for Italy, Spain and France) was the basis for setting the rules for assigning a specific location into three ALDREN climate zones for EVC rating and scale.

The heating degree-days (HDD) for assignment of the assessed building to the ALDREN climate zone are calculated according to Eurostat (JRC) rules from the Typical Meteorological Year (TMY) used by software for energy calculation.

The intervals for climate zones are presented in Table 18.

Table 18 Intervals for distribution of building locations into three ALDREN climate zones

ALDREN climate zone		HDD from reference year used for calculation of EP (θ_i =18°C, base temperature 15°C) in K.day
Zone 1	Warm	≤ 1200
Zone 2	Moderate	1201 - 4000
Zone 3	Cold	> 4000

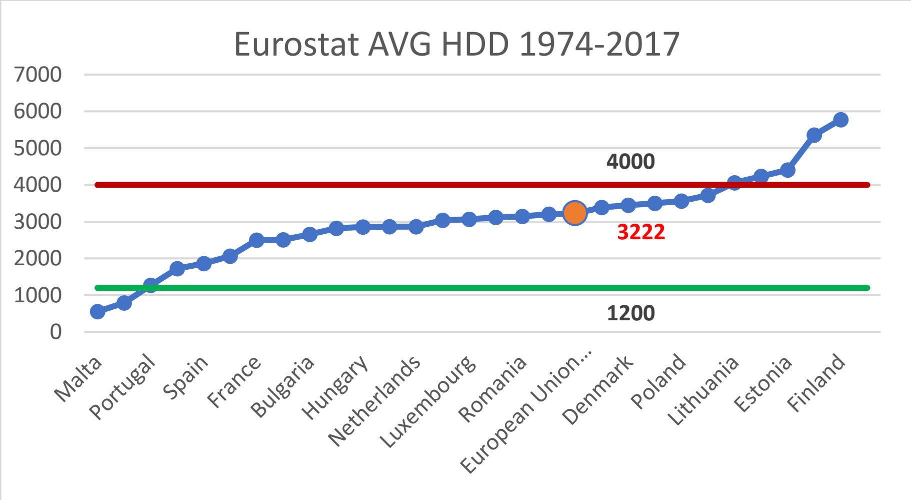


Figure 25 Average heating degree-days per country (Source: Eurostat [19])

The steps to assign a specific building location to ALDREN climate zone are:

- based on the .csv file with the Typical Meteorological Year (TMY) used for calculation:
  - Identify the external temperature for each hour (8760 h)
  - Calculate the HDD using the Eurostat (JRC) rules [19] for the mean air temperature of the day: If $T_m \leq 15°C$, then [$HDD = \sum_i(18°C - T^i_m)$], otherwise [HDD = 0], where T^i_m is the mean air temperature of the day i.
- Assign the building to the zone according to the intervals in Table 18.

The calculation of the HDD is based on the base temperature, which is defined as the lowest daily mean air temperature that does not lead to the indoor heating. The real value of the base temperature depends on several factors associated with the building and the surrounding environment. By using a general climatological approach, the base temperature in the HDD calculation is set to a constant value of 15°C [19].

The heating degree-days used for calculation of model buildings in this study are in Table 19.

Table 19 The heating degree-days for calculation of model buildings in three climate zones

Model building location	HDD obtained from the TMY used for energy calculation	ALDREN Climate Zone	
Palermo	864 K.day	Zone 1	Warm
Bratislava	3040 K.day	Zone 2	Moderate
Helsinki	4128 K.day	Zone 3	Cold

A1.6 Occupancy, uses and internal gains

Conventional occupancy and use scenarios have to be defined in the simulation software in order to depict the standard conditions for energy calculation. The national standard conditions shall be used for ALDREN energy performance calculation. European standards can be referred to, if the national standard inputs are not conforming to the simulation tools' expectations. In fact, the hourly data are not available in every Member State. The standard conditions aim to provide reference uses in order to compare the results within and among countries.

French RT2012 [17] can provide scenarios for offices and hotels. These hourly data concern heating and cooling set-point temperatures, occupancy hours, internal loads and DHW drawings.

These sets of scenarios are defined for several building uses, from residential housing to school buildings.

The use patterns for the scale testing are related to the use scenarios for offices and hotels. For hotels, the data on use is defined according to the number of stars and a distinction is made between day-uses (reception, catering, circulations, WC) and night-uses (bedrooms, circulations, WC). Three-stars hotels are considered for the model buildings calculation for testing the scale for hotels.

The scenarios used for the scale testing are summarised in Table 20, both for offices and hotels. The Figure 26 shows the hourly standard internal gains used in the hotel's zones during the occupancy and vacancy periods.

Table 20 General scenarios settings for offices and hotels

Settings	**OFFICES**	**HOTELS Day Use**	**HOTELS Night Use**
Occupation range	Mon.-Fri. 8-18	6-20	18-9
Heating set-point temperature	20/16/7	20/16/7	20/16/7
Cooling set-point temperature	26/30/30	26/30/30	26/30/30
Lighting schedules	Mon.-Fri. 8-18	6-20	7-9/19-23
Ventilation schedules	Mon.-Fri. 8-18	6-20	0-24
Nominal occupancy (per/m²)	0.1	0.28	0.032
Internal loads - occupation (W/m²)	10.6	16.48	3.22
Internal loads - inoccupation (W/m²)	9.6	6.76	1.22
Weekly DHW needs (40 °C)	1.25 l/m²	0.24 l/m²	655.2 l/room

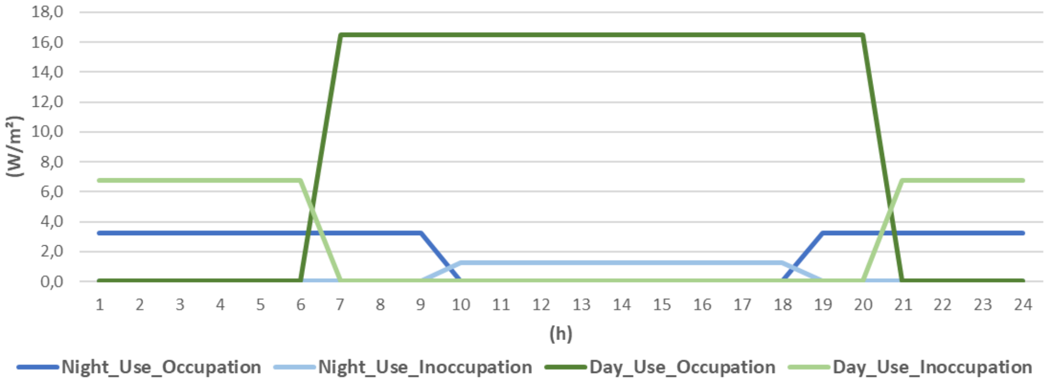


Figure 26 Standard internal gains in hotels [17]

A1.7 Software for testing the scale

CYPE solutions have been used for building modelling and simulation. IFC Builder is a 2D/3D building modelling software. The geometry modelling obtained with this software is converted in order to run energy simulation.

CYPETHERM COMETh [49] is a building energy simulation (BES) software using COMETh engine, that is the basis of French regulation RT2012. Based on the geometry modelling, building the envelope components and energy systems are described. Inputs on the internal and external conditions are necessary to run the simulation. Internal conditions are related to the uses and standard scenarios previously discussed. External conditions concern the hourly climate data. An annual calculation of energy needs and use is conducted with an hourly time step. The evaluated energy use is related to heating, cooling, ventilation, lighting, domestic hot water (DHW) and the auxiliary energy.

The dynamic calculation integrates energy losses from distribution networks, mechanical and natural air exchanges, solar and lighting gains in the overall energy balance. Different thermal groups can be specified. In each group are described the systems related to lighting, ventilation, DHW, heating and cooling. Group and intergroup networks are specified. Heating and cooling periods as well as the scenarios presented above are also filled in.

The output of BES software is the final energy consumption. A post-calculation is processed with Excel to obtain the primary energy use from primary energy factors (PEF) according to the methodology described above.

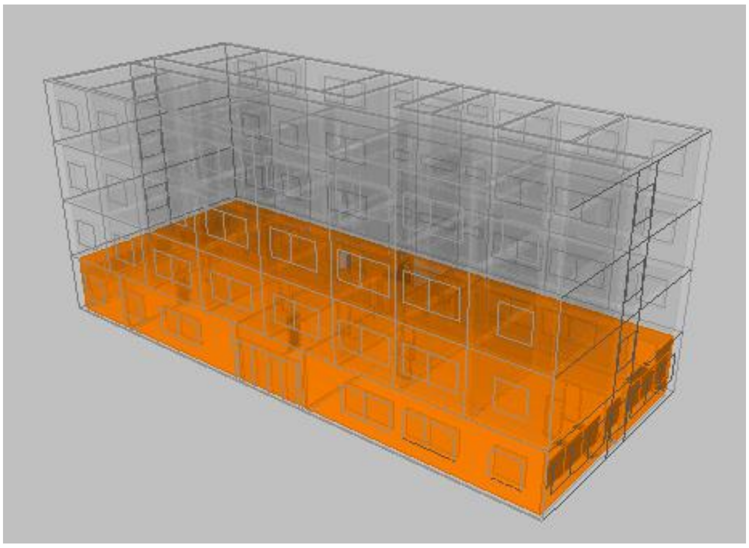


Figure 27 3D view of building in CYPETHERM COMETh software [49]

It was assumed in the project proposal, that by the end of the project the building energy simulation software fully based on EPB standards developed under mandate M/480 will be available. This did not happen.

A2 Model buildings for testing the scale

The energy rating scale was tested on several model buildings. The aim was to depict a consistent sample of existing buildings for testing the scale. The model buildings are of relatively compact shape and differ mostly in the size (number of floors, total floor area, construction height) with the impact on the shape factor.

The properties of the building components and the geometry are based on the review of the national reports from the cost-optimal level of energy performance calculation in 2013 [22] by Member states. The definition of typical national existing buildings was required from Member States by Regulation No. 244/2012 [4]. The diversity in geometry indicates the sensitivity of energy performance to the size of buildings.

The EVC rating scale was tested in each of three climates on:

- 5 office buildings
- 3 hotel buildings

The shape of the hotel buildings is similar to offices, but the indoor conditions and the distribution of spaces is related to specific uses of hotels.

These different levels of building envelope quality and technical systems were defined for 3 climate zones and have been applied to model buildings:

- **existing building** (EX) – initial stage, baseline based on the description of typical existing buildings in national reports from cost-optimal level calculation in 2013.
- **CO(2013)** – approximately a cost-optimal level of energy performance based on national reports from calculation in 2013, which correspond to the reference value on the scale (energy class “D”).
- **NZEB** – a target based on national definitions and best practices for NZEB

All levels of envelope and technical systems, EX, CO(2013) and NZEB, are combined with the production of PV electricity as one of the measures. Auto-consumption by building of electricity produced on-site and exports were calculated in each hour.

The building envelope features, energy systems specifications, climate data and use scenarios, presented above, are specified as inputs in the BES software CYPETHERM COMETH.

The renovation steps have been identified with the main target to achieve at least 60% of primary energy savings or the ALDREN NZEB level.

The EPBD asks MSs to set the NZEB level as a minimum requirement from 31.12.2020 onwards and to ensure that also all existing buildings undergoing major or deep renovation are renovated to the same level if it is economically, technically and operationally feasible.

The main target of ALDREN’s renovation strategies is the ALDREN **energy class “A”,** which is the approximation to the national NZEB level. Due to the different input parameters, calculation methods, boundary conditions and indicators used in the national NZEB definitions, the ALDREN NZEB is not necessarily in compliance with the national NZEB definition. The building renovation designer must ensure that the national minimum requirements for existing buildings are met.

A2.1 Offices

The reference value for ALDREN energy rating scale for office buildings has been determined on the basis of the calculation of five model buildings. The geometry of the model office buildings is presented in Table 21 and Figure 28. The floor area is between 1 440 m² and 11 880 m² which corresponds to a shape factor from 0.462 to 0.240.

Offices are simulated with a single zone, because the use is considered homogeneous throughout the building.

Table 21 Geometry of model office buildings

Parameter		B1a	B1b	B2	B4	B6
Number of floors		4	4	7	5	11
Floor height	m	3	3.3	3.3	3.3	3.3
Gross Internal Floor Area (GIA) (typical floor)	m²	360	360	360	1 080	1 080
Total Gross Internal Floor Area (GIA)	**m²**	**1 440**	**1 440**	**2 520**	**5 400**	**11 880**
Building Volume	m³	4 320	4 752	8 316	17 820	39 204
Shape factor (A_e/V_b)	1/m	0.462	0.446	0.368	0.327	0.240
Net Internal Floor Area (NIA)	**m²**	**1 365**	**1 365**	**2 384**	**5 133**	**11 291**
Share of transparent constructions from the building envelope	**%**	25.6	24.1	29.2	18.0	24.5

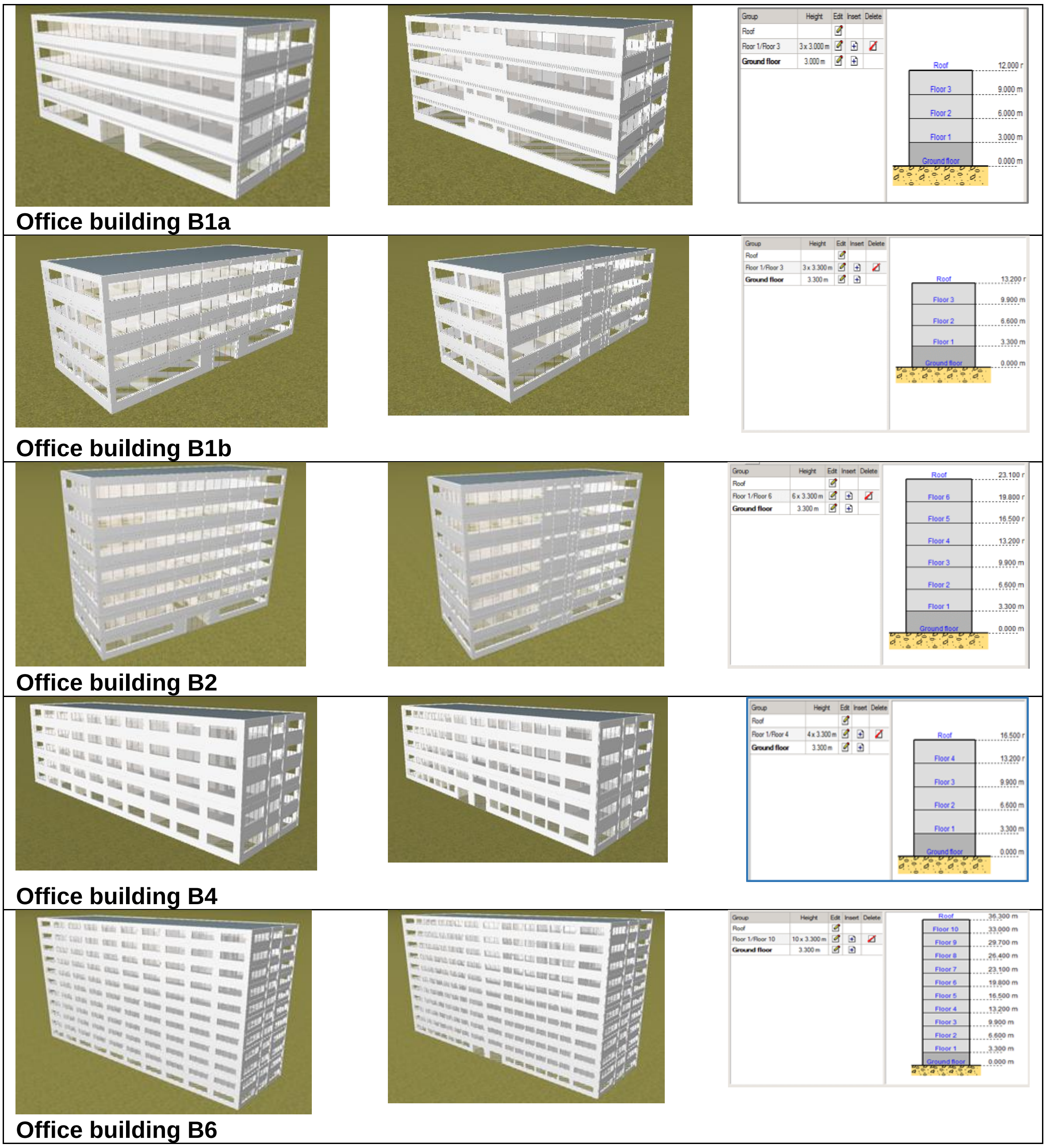


Figure 28 Model office buildings for scale determination and testing

A2.2 Hotels

The reference value for ALDREN energy rating scale for hotels has been determined on the basis of the calculation of 3 different model hotel buildings.

The geometry of the hotel buildings is similar to offices presented above, but the layout of the interior spaces is related to the specific use of the hotels. Façades are also different, with a lower proportion of glazed area for hotels compared to offices. The hotel buildings are divided into 2 zones. The ground floor of the hotel buildings is linked to the "day use" of French RT2012 standard scenarios. The other floors are gathered in one "night use" zone.

The hotel's energy uses actually include the hosting and non-hosting functions. In line with the recommendation of Hotel Energy Solutions (HES)[5] , only the hosting functions (guests' rooms, reception hall, offices, bar, restaurant, sitting rooms, meeting rooms) are included in the calculation of energy performance of hotel buildings .

Non-hosting functions (kitchen, laundry, swimming pool, spa, technical rooms, sauna, gym) are not included in the calculation of energy performance, because they are of a technological nature and cannot be regulated in connection with the building itself.

Features of model hotel buildings and drawings are presented in Table 22.

Table 22 Geometry of model hotel buildings

		B1b	B4	B6
Number of floors		4	5	11
Floor height	m	3.3	3.3	3.3
Gross internal Floor Area (GIA) (typical floor)	m²	360	1 080	1 080
Total Gross Internal Floor Area (GIA)	**m²**	**1 440**	**5 400**	**11 880**
Volume	m³	4 752	17 820	39 204
Form factor (A_e/V_b)	1/m	0.446	0.324	0.238
Net Internal Floor Area (NIA)	**m²**	1 365	5 133	11 291
Share of transparent constructions from building envelope	**%**	13.6	12.1	16.4

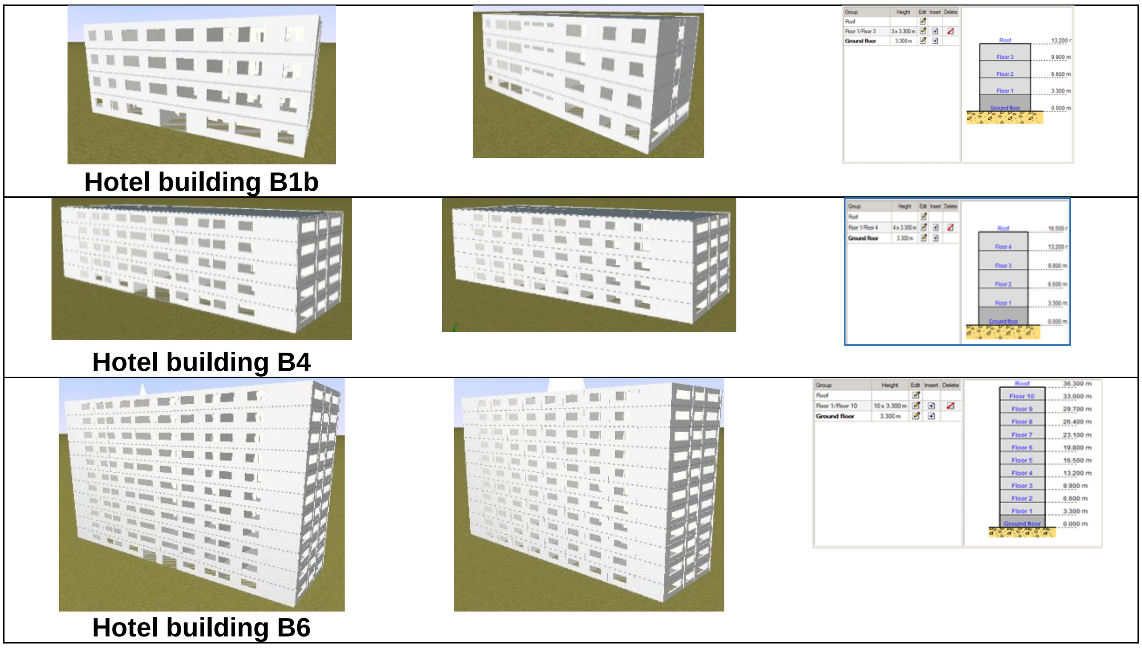


Figure 29 Model hotel buildings for scale determination and testing

[5] http://hotelenergysolutions.net/content/nearly-zero-energy-buildings-nzeb

A2.3 Definition of existing building levels for testing the scale

Different configurations of typical existing buildings for each climate zone were identified and calculated in order to determine and test the energy rating scale. Typical existing buildings (EX) were defined as the average state of old existing buildings where there were no renovation actions conducted. The corresponding features have been defined on the basis of an review of EU countries' 2013 reports on cost-optimal level of energy performance calculation [22] and complementary studies were used to complete this source of data.

Questionnaires were filled in by consortium partners representing involved Member States (Slovakia, France, Spain) on the characteristics of typical old existing office and hotel buildings in their country.

Building envelope

The considered characteristics for existing buildings take into account a different climate zone. The main features of existing buildings' envelopes in Bratislava (BRA), Palermo (PAL) and Helsinki (HEL), considered as the inputs in the BES software, that are based on the description of existing buildings in the specific national reports from cost-optimal level calculation (2013) are presented in Table 23.

Table 23 Envelope characteristics for existing buildings in three climate zones

Climate	Bratislava (BRA)	Palermo (PAL)	Helsinki (HEL)
Parameter	Initial state: average existing building in CO report (2013), Slovakia	Initial state: average existing building in CO report (2013), Italy	Initial state: average existing building in CO report (2013), Finland
Envelope			
U value-walls (W/(m².K))	1.45	1.53	0.29
U-value roof (W/(m².K))	1.00	1.20	0.23
U-value floor (W/(m².K))	0.42	0.49	0.37
Thermal bridges	EPB standard detailed calculation		
Windows-doors			
U-value-doors (W/(m².K))	4.30	4.30	2.50
U-value-windows (W/(m².K))	2.70	4.00	2.10
Solar heat gain coefficient	0.78	0.87	0.72
Transmittance τ_{eff}	0.82	0.9	0.74
Type of windows	Double glazing - old simple	simple glazing	Double glazing
Air tightness			
Air tightness airflow rate $q_{ve,k}$ ((m³/h)/m²)	1.7	1.2	1.2

HVAC systems and domestic hot water preparation

Energy systems included in the calculation of existing model buildings are listed in Table 24. Heating is provided by a standard gas boiler with water distribution. Although cooling systems are not always installed in old buildings in Europe, individual chillers are modelled in order to cover the same uses and provide the same comfort in all model buildings. This assumption allows a fairer comparison of energy performance.

Table 24 HVAC systems considered for calculation of existing office and hotel buildings

EXISTING	Heating	Cooling	Ventilation	Hot water
Generation System	Standard old gas boiler	Individual split units	Natural ventilation	Standard old gas boiler
Distribution	Water bi-tube. High temperature.	Direct air distribution		Distribution network
Emission	Old standard radiators	Air-conditioning diffusers		Standard taps
Control	-	-	-	-

Lighting

Configurations of lighting equipment and controls in existing office and hotel buildings considered for calculation of model buildings are presented in Table 25. Two different zones and associated equipment are considered in hotels. They are related to day-use (reception, offices) and night-use (circulations and bed rooms). The same settings were defined for all three climates.

Table 25 Lighting systems considered for calculation of existing office and hotel buildings

EXISTING - OFFICES	Office rooms	WC	Corridors
Equipment	Fluorescent tube, incandescent lamps		
Power (W/m²)	25	30	8
Control	Manual control		

EXISTING – HOTELS - DAY USE	Office rooms	WC	Entrance
Equipment	Fluorescent tube, incandescent lamps		
Power (W/m²)	25	30	25
Control	Manual control		
EXISTING – HOTELS - NIGHT USE	**Bed rooms**	**WC**	**Corridors**
Equipment	Fluorescent tube, incandescent lamps		
Power (W/m²)	15	30	8
Control	Manual control		

A2.4 Definition of cost-optimal levels for scale determination and testing

The approximate cost-optimal level of energy performance in 2013 for offices and hotels is another level that has been identified for the configuration for each climate zone in order to determine and test the energy rating scale.

Calculation of the cost-optimal level of energy performance by Member States under Regulation no. 244/2012 [4], is based on costs optimization over 20 years for non-residential buildings. This calculation is based on important assumptions, including the evolution of energy costs. Member States have provided the Commission with reports presenting typical solutions corresponding to cost-optimal buildings in their own national context. Based on these reports, which are public, the model buildings for cost-optimal level were identified.

Because of unified and transparent approach based on EU Regulation [4], the approximation to the cost-optimal level calculated in 2013 is proposed to be the reference point on the ALDREN rating scale (energy class “D”).

Building envelope

Some of the input parameters for the envelope **depend on the climate** (e.g. U-values). Regression formulas for the calculation of U-values for external envelope elements of model buildings, depending on heating degree-days, were derived from national reports on the cost-optimal level of energy performance calculation (2013). A graphical illustration of the regression curves for the calculation of U-values as a function of the heating degree-days is shown in Figure 30.

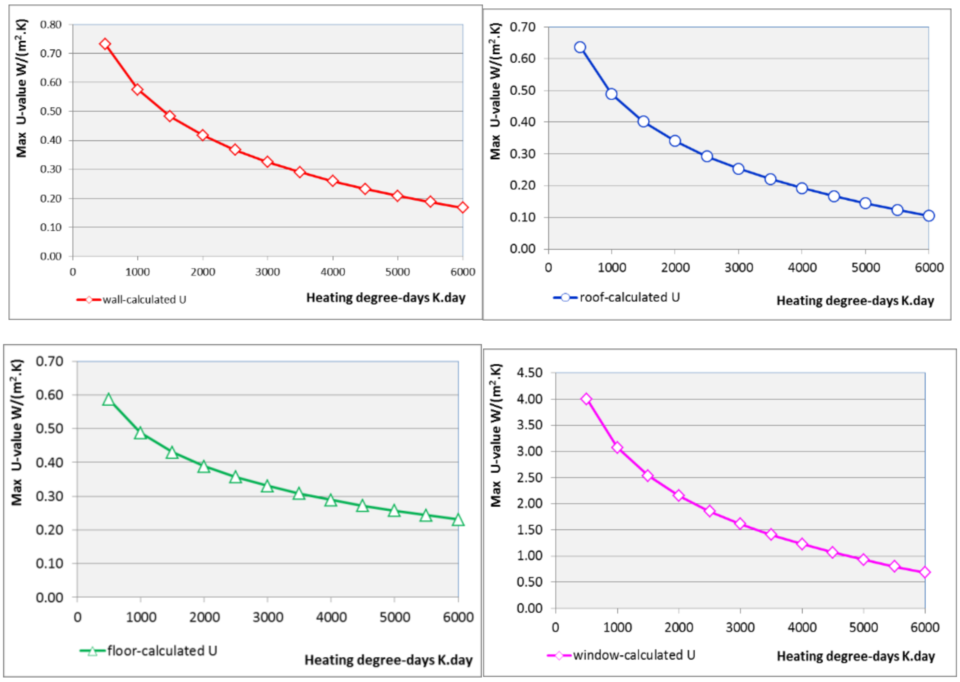


Figure 30 U-values depending on heating degree-days [36]

The U-values for Bratislava and Palermo were calculated based on HDD and compared with the national reports. For Helsinki, the U-values from Report on the cost-optimal level calculation were considered.

The envelope of a cost-optimal building includes well-insulated walls and roof with a climate-dependent insulation thickness. In addition, energy efficient double glazing is a general rule, as well as better control of air exchange by mechanical ventilation and improved air tightness. The main features of cost-optimal model buildings that were inputs to the calculation software are listed in Table 26.

Table 26 Envelope characteristics for cost-optimal buildings in three climate zones

Climate	**Bratislava (BRA)**	**Palermo (PAL)**	**Helsinki (HEL)**
Parameter	CO reports (2013)		
Envelope			
U value-walls (W/(m².K))	0.26	0.56	0.19
U-value roof (W/(m².K))	0.20	0.48	0.14
U-value floor (W/(m².K))	0.27	0.46	0.23
Thermal bridges	EPB standard detailed calculation		
Windows-doors			
U-value-doors (W/(m².K))	2.50	4.00	1.00
U-value-windows (W/(m².K))	1.25	3.00	0.87
Solar heat gain coefficient	0.65	0.78	0.5
Transmittance τ_{eff}	0.78	0.82	0.69
Type of windows	Double glazing - new selective layers	Double glazing	Double glazing - new selective layers
Air tightness			
Air tightness airflow rate $q_{ve,k}$ ((m³/h)/m²)	1.2	1.2	1.2

HVAC systems and domestic hot water preparation

The energy systems of typical cost-optimal buildings considered in the calculation of model buildings are described in Table 27. Heating and cooling are provided by a condensing gas boiler and a centralized efficient cooler. Similar HVAC systems were considered for offices and hotels.

Table 27 HVAC systems considered for calculation of cost-optimal (2013) office and hotel buildings

COST-OPTIMAL	Heating	Cooling	Ventilation	Hot water
Generation System	Condensing gas boiler	Standard cooler	Simple flow extraction	Electric heater with storage
Distribution	Water bi-tube. Intermediate temperature. Good insulation	Water distribution	-	Direct drawings
Emission	Efficient radiators	Fan coils	-	Low-consumption taps
Control	Night and weekend setback	Night and weekend setback	Only during occupation time	-

Lighting

Configurations of lighting equipment and controls in cost-optimal office and hotel buildings considered for calculation of model buildings at the cost-optimal level are presented in Table 28. LED lamps are used in all spaces with automatic occupancy detection control.

Table 28 Lighting systems considered for calculation of cost-optimal office and hotel buildings

CO - OFFICES	Office rooms	WC	Corridors
Equipment	LED		
Power (W/m²)	10	10	5
Control	Automatic occupancy detection		

CO – HOTELS - DAY USE	Office rooms	WC	Entrance
Equipment	LED		
Power (W/m²)	10	10	10
Control	Automatic occupancy detection		
CO – HOTELS - NIGHT USE	**Bed rooms**	**WC**	**Corridors**
Equipment	LED		
Power (W/m²)	8	10	5
Control	Automatic occupancy detection (WC, corridors)		

A2.5 Definition of NZEB building levels for scale testing

According to EPBD [2], the Nearly zero-energy building (NZEB) means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The implementation of this definition at the national level by Member States can differ in terms of requirements, indicators and calculation method.

ALDREN NZEB is defined by four indicators as described in protocol in chapter 4.2. Energy class “A” has to be achieved for the primary energy.

ALDREN protocol requires that the recommendations for deep renovation presented in certificate are towards the NZEB performance level.

Questionnaires were filled in by consortium partners representing involved Member States (Slovakia, France, Spain) on the characteristics of NZEB and best practice for office and hotel buildings in their country.

Technical measures for improvement of energy performance of existing buildings to NZEB are divided in 7 main areas:

- Envelope
    - external walls
    - windows.
    - roof
    - basement, floor at the ground
    - thermal bridges
    - shading
- Heating systems
    - generation
    - distribution
    - emission
    - storage
- Domestic hot water preparation
    - generation
    - distribution
    - emission
    - storage
- Cooling and ventilation systems
- Lighting
- Control system
- Renewable energy sources (RES).

Building envelope

The considered characteristics for the calculation of NZEB model buildings are shown in Table 29. Intermediate states, (Steps 1 and 2), corresponding to the renovation packages, were also calculated for model buildings and are presented in Table 29.

Increased insulation thickness, reduced thermal bridges, triple glazing and reduced air leakage are among the main features of the envelope at the NZEB level. Triple glazed windows reduce the energy losses but also reduce the solar gains.

Table 29 Building features of NZEB buildings and intermediate renovated states towards NZEB

	Bratislava (BRA)			Palermo (PAL)			Helsinki (HEL)		
	Step 1	**Step 2**	**NZEB**	**Step 1**	**Step 2**	**NZEB**	**Step 1**	**Step 2**	**NZEB**
Envelope									
U value-walls (W/(m².K))	EX	0.19	0.19	EX	0.32	0.32	EX	0.17	0.17
U-value roof (W/(m².K))	EX	0.15	0.15	EX	0.27	0.27	EX	0.09	0.09
U-value floor (W/(m².K))	EX	0.25	0.25	EX	0.32	0.32	EX	0.23	0.23
Windows-doors									
U-value-doors (W/(m².K))	EX	2.00	2.00	EX	3.00	3.00	EX	1.00	1.00
U-value-windows (W/(m².K))	1.00	1.00	1..00	2.20	2.20	2.20	0.80	0.80	0.80
Solar heat gain coefficient g-value	0.50	0.50	0.5	0.72	0.72	0.72	0.5	0.5	0.5
Transmittance τ_{eff}	0.69	0.69	0.69	0.74	0.74	0.74	0.69	0.69	0.69
Type of windows	Triple glazing	Triple glazing	Triple glazing	double glazing	double glazing	double glazing	Triple glazing	Triple glazing	Triple glazing

	Bratislava (BRA)			Palermo (PAL)			Helsinki (HEL)		
Ventilation									
Air tightness, airflow rate $q_{ve,k}$ ((m³/h)/m²)	1,0	1,0	1,0	1,0	1,0	1,0	0,6	0,6	0,6
Systems									
Heating	EX	EX	NZEB	EX	EX	NZEB	EX	EX	NZEB
Cooling	EX	EX	NZEB	EX	EX	NZEB	EX	EX	NZEB
Ventilation	EX	EX	NZEB	EX	EX	NZEB	EX	EX	NZEB
DHW	EX	EX	NZEB	EX	EX	NZEB	EX	EX	NZEB
Lighting	EX	EX	NZEB	EX	EX	NZEB	EX	EX	NZEB

HVAC systems and domestic hot water preparation

The configurations of the energy systems to be considered in the calculation of typical NZEB buildings were investigated in a questionnaire. A dual service heat pump was chosen for both, heating and cooling. Energy losses are also reduced by a double flow ventilation system with heat recovery.

Table 30 HVAC systems considered for calculation of NZEB office and hotel buildings

NZEB	Heating	Cooling	Ventilation	Hot water
Generation System	Dual service Heat pump	Dual service Heat pump	Double flow ventilation	Electric heater with storage
Distribution	Water bi-tube. Low temperature. Good insulation	Water distribution	-	Direct drawings
Emission	Efficient radiators	Fan coils	-	low-consumption taps
Control	Night and weekend setback	Night and weekend setback	Only during occupation time	-

Optimised control of the HVAC system was considered in calculation of NZEB buildings. In offices, the heating and cooling set-point temperatures are reduced during inoccupation periods. The reduced distribution water temperature, combined with the low-temperature radiators, allow the energy use for heating to be reduced. In addition, ventilation is on only during working daytime.

Reduced set-point temperatures are also modelled in both, day and night areas of use in hotels. Controls of the double flow ventilation are also considered with fans working only during the occupation time in the day-use spaces.

Lighting

The following tables present lighting equipment and controls in existing buildings for offices and hotels configurations.

Configurations of lighting equipment and controls at the NZEB level for office and hotel buildings considered for calculation of model buildings are presented in Table 31.

Table 31 Lighting systems considered for calculation of NZEB office and hotel buildings

NZEB - OFFICES	Office rooms	WC	Circulations
Equipment	LED		
Power (W/m²)	10	10	5
Control	Automatic occupancy detection		

NZEB – HOTELS - DAY USE	Office rooms	WC	Entrance
Equipment	LED		
Power (W/m²)	10	10	10
Control	Automatic occupancy detection		
NZEB – HOTELS - NIGHT USE	**Bed rooms**	**WC**	**Corridors**
Equipment	LED		
Power (W/m²)	8	10	5
Control	Automatic occupancy detection (WC, corridors)		

Renewable energy sources

The NZEB can be only achieved with the on-site renewable energy production. A feasible solution for offices and hotels is the production of electricity from PV. For hotels, thermal solar energy production for the hot water preparation is also a feasible solution.

PV electricity production

PV power plants are integrated in order to compensate the building primary energy balance. PV panels installed on the building's roof produce renewable energy. A medium-efficiency plant is taken into account composed of multi-crystallin panels with a nominal yield around 17 %. A 30° inclination optimizes the electricity production. The occupied roof area is around 340 m² for the smallest building (B1). Details of the panels and of the whole plant are presented in the Table 32.

Table 32 Characteristics of the PV electricity production plant

PV panel	
PV panel area (m²)	1,63
PV panel power (Wc)	270
PV panel technology	Multi-crystallin
PV panel reference	Viessmann Vitovolt 300 P270
Transmission-absorption coefficient	0,9
rear face confinement	medium
performance indicator (power/area) (Wc/m²PV)	165,6
PV plant	
Direction (0° south)	0
Inclination (0° horizontal)	30
ratio of lost area	0,2
Number of PV panels	200
Total power (Wc)	54000
Total PV area (m²)	326,0
Occupied roof area (m²)	338,8
Inverter	
Inverter power (W)	50000
Inverter efficacity	0,95

The production of this PV power plant is simulated with the three standard climate data for Bratislava, Palermo and Helsinki. The same plant and panel's area are modelled for each building. A configuration with a doubled area is also studied on the largest B6 buildings.

Solar thermal energy for DHW

Thermal solar collectors are also simulated in hotels to provide a part of energy demand for domestic hot water (DHW). This use represents a major part of energy uses and is difficult to reduce due to the necessary water consumption from hotels customers. Part of the thermal panels is associated to a storage tank allowing water pre-heating. The system configuration is shown on the Figure 31.

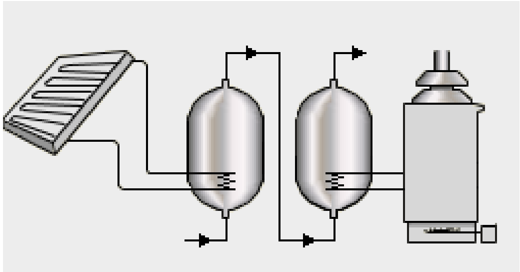


Figure 31 Scheme of the DHW system integrating the solar thermal plant [49]

The system has been sized according to simplified expert rules in order to optimize the performance of the system. The main settings used in the simulation software are presented in the Table 33. Even if their DHW needs are different, buildings B4 and B6 have the same roof area.

Table 33 The characteristics of the solar thermal plant for hotels

Parameter/Building	B1b	B4	B6
Thermal panels			
Area (m^2)	30	100	100
inclination	45°		
Main DHW storage			
Volume (l)	500	1 200	2 500
Pre-heating storage			
Volume (l)	1 500	5 000	5 000

A2.6 Parameters influencing energy performance

The sensitivity analysis of some parameters is presented in next chapters.

Geometry

The geometry of existing buildings cannot be significantly influenced by renovation. The same improvement of thermal envelope and systems could not be enough to achieve the targets for all building geometries. The size and shape factor of model office buildings for ALDREN scale testing are in Figure 32.

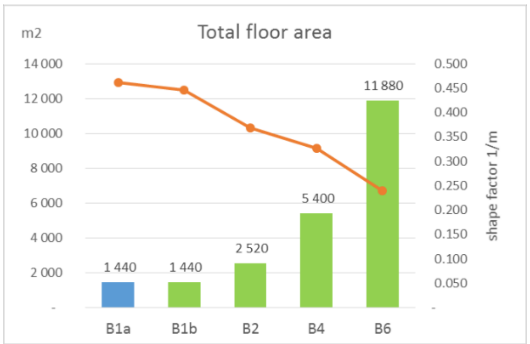


Figure 32 The size and shape factor of model office buildings for scale testing

Most important geometric parameters influencing energy performance are:

- the size and compactness of the building, that has an influence on the ratio of thermal envelope to volume (shape factor),
- the height of the floor, that may vary for office and hotel buildings (e.g. from 3 to 5 m) with a huge impact on energy expressed in kWh/(m^2.a),
- the ratio of transparent constructions of the building envelope,
- combination of parameters, e.g. a better shape factor for heat losses is worse for the availability of daylight.

The impact of building size, compactness and floor height (smaller height for buildings B1) on the final energy of model buildings is evident from Figure 33.

In case of old existing buildings, in the state before renovation (EX), the impact is high. By improvement of envelope properties by renovation this impact is neutralised, so that the NZEB buildings are insensitive to the geometry of the buildings. The differences are small, that allow the use of absolute values for requirements for high-performance buildings (NZEB) without taking into account the geometry.

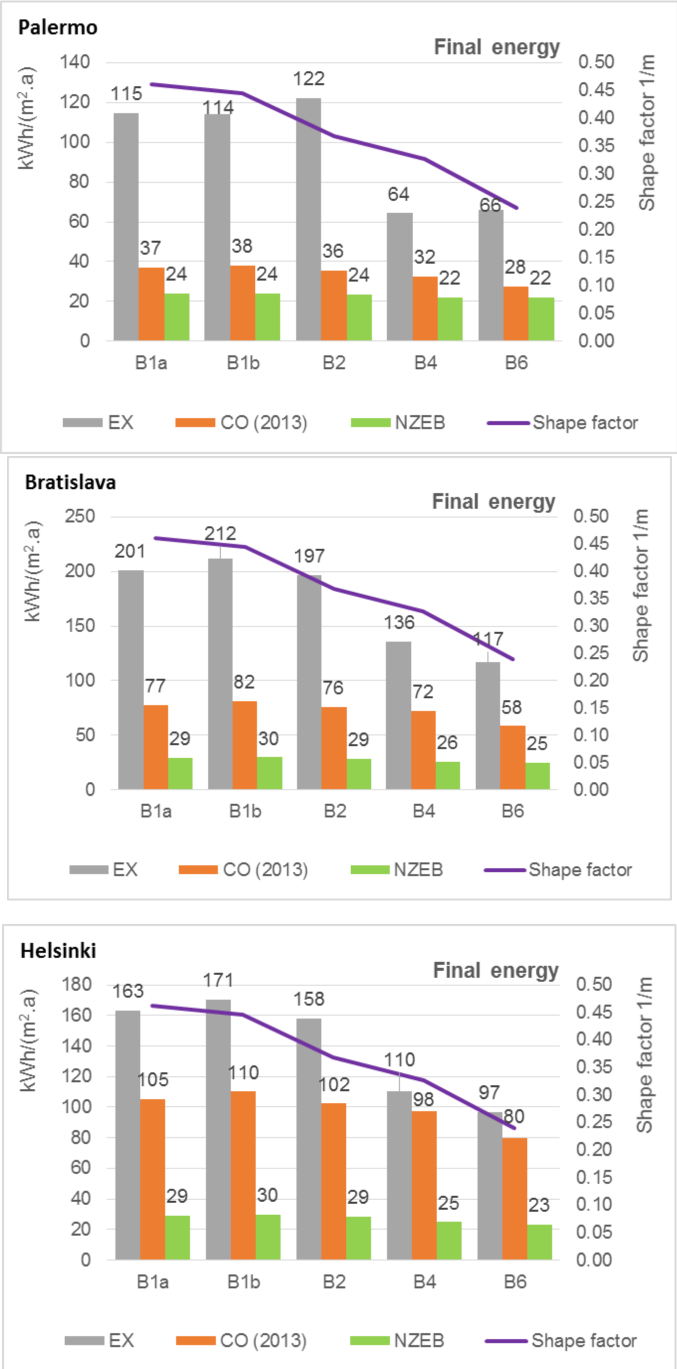


Figure 33 Final energy of model buildings of different geometry in different climates

Small buildings have the worst geometry from the point of view of thermal losses (high losses to volume). This can be partly compensated by more favourable geometry for lighting (more daylight to volume). The difference in primary energy is evident in Figure 34.

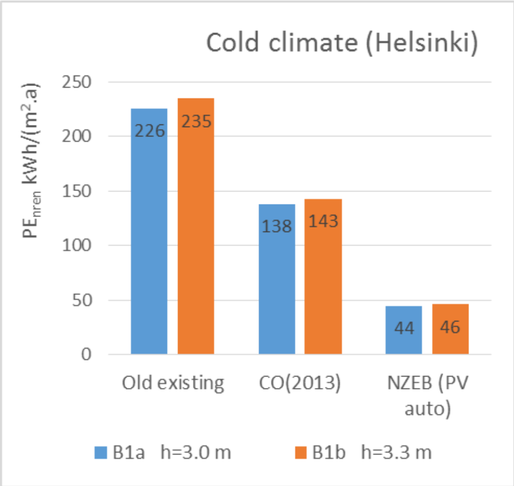


Figure 34 Influence of floor height on energy performance indicator

The typical **height of the floor** has a big variability in EU non-residential building stock. The values for typical existing office buildings in EU countries' 2013 reports on cost-optimal level calculation [22] vary from 3.0 m to 4.2 m.

The small difference in floor height between model buildings B1a and B1b shown in Figure 34 causes a difference of 2–4 % in energy performance indicator expressed in non-renewable primary energy between building B1b (floor height 3.3 m) compared to building B1a (floor height 3.0 m).

Inertia

Building inertia is a parameter influencing both heating and cooling energy consumption. The energy storage in the mass of walls allows a delay of thermal exchanges between the indoor and outdoor spaces. This parameter is mainly related to the building structure composition but also to the indoor partitioning walls and furniture which can be only partly influenced by renovation.

A sensitivity analysis has been conducted on the model buildings presented above. The definition of settings in CYPETHERM COMETH software allows the manual specification of inertia between a “very light” and “very heavy” inertia but also propose to make the calculation according to EN ISO 13786 standard.

The sensitivity analysis in Figure 35 questions the effects of inertia on heating and cooling energy use of B1b office building for Existing (EX), Cost Optimal (CO) and NZEB configurations.

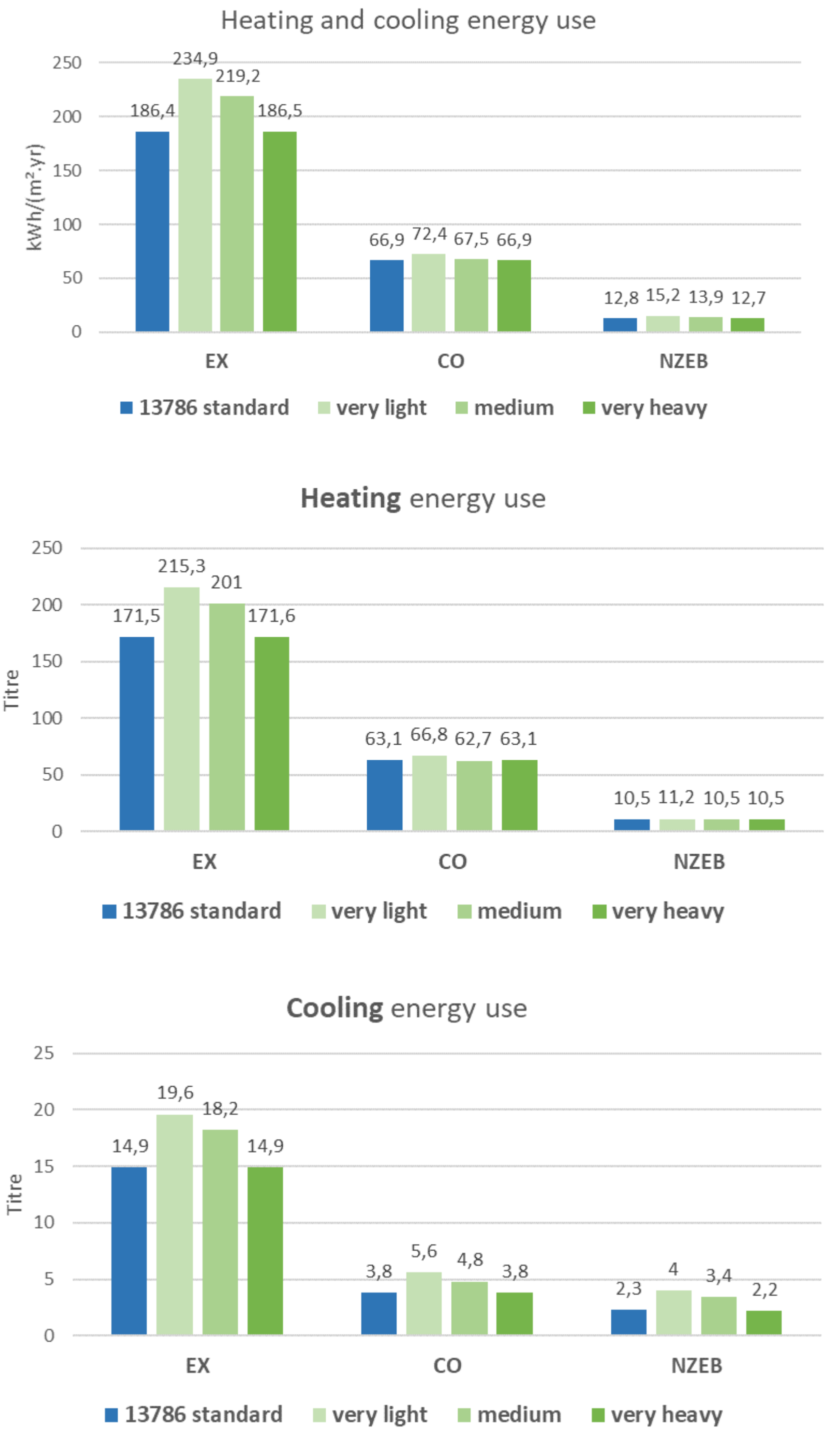


Figure 35 Sensitivity analysis on inertia effects on heating and cooling energy use

Regarding the results of the sensitivity analysis, we can notice a 26 % difference in energy consumption between “very heavy” and “very light” inertia. This value is 8 % for CO building and 20 % for NZEB. This difference is mainly related to cooling needs reduction associated with a heavier inertia. Indeed, the change for cooling between the two extreme configurations is 32 %, 47 % and 82 % for EX, CO and NZEB configurations.

The results with the detailed standard calculation are close to the “very heavy” setting. The thick concrete walls (slabs, ceilings and horizontal walls) of the building structure explain these results.

This sensitivity analysis emphasizes the need of proper setting of inertia in energy modelling in order to get reliable annual energy use. This physical issue is related to the dynamic thermal behaviour of the building and therefore dynamic simulation with short time step is needed to integrate it with sufficient accuracy.

Lighting

Lighting energy consumption is a major concern in high-performing non-residential buildings. A questioning of lighting equipment and control is needed to achieve deep renovation goals. A specific study was conducted on lighting configurations in offices to assess the energy decrease associated to lighting renovation.

This study is based on BES modelling with CYPETHERM COMETH [49]. Lots of different settings can be specified in the software’s interface. They are related to installed power and control strategy in space and time. Models are based on a stochastic approach and associate occupancy rates and indoor natural light to lighting switches probabilities. Different coefficients depict these probabilities and their values depend on control strategies [17].

Results presented in the following figure, distinguish configurations where there is, or there is not, a space partitioning of the lighting control. Five stages of lighting settings were studied. The existing state (level 0) corresponds to incandescent lamps (P = 25 W/m²) with manual switches. A replacement of existing lamps by LED lamps is considered (level 1) as well as smarter control strategy, with motion sensor control (level 2), light sensor control (level 3), or combined sensors (level 3). Energy use in kWh/(m².a) is presented below for the five configurations.

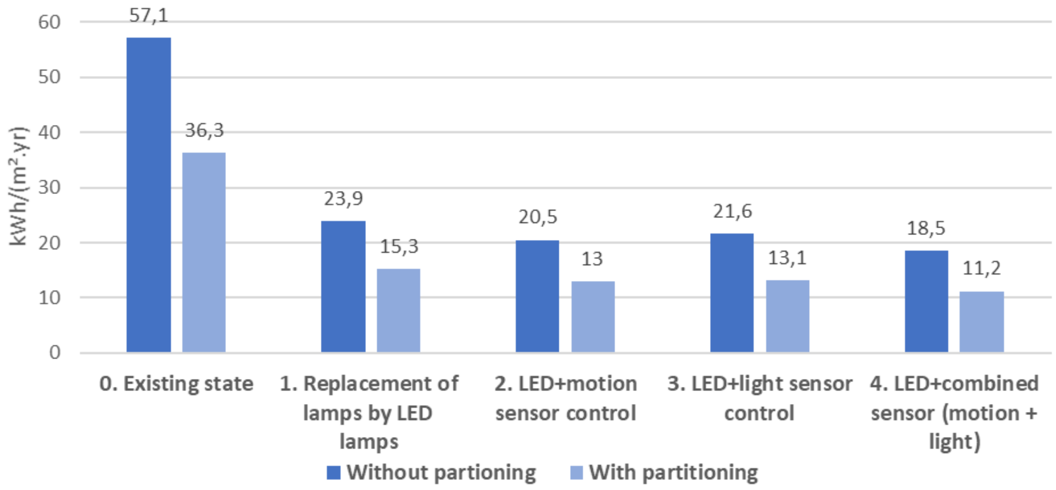


Figure 36 Sensitivity analysis on lighting energy use depending on settings

Space partitioning allows a reduction of energy use. When light is needed somewhere (due to new occupation or insufficient natural light), a smaller portion of the lamps is turned on. The main decrease in energy use is related to the change of lamps, from old existing state incandescent lamps to LED technology, leading to a 55 % reduction. Advanced control strategies cause a limited decrease of energy consumption (around 15 %). Motion sensor control, detecting occupancy, leads to slightly better results than light sensor control. When both kinds of sensors are considered, the reduction is around 25 % compared to the manual control setting.

Although these results are reliant on the specific models used in the software used to conduct this study, the latter allows a valuable estimation of energy gains associated to different configurations of lighting renovation.

Renewable energy production

The renewable energy production can be limited for existing buildings by availability of space for installation of generators (e.g. PV panels). Also, the cost optimality of installed PV panels is in question for energy performance assessment. It is not the goal to force oversizing only in order to achieve a better energy class if the export of PV electricity to the grid is not valorised for owner in some MSs.

The hourly calculation step for balance used in ALDREN procedures provides a correct picture of the cost-effectiveness of investment in PV electricity production, especially in countries where the exported PV electricity to the grid does not bring any benefit to building owner.

The influence of PV production on energy class can be overestimated in a case only the auto-consumed electricity from PV can be counted for building energy performance.

A sensitivity analysis was carried out in order to study different PV technologies and the difference between consideration of export and auto-consumption. Estimation of auto-consumption is made possible by the hourly calculation time-step for which production and demand can be associated.

Table 34 Characteristics of PV plants options studied

PV panel	PV1	PV2	PV3
PV panel area (m²)	1,63	1,63	2,16
PV panel power (Wc)	327	270	128
PV panel technology	Mono-crystallin	Multi-crystallin	Amorphous
PV panel reference	SunPower E20-327-COM	Viessmann Vitovolt 300 P270	Talev VMZ-souple-amorphe
Transmission-absorption coefficient	0,9	0,9	0,9
Rear face confinement	medium	medium	confined
Performance indicator (power/area) (Wc/m²PV)	200,4	165,6	59,4
PV plant			
Direction (0° south)	0	0	0
Inclination (0° horizontal)	30	30	0
Ratio of lost area	0,2	0,2	0,05
Number of PV panels	200	200	150
Total power (Wc)	65400	54000	19200
Total PV area (m²)	326,4	326,0	323,4
Occupied roof area (m²)	339,2	338,8	339,6

All 3 options for PV plants reported in Table 34 were applied to ALDREN model buildings. For scale testing only option PV2 was used, so that there is a margin for improvement by more efficient PV solutions.

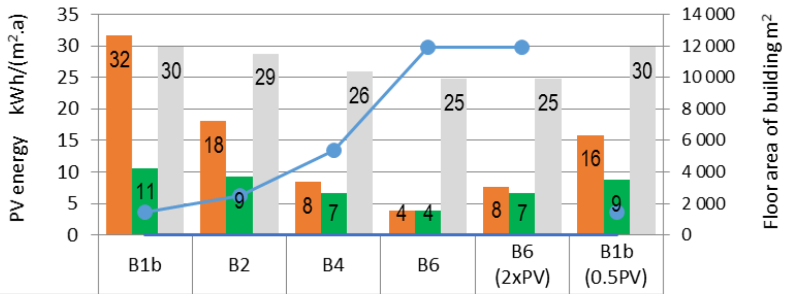
The hourly calculation step is an important requirement of ALDREN calculation methodology. Electricity produced by PV and consumed by building are balanced in the same hour.

The PV electricity auto-consumption based on hourly calculation step for different ratio between production of PV electricity and demand is presented in Figure 37, which is an example of NZEB model building B2 located in Bratislava with the PV2 plant described in Table 34.

Figure 37 shows the importance of correct sizing of PV panels for auto-consumption. The same power is installed on 5 model buildings (NZEB level) of different size (B1-B6) with heat pumps for heating and cooling. PV panels are also doubled as an alternative for large building B6 and halved for small building B1b.

In case of full use of the roof potential in the small building B1b and the yearly production close to the yearly electricity demand, only about 33% of produced PV electricity is auto-consumed in the building. 77% of produced PV electricity is exported to the grid.

The most efficient sizing for auto-consumption is in the case of large building B6 with the installed PV output, which represents only 15% of yearly electricity demand. In this case, 100% of produced PV electricity is consumed by the building. However, the **impact on energy class is small** (energy class “A” is not achieved).



	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PV production total	31.6	18.0	8.4	3.8	7.7	15.8
PV auto-consumption	10.6	9.2	6.6	3.8	6.6	8.7
Electricity use	29.8	28.7	25.9	24.7	24.7	29.8
Building floor area	1 440	2 520	5 400	11 880	11 880	1 440
Numer of floors	4	7	5	11	11	4

Indicator	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
PE_{nren} (PV auto-consum) kWh/(m².a)	44.3	44.8	44.5	48.0	41.7	48.5
ALDREN energy class	A	A	A	B	A	B
PE_{nren} (PV export) kWh/(m².a)	-4.1	24.5	40.2	48.0	39.2	32.2
ALDREN energy class	A+	A	A	B	A	A
PV auto-consum. from PV production	33%	51%	78%	**100%**	86%	55%
PV auto-consum. from electricity use	35%	32%	25%	**15%**	27%	29%
PV production from electricity use	106%	63%	32%	**15%**	31%	53%

Figure 37 The auto-consumption of produced PV electricity for various sizes of buildings in Bratislava

An hourly calculation step is necessary to avoid overestimation of PV production in case only auto-consumption is counted for the energy performance of building assessment (export is not counted). The difference between the use of the hourly balance step and the monthly or even a annual step is shown in Figure 38. The grid is considered as a storage for produced PV electricity in case of a monthly or annual step used to balance electricity generation and demand.

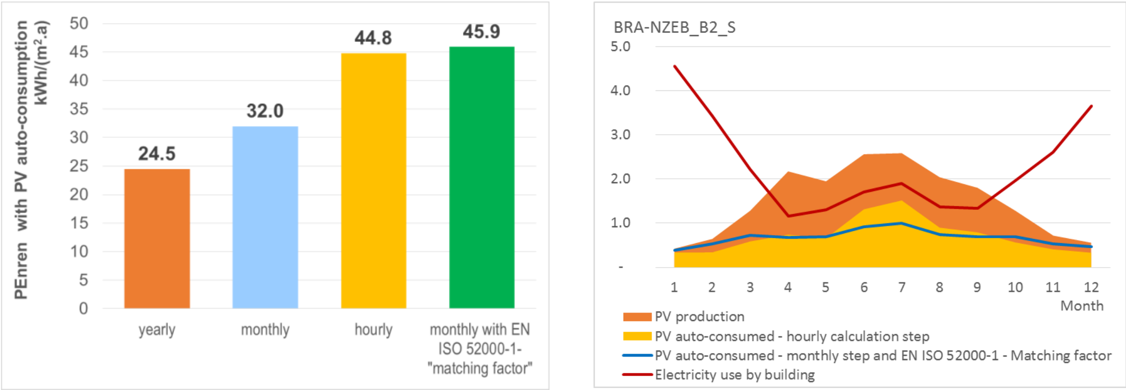
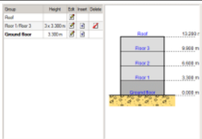


Figure 38 Influence of time step for balance of generation and use of PV electricity on the EP indicator

A3 Results from calculation of energy performance of model buildings

A detailed calculation of energy performance, energy class and costs has been performed for each model building in each climate and for each configuration for the level of performance EX, CO(2013) and NZEB. An example of reporting results is shown in Figure 40.

B1b



Office building

Dimensions [1]	w x l x h	12	x	30	x	13.2	m
	number of					4	floors
	floor high					3.3	m
Floor area (typical floor)						360	m²
Total floor area						1 440	m²
Volume						4 752	m³

Note: [1] Dimensions measured from the internal surface of the external w all (the thickness of the external w all is variable).

RESULTS

B1b_BRA_NZEB_S

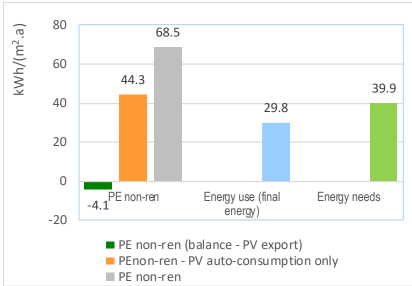
ermal envelope (int.dim.)	1 694	m²	Air permeability of the envelope under 4Pa =	1	m³/(h·m²)	PV2
Volume (int.dim.)	3 802	m^3	$U_{bât}$ =	0.54	W/(m²K)	
Form factor (int.dim.)	0.446	1/m	REF =	129	kWh/(m².a)	

Primary energy

			RER
PE total	74.5	kWh/(m².a	105%
PE non-ren	68.5	kWh/(m².a)	C
$PE_{non-ren}$ - PV auto-consumption only	44.3	kWh/(m².a)	A
PE non-ren (balance - PV **export)**	-4.1	kWh/(m².a)	A+

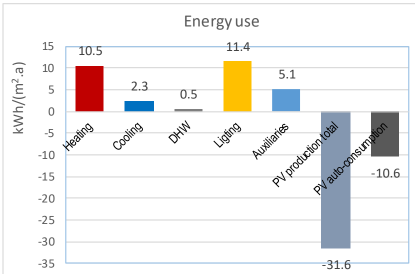
		PE_{nren}		
PV production total	-31.6	-72.6	kWh/(m².a)	PV 2_SL
PV auto-consumption	-10.6	-24.3	kWh/(m².a)	
PV export	-21.0	-48.3	kWh/(m².a)	

CO2 emissions	12.5	kgCO2/(m².a)
CO2 (PV auto-consumption only)	8.1	kgCO2/(m².a)
CO2 (balance with PV **export)**	-5.2	kgCO2/(m².a)



Energy use (Final energy)

Energy use (final energy)	**29.8**	kWh/(m².a)	
Heating	10.5	kWh/(m².a)	
Cooling	2.3	kWh/(m².a)	12.8
DHW	0.5	kWh/(m².a)	
Ligting	11.4	kWh/(m².a)	
Auxiliaries	5.1	kWh/(m².a)	
ventilation aux.	3.6	kWh/(m².a)	
distribution aux.	1.5	kWh/(m².a)	

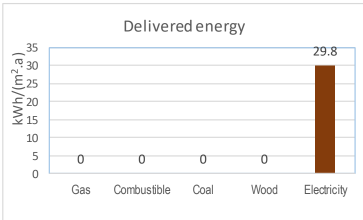


Energy needs

Energy needs	**39.9**	kWh/(m².a)
Heating	25.2	kWh/(m².a)
Cooling	3.3	kWh/(m².a)
Lighting	11.4	kWh/(m².a)

Delivered energy

	Unités	Gas	Combustible	Coal	Wood	Electricity	Annual
Heating	kWh/(m².a)	0.0	0.0	0.0	0.0	10.5	10.5
Cooling	kWh/(m².a)	0.0	0.0	0.0	0.0	2.3	2.3
DHW	kWh/(m².a)	0.0	0.0	0.0	0.0	0.5	0.5
Lighting	kWh/(m².a)	0.0	0.0	0.0	0.0	11.4	11.4
Ventilation	kWh/(m².a)						0.0
						TOTAL without auxiliary	**24.7**
ventilation aux.	kWh/(m².a)					3.6	3.6
distribution aux.	kWh/(m².a)					1.5	1.5
TOTAL		0	0	0	0	29.8	**29.8**
Cost	€/m2	0	0	0	0	4.702	**4.702**
Primary energy and CO2		0	0	0	0	3.037	**3.037** Energy cost with PV



	Unités	Gas	Combustible	Coal	Wood	Electricity	Annual
PE_{nren}	kWh/(m².a)	0.0	0.0	0.0	0.0	68.5	**68.5**
PE_{tot}	kWh/(m².a)	0.0	0.0	0.0	0.0	74.5	**74.5**
CO2	kgCO2/(m².a)	0.0	0.0	0.0	0.0	12.5	**12.5**
Annex B EN ISO 52000-1 Tab. B.16							
PEF_{nren} f_{pnren}		1.1	1.1	1.1	0.2	2.3	
PEF_{tot} f_{ptot}		1.1	1.1	1.1	1.2	2.5	
CO2 K_{CO2e}	(g/kWh)	220	360	360	40	420	
PEF non-ren **exported** f_{pnren}		1.1	1.1	1.1	0.2	2.3	
CO2 - **exported** K_{CO2e}	(g/kWh)	220	360	360	40	420	
Cost	€/kWh	0.037	0	0	0	0.158	

Figure 39 Example of results from calculation of EP indicators for model building

An example of the contribution of individual services to energy use for office building B1b is shown in Figure 40.

Lighting becomes more important after improvement of building to the NZEB level.

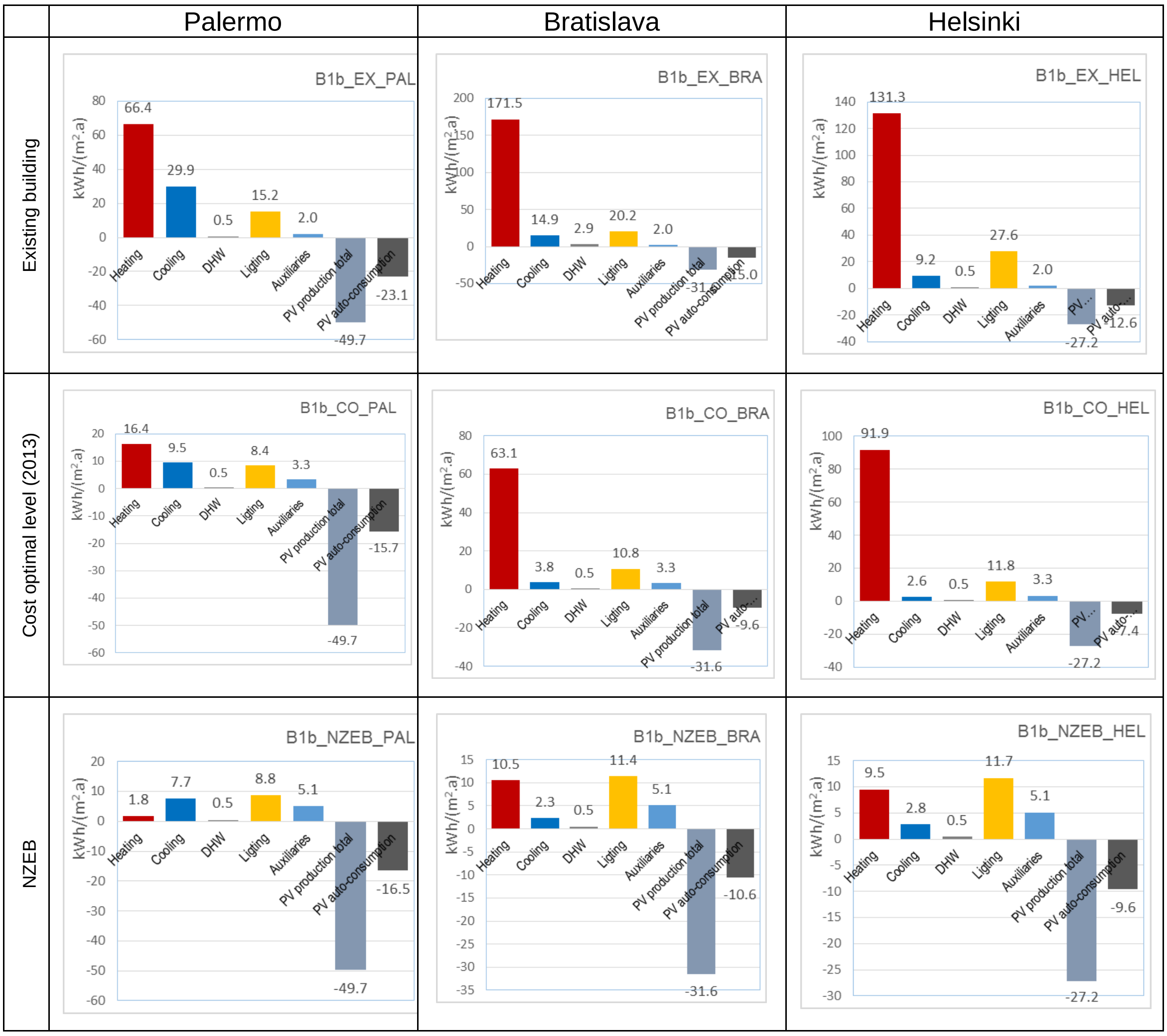


Figure 40 Energy use per service for different levels of building quality – office building B1b

An example of the contribution of individual services to energy use for hotel building B1b is presented in Figure 41.

DHW is the main energy consumer in hotels at the NZEB level in all climates and remains almost constant whatever the energy efficiency and quality of building improvement is.

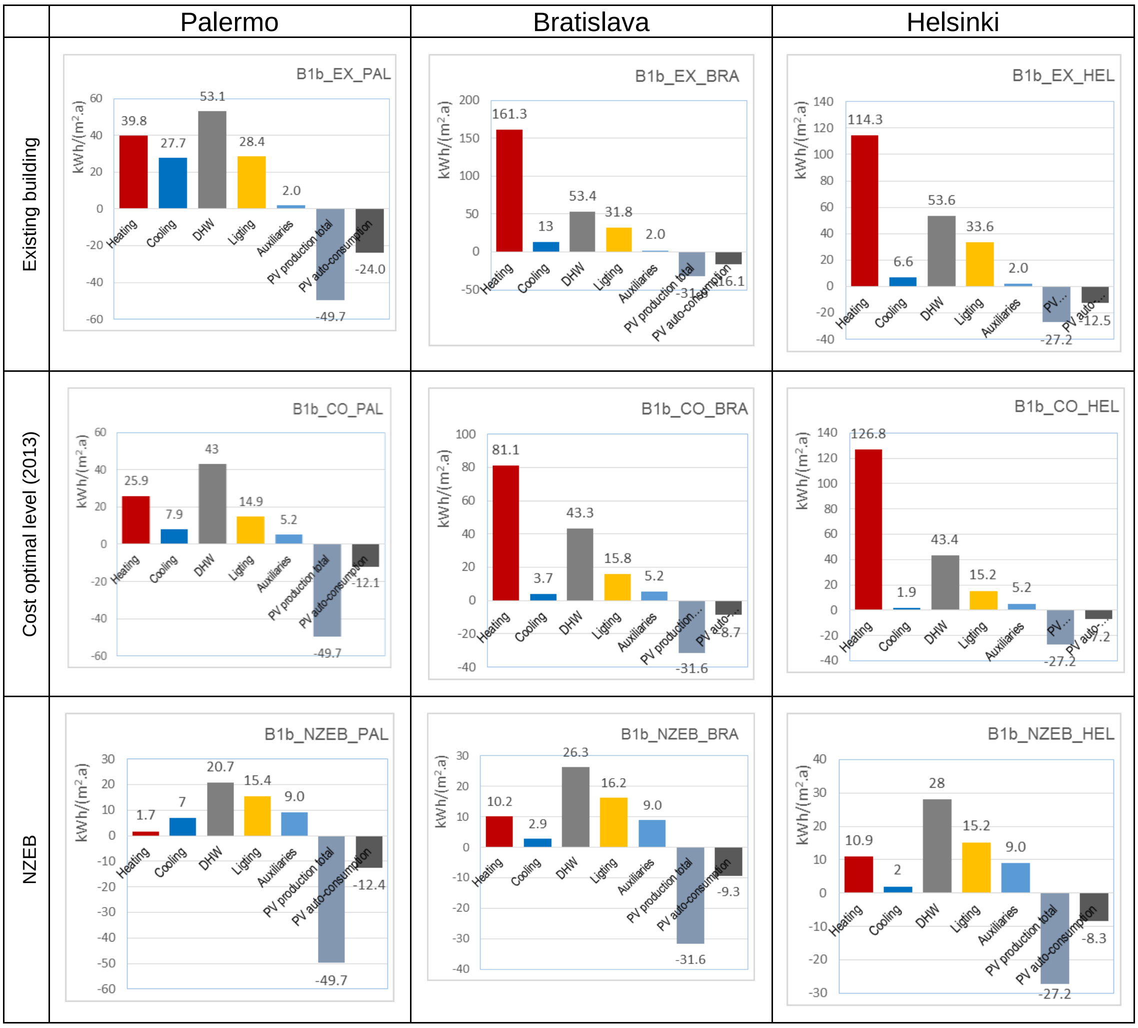


Figure 41 Energy use per service for different levels of building quality – hotel building B1b

Based on the review of reports from the calculation of the cost-optimal level by MSs in 2013, Figure 42 shows a better quality of old existing buildings in the colder climate of Helsinki compared to Bratislava.

The cost-optimal level of energy performance in 2013 depends on climate conditions. The NZEB level is less sensitive to external temperature and heating degree-days. The differences at the NZEB level are mainly due to solar gains.

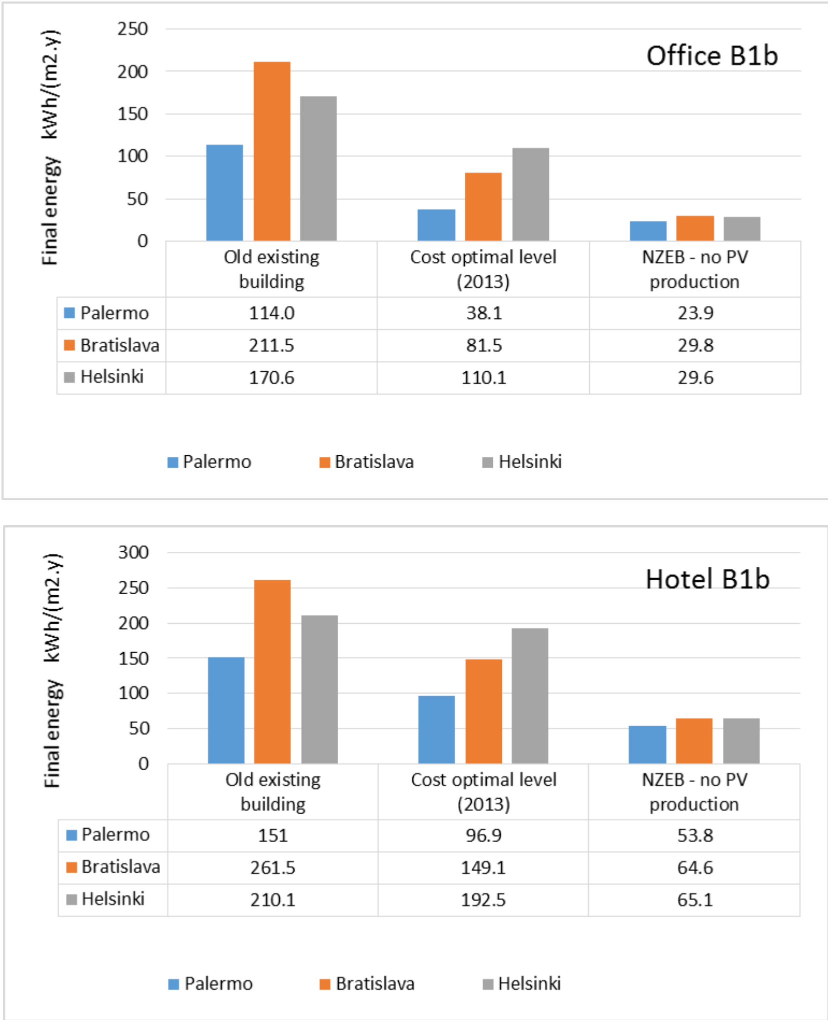


Figure 42 Final energy for office and hotel model building B1b in different climates

A4 Testing possibilities and consolidation of the scale and reference

A4.1 Scale shape

The scale is the tool for rating the energy performance of building against a specific reference. The shape of the ALDREN scale is based on EN ISO 52003-1:2017 [8], where two scale shape options are possible:

- method 1 with two reference points that are the energy performance regulatory reference R_r and the building stock reference R_s,
- method 2 with a single reference point with a flexible position of the reference point on the scale depending on its value that is recommended to be close to the cost optimal level.

The energy rating method 2 with a single reference point is used for the ALDREN scale, which is also the default option for non-residential buildings in Table B.6 in Annex B of EN ISO 52003-1:2017 [8].

The ALDREN rating is a relative non-linear stepped scale with seven main energy classes (A-G) based on one reference point located at the upper limit of energy class "D" (class 4).

The limits for energy classes on the scale are based on a relative value, which is the ratio of the energy performance (EP) of the assessed building to the reference energy performance (Ref):

$$R_{(EP/Ref)} = \frac{EP}{Ref} \qquad (1)$$

where: EP is the energy performance of assessed building expressed in non-renewable primary energy in kWh/(m².a),

Ref is the reference energy performance

The upper limits of energy classes are calculated as a geometric series with a quotient $\sqrt{2}$ expressed by the function:

$$y = \sqrt{2}^{(n-n_0)} \qquad (2)$$

where:

n is the position of energy class n on the scale;
n_0 is the position of the energy class for reference point (Ref) on the scale; for VCS it is assumed that $n_0 = 4$ (reference point is in class "D")

The intervals for energy classes based on one reference point (Ref) are presented in Table 35 and Figure 43.

Table 35 Energy performance classes as the ratio of energy performance of assessed building (EP) to **reference (Ref)**

Class	Energy classes
A+	EP< 0
A	0 < EP ≤ 0.35 Ref
B	0.35 Ref < EP ≤ 0.50 Ref
C	0.50 Ref < EP ≤ 0.71 Ref
D	0.71 Ref < EP ≤ **1.00 Ref**
E	1.00 Ref < EP ≤ 1.41 Ref
F	1.41 Ref < EP ≤ 2.00 Ref
G	2.00 Ref < EP

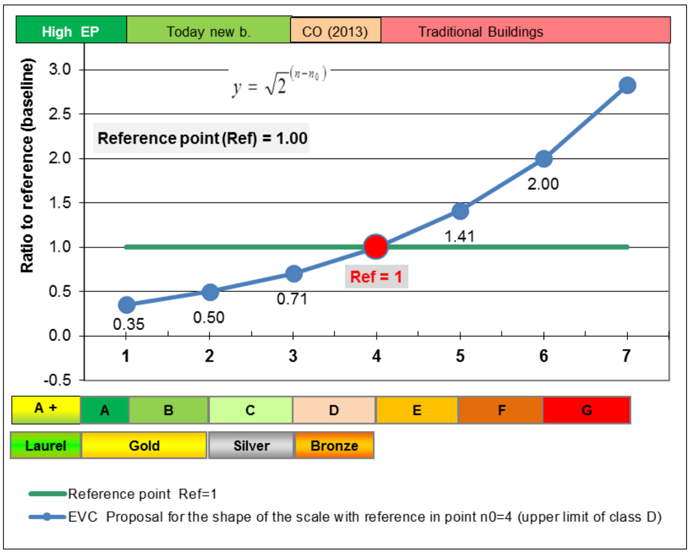


Figure 43 Upper limits of energy classes as the ratio of energy performance of assessed building (EP) to the reference (Ref)

A4.2 Reference point on the scale

According to EN ISO 52003-1:2017 [8] the decision has to be taken if the requirement or reference is a **fixed** numeric value, or a **variable** numeric value tailored to the specific characteristics of each individual project. This is important for the actual strictness of energy performance reference in the technological and economic terms. A variable reference value may be necessary for reasons of cost-optimal performance.

The different aspects of establishing the requirements (including the question whether fixed or variable values are most appropriate) are discussed in EN ISO 52003-1:2017 [8] and in the technical report ISO/TR 52003-2:2017 [9].

According to EN ISO 52003-1:2017 tab. 2 [8], the most important characteristics for a variable reference to consider when rating energy performance are in particular:

- Building category – that is related to several boundary conditions and hypotheses (indoor environment, services, temperature set-point for heating and cooling, internal gains, occupation hours, occupation density, ventilation rate, illumination level, domestic hot water need etc.). (ALDREN scale differs for **offices** and **hotels**);
- The size of the building and the area of the thermal envelope often expressed by the shape factor, or only by normalisation to m^2 of floor area. (Buildings of **various sizes** were tested in ALDREN study);
- Climate conditions - outdoor temperatures, solar radiation, etc. (**3 climate zones** are proposed for ALDREN reference point on the scale);

Two options for reference (Ref) were tested in this study:

- Fixed reference values per building category,
- Fixed reference values per building category and climate.

The reference on the ALDREN scale is based approximately on the Cost optimal level of energy performance calculated by Member States in 2013 and reported to the Commission [22].

Energy Class „A“ is the ALDREN NZEB level. Note: Additional three requirements must be fulfilled to achieve the ALDREN NZEB (needs, efficiency of systems, thermal comfort).

Fixed reference values per building category

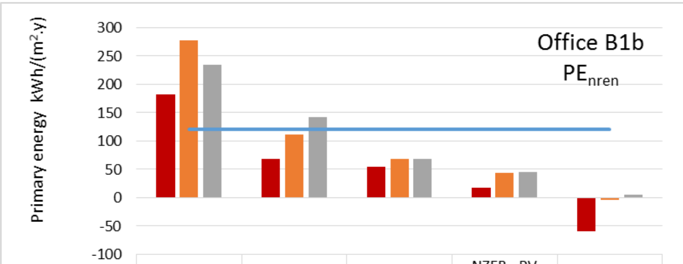
The fixed reference values per building category for all climates were presented in 2016 in consultation of the EVCS with stakeholders [36]. The values proposed were:

Offices: Ref = 120 kWh/(m^2.a)

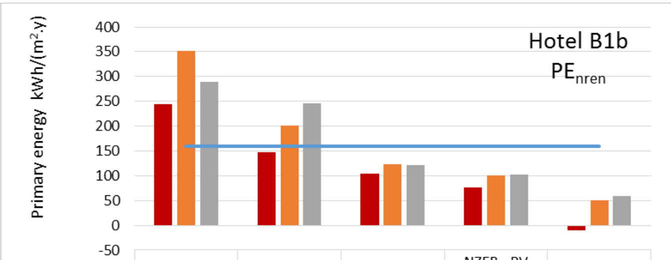
Hotels and restaurants: Ref = 160 kWh/(m^2.a)

The absolute values have been drawn by the Commission from the average consumption for the non-residential building stock and from the study by the Swiss Minergie [46] and EEFIG report [44].

The results from model buildings calculation and comparison with proposed fixed reference values in 2016 per building category are presented in Figure 44.



	Old existing building	Cost optimal level (2013)	NZEB - no PV production	NZEB - PV auto consumed	NZEB - PV export
Palermo	182.5	68.0	55.0	17.0	-59.4
Bratislava	277.2	111.7	68.5	44.3	-4.1
Helsinki	234.8	143.0	68.1	46.0	5.5
REF	120	120	120	120	120



	Old existing building	Cost optimal level (2013)	NZEB - no PV production	NZEB - PV auto consumed	NZEB - PV export
Palermo	243.9	147.0	104.4	75.8	-9.9
Bratislava	352.1	200.7	122.5	101.0	49.9
Helsinki	290.1	245.4	122.0	102.8	59.4
REF	160	160	160	160	160

Figure 44 Non-renewable primary energy of model buildings against the fixed reference values per building category

Figure 44 shows that with the fixed reference values for all climates, the huge technical potential for improvement to the NZEB level for buildings in warm and moderate climate would be lost as they will be identified as well performing. This could be logical in terms of cost-effectiveness of investment (investments in cold climate are more cost-effective), but not in terms of technical possibilities for improvement. Cost-effectiveness is limited to a specific time, as new solutions, prices for innovative solutions and energy prices evolve over the life-cycle of a building. The lock-in effect due to sub-optimal renovation could harm EU objectives towards decarbonisation.

National numerical indicators for the definition of NZEB take into account the climate [22]. With fixed values for all climates, the ALDREN NZEB level may be far from the national NZEB definitions.

For the above-mentioned reasons, the ALDREN methodology proposes different reference values for building categories (office buildings, hotels) and for three climate zones (warm, moderate, cold).

Fixed reference values per building category and climate

ALDREN reference values on the scale for office buildings lead to the ALDREN NZEB level that is in line with the average values in Commission Recommendation (EU) 2016/1318 [6] adapted to gross internal floor area (GIA) used in ALDREN.

For hotels, the ALDREN reference values lead to the ALDREN NZEB level that is in line with the recommended values by neZEH initiative [40].

The ALDREN refence values for the scale expressed in non-renewable primary energy are reported in Figure 45.

Offices

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**70**	**25**
Moderate	**130**	**46**
Cold	**170**	**60**

Hotels

Climate zone	ALDREN REF	ALDREN NZEB
Warm	**200**	**70**
Moderate	**270**	**95**
Cold	**310**	**109**

Figure 45 The reference values (REF) for ALDREN scale and ALDREN NZEB in kWh/(m^2.a) of non-renewable primary energy

A5 Results from scale testing

Office buildings

The results of calculation of energy performance of office buildings (Figure 46 and Figures 48-50) show that the scale is suitable for rating the existing buildings and the renovation actions.

Cost optimal level (2013) is placed approximately in class “D” and the NZEB level in line with the Commission recommendation [6] can be achieved.

Hotels

The results of calculation of energy performance of hotel buildings (Figure 47 and Figures 51-53) show the difficulty to achieve improvement to energy class “A” for NZEB level defined as 35% from reference at the cost optimal (2013) level.

It is feasible to achieve for hotel buildings improvement to 50% of the cost optimal level (2013), because the DHW needs take the highest part of energy needs and related primary energy use. These needs are similar whatever the building energy efficiency is. Solar thermal panels cannot cover the overall needs because the required temperature and volume are too high.

The RT2012 [17] standard scenarios used for calculation of energy performance describe an average and constant use all over the year (annual use). It does not take into account the potential seasonal use. This is suitable for the context where winter is also a touristic season.

The occupancy ratio will have a big impact on energy use related to all services including DHW. A specific study could be carried out about standard scenarios in hotels at European-wide scale.

The possible solution is to move the reference point to class “C” or improvement of calculation methodology.

The findings from the energy performance calculation of hotel buildings are:

- next improvements in energy performance of hotel buildings need to be investigated, to achieve NZEB as 35% of cost optimal (2013) level
- Calculation methodology could be adapted to hotels, to take properly into account all technologies, e.g. the intermittency for hotels, consideration of advanced control systems allowing control of unoccupied rooms.
- The typical use of hotels as asked by EPBD for energy performance calculation cannot be standardised for different types of hotels identified in neZEH initiative [31]. The energy performance reference adaptation case by case to real occupancy (e.g. annual, seasonal, average % occupancy) of each hotel is needed to avoid big gap between calculated and real energy performance. Reference based on mirror building could solve this problem.

Results from scale testing

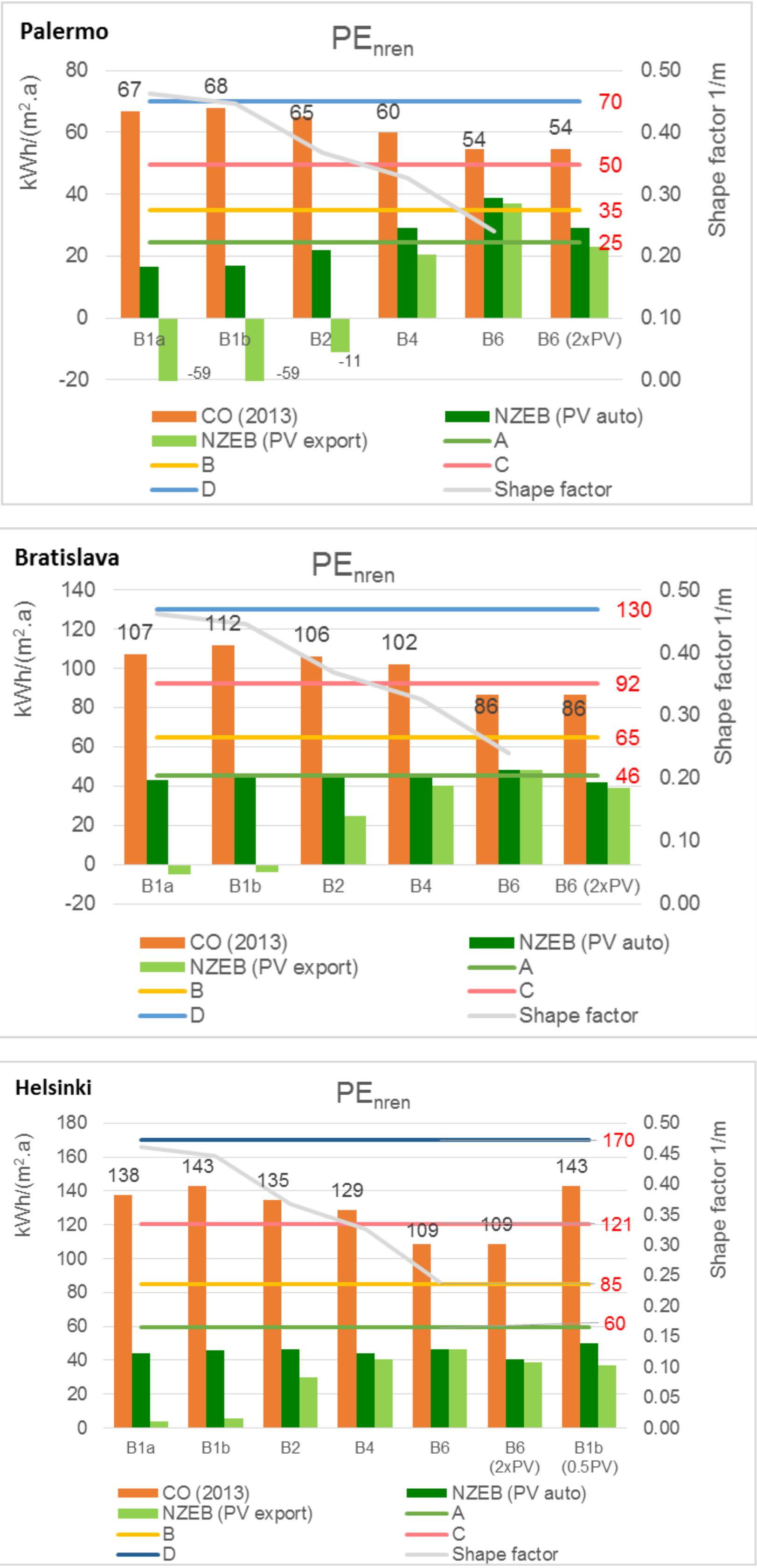


Figure 46 Energy performance indicators and energy classes achieved for office buildings

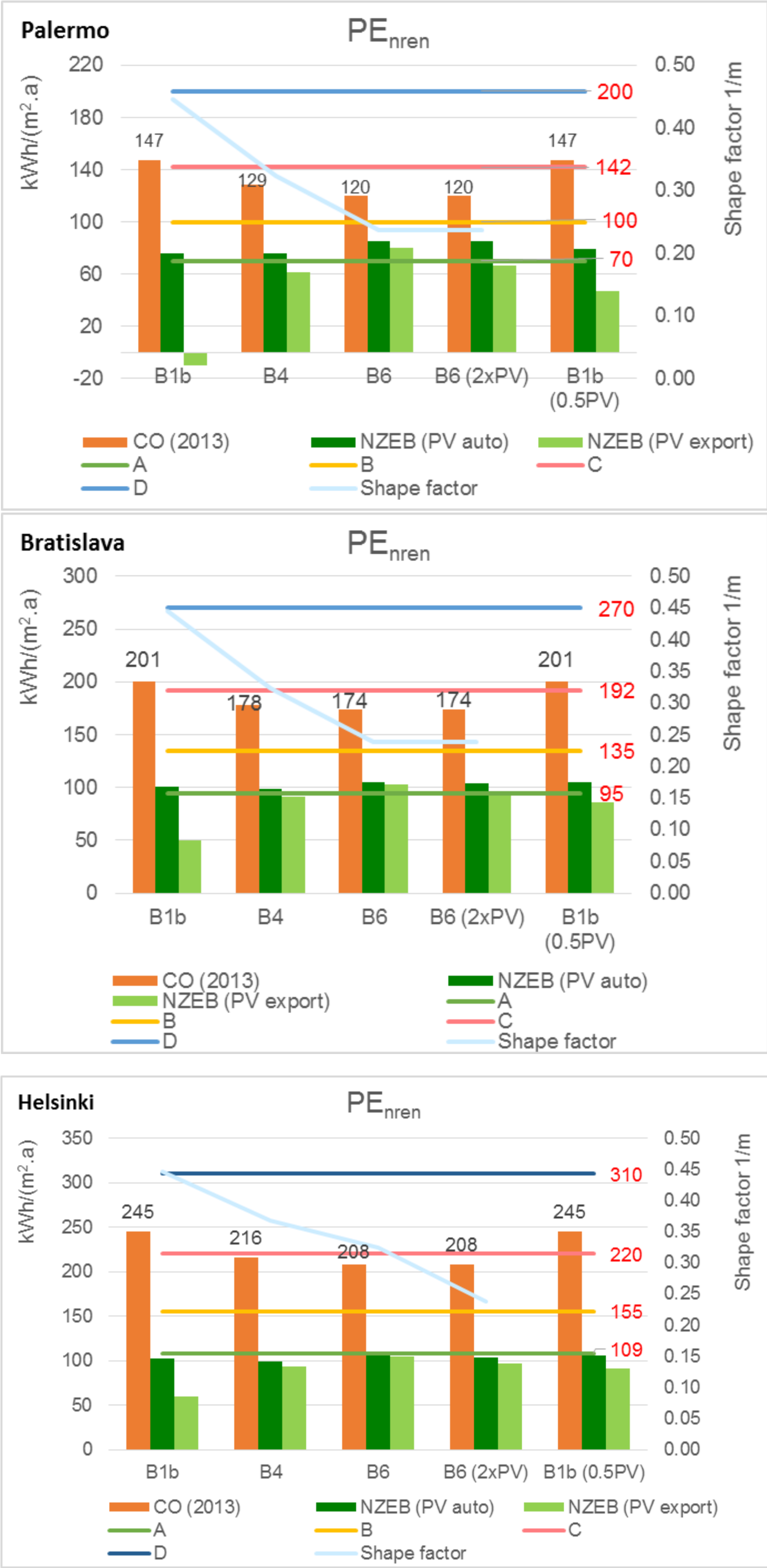


Figure 47   Energy performance indicators and energy classes achieved for hotel buildings

Office buildings

Reference (Ref) 70

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	G	G	G	F	F	F	G
	CO (2013)	D	D	D	D	D	D	D
	NZEB	D	D	D	D	D	D	D
		B1a	B1b	B2	B4	B6	B6	B6
PE_{nren} (PV auto-consumption only)	EX	F	F	G	E	F	E	G
	CO (2013)	B	B	B	C	C	B	C
	NZEB	A	A	A	B	C	B	A
PE_{nren} (balance - PV export))	EX	D	D	F	E	F	E	F
	CO (2013)	A+	A+	A	B	C	B	A
	NZEB	A+	A+	A+	A	C	A	A+

Warm (Palermo)

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	182.9	182.5	186.6	116.5	115.0	115.0	182.5
	CO (2013)	66.6	68.0	65.1	59.8	54.5	54.5	68.0
	NZEB	55.2	55.0	54.3	50.8	50.8	50.8	55.0
PE_{nren} (PV auto-consumption only)	EX PV auto	128.9	129.4	150.4	93.2	101.7	92.1	149.0
	CO (2013)	29.8	31.7	35.3	39.8	42.3	33.5	39.9
	NZEB (PV auto)	16.6	17.0	22.0	29.0	38.7	29.1	24.6
PE_{nren} (balance - PV export))	EX PV export	68.6	68.2	121.3	86.0	101.1	87.3	125.3
	CO (2013)	-47.7	-46.4	-0.3	29.3	40.6	26.8	10.8
	NZEB	-59.1	-59.4	-11.1	20.3	37.0	23.1	-2.2
FINAL energy	EX	114.6	114.0	122.0	64.3	65.8	65.8	114.0
	CO (2013)	36.8	38.1	35.7	32.3	27.5	27.5	38.1
	NZEB	24.0	23.9	23.6	22.1	22.1	22.1	23.9
PV production		-49.7	-49.7	-28.4	-13.3	-6.0	-12.1	-24.9
PV auto-consumption	EX	-23.5	-23.1	-15.8	-10.1	-5.8	-9.9	-14.6
	CO (2013)	-16.0	-15.7	-12.9	-8.7	-5.3	-9.1	-12.2
	NZEB	-16.8	-16.5	-14.0	-9.5	-5.3	-9.5	-13.2
FINAL energy (with PV auto subtracted)	EX-PV auto	91.1	90.9	106.2	54.2	60.0	55.9	99.4
	CO-PV auto	20.8	22.4	22.8	23.6	22.2	18.4	25.9
	NZEB-PV auto	7.2	7.4	9.6	12.6	16.8	12.6	10.7
FINAL energy savings	EX-PV auto	20%	20%	13%	16%	9%	15%	13%
	CO-PV auto	82%	80%	81%	63%	66%	72%	77%
	NZEB-PV auto	94%	93%	92%	80%	74%	81%	91%
Energy needs	EX	85.1	85.5	81.6	50.7	53.2	53.2	85.5
	CO (2013)	36.5	34.1	31.5	24.3	24.4	24.4	34.1
	NZEB	33.4	32.5	27.1	19.7	23.9	23.9	32.5

Figure 48 Results from testing the scale and reference for office buildings in warm climate (Palermo)

Reference (Ref) = 130

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	G	G	F	F	E	E	G
	CO (2013)	D	D	D	D	C	C	D
	NZEB	C	C	C	B	B	B	C
PE_{nren} (PV auto-consumption	EX	F	F	F	E	E	E	F
	CO (2013)	C	C	C	C	C	C	D
	NZEB	A	A	A	A	B	A	B
PE_{nren} (balance - PV export))	EX	F	F	F	E	E	E	F
	CO (2013)	A	A	B	C	C	C	C
	NZEB	A+	A+	A	A	B	A	A

Moderate (Bratislava)

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	266.8	277.2	258.6	188.7	167.6	167.6	277.2
	CO (2013)	107.2	111.7	105.8	101.8	86.3	86.3	111.7
	NZEB	67.6	68.5	66.0	59.6	56.8	56.8	68.5
PE_{nren} (PV auto-consumption	EX PV auto	230.3	242.6	233.7	172.3	158.8	151.6	253.9
	CO (2013)	84.8	89.6	87.0	88.0	77.5	71.3	93.8
	NZEB (PV auto)	43.1	44.3	44.8	44.5	48.0	41.7	48.5
PE_{nren} (balance - PV export))	EX PV export	194.2	204.6	217.1	169.4	158.8	150.0	240.9
	CO (2013)	34.6	39.1	64.3	82.5	77.5	68.7	75.4
	NZEB	-5.0	-4.1	24.5	40.2	48.0	39.2	32.2
FINAL energy	EX	201.3	211.5	196.7	136.1	117.2	117.2	211.5
	CO (2013)	77.3	81.5	76.0	72.4	58.4	58.4	81.5
	NZEB	29.4	29.8	28.7	25.9	24.7	24.7	29.8

PV production		-31.6	-31.6	-18.0	-8.4	-3.8	-7.7	-15.8
PV auto-consumption	EX	-15.9	-15.0	-10.8	-7.1	-3.8	-6.9	-10.1
	CO (2013)	-9.8	-9.6	-8.2	-6.0	-3.8	-6.5	-7.8
	NZEB	-10.7	-10.6	-9.2	-6.6	-3.8	-6.6	-8.7
FINAL energy (with PV auto subtracted)	EX-PV auto	185.4	196.5	185.9	129.0	113.4	110.3	201.4
	CO(2013)-PV auto	67.5	71.9	67.8	66.4	54.6	51.9	73.7
	NZEB-PV auto	18.7	19.2	19.5	19.3	20.9	18.1	21.1
FINAL energy savings	EX-PV auto	8%	7%	6%	5%	3%	6%	5%
	CO(2013)-PV auto	66%	66%	66%	51%	53%	56%	65%
	NZEB-PV auto	91%	91%	90%	86%	82%	85%	90%

Energy needs	EX	138.9	146.5	134.5	96.3	83.8	83.8	146.5
	CO (2013)	55.8	57.3	52.8	41.1	37.1	37.1	57.3
	NZEB	38.4	39.9	35.8	25.6	23.5	23.5	39.9

Figure 49 Results from testing the scale and reference for office buildings in moderate climate (Bratislava)

Reference (Ref) 170

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	E	E	D	D	D	E
	CO (2013)	D	D	D	D	C	C	D
	NZEB	B	B	B	A	A	A	B
PE_{nren} (PV auto-consumption only	EX	E	E	E	D	D	D	E
	CO (2013)	C	D	C	C	C	C	D
	NZEB	A	A	A	A	A	A	A
PE_{nren} (balance - PV export))	EX	D	E	E	D	D	D	E
	CO (2013)	B	B	C	C	C	C	C
	NZEB	A	A	A	A	A	A	A

Cold (Helsinki)

		B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	225.8	234.8	220.1	164.8	149.8	149.8	234.8
	CO (2013)	137.8	143.0	134.7	128.6	108.9	108.9	143.0
	NZEB	66.7	68.1	65.6	57.0	53.8	53.8	68.1
PE_{nren} (PV auto-consumption only	EX PV auto	196.4	205.7	198.0	150.1	142.2	135.7	214.3
	CO (2013)	120.3	125.9	119.4	117.1	101.3	96.2	128.4
	NZEB	44.4	46.0	46.6	43.9	46.2	40.5	50.0
PE_{nren} (balance - PV export))	EX PV export	163.2	172.2	184.3	148.1	142.2	134.6	203.5
	CO (2013)	75.2	80.3	99.0	111.9	101.3	93.7	111.6
	NZEB	4.1	5.5	29.8	40.3	46.2	38.6	36.8
FINAL energy	EX	163.3	170.6	158.2	110.3	96.9	96.9	170.6
	CO (2013)	105.2	110.1	102.3	97.6	79.9	79.9	110.1
	NZEB	29.0	29.6	28.5	24.8	23.4	23.4	29.6
PV production		-27.2	-27.2	-15.6	-7.3	-3.3	-6.6	-13.6
PV auto-consumption	EX	-12.8	-12.6	-9.6	-6.4	-3.3	-6.1	-8.9
	CO (2013)	-7.6	-7.4	-6.7	-5.0	-3.3	-5.5	-6.3
	NZEB	-9.7	-9.6	-8.2	-5.7	-3.3	-5.8	-7.8
FINAL energy (with PV auto subtracted)	EX-PV auto	150.5	158.0	148.6	103.9	93.6	90.8	161.7
	CO-PV auto	97.6	102.7	95.6	92.6	76.6	74.4	103.8
	NZEB-PV auto	19.3	20.0	20.3	19.1	20.1	17.6	21.8
FINAL energy savings	EX-PV auto	8%	7%	6%	6%	3%	6%	5%
	CO-PV auto	40%	40%	40%	16%	21%	23%	39%
	NZEB-PV auto	88%	88%	87%	83%	79%	82%	87%
Energy needs	EX	116.3	120.7	112.0	77.7	68.3	68.3	120.7
	CO (2013)	70.9	73.9	68.0	53.3	47.5	47.5	73.9
	NZEB	37.6	38.9	34.8	23.6	20.8	20.8	38.9

Figure 50 Results from testing the scale and reference for office buildings in cold climate (Helsinki)

Hotel buildings

Reference (Ref) 200

		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	D	D	D	E
	CO (2013)	D	C	C	C	D
	NZEB	C	B	B	B	C
		B1b	B4	B6	B6	B6
PE_{nren} (PV auto-consumption only)	EX	D	D	D	D	E
	CO (2013)	C	C	C	C	C
	NZEB	B	B	B	B	B
PE_{nren} (balance - PV export))	EX	C	D	D	C	D
	CO (2013)	A	B	C	B	B
	NZEB	A+	A	B	A	A

Warm (Palermo)

		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	243.9	187.6	166.0	166.0	243.9
	CO (2013)	147.0	128.6	120.1	120.1	147.0
	NZEB	104.4	91.6	94.1	94.1	104.4
PE_{nren} (PV auto-consumption only)	EX PV auto	188.8	161.6	153.2	147.2	204.2
	CO (2013)	119.3	111.6	112.1	111.4	122.8
	NZEB	75.8	75.6	85.5	84.8	79.6
PE_{nren} (balance - PV export))	EX PV export	129.5	157.1	152.1	138.2	186.7
	CO (2013)	32.7	98.1	106.3	92.4	89.9
	NZEB	-9.9	61.1	80.2	66.3	47.2
FINAL energy	EX	151.0	117.2	108.9	108.9	151.0
	CO (2013)	96.9	86.7	85.9	85.9	96.9
	NZEB	53.8	50.1	56.4	56.4	53.8
PV production		-49.7	-13.3	-6.0	-12.1	-24.9
PV auto-consumption	EX	-24.0	-11.3	-5.6	-8.1	-17.2
	CO (2013)	-12.1	-7.4	-3.5	-3.8	-10.6
	NZEB	-12.4	-6.9	-3.7	-4.0	-10.8
FINAL energy (with PV auto subtracted)	EX-PV auto	127.0	105.9	103.3	100.8	133.8
	CO-PV auto	84.8	79.3	82.4	82.1	86.3
	NZEB-PV auto	41.4	43.2	52.7	52.4	43.0
FINAL energy savings	EX-PV auto	16%	10%	5%	7%	11%
	CO-PV auto	44%	32%	24%	25%	43%
	NZEB-PV auto	73%	63%	52%	52%	72%
Energy needs	EX	87.2	67.5	52.3	52.3	87.2
	CO (2013)	47.5	38.4	32.3	32.3	47.5
	NZEB	37.3	31.2	25.0	25.0	37.3

Figure 51 Results from testing the scale and reference for hotel buildings in warm climate (Palermo)

Reference (Ref) = 270

		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	E	D	D	D	E
	CO (2013)	D	C	C	C	D
	NZEB	B	B	B	B	B
PE_{nren} (PV auto-consumption o	EX	E	D	D	D	E
	CO (2013)	C	C	C	C	C
	NZEB	B	B	B	B	B
PE_{nren} (balance - PV export))	EX	E	D	D	D	E
	CO (2013)	B	C	C	C	C
	NZEB	A	A	B	A	A

Moderate (Bratislava)

		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	352.1	262.0	231.9	231.9	352.1
	CO (2013)	200.7	177.7	173.6	173.6	200.7
	NZEB	122.5	110.2	111.6	111.6	122.5
PE_{nren} (PV auto-consumption o	EX PV auto	315.0	243.0	223.1	218.0	324.4
	CO (2013)	180.7	165.6	167.6	167.0	183.6
	NZEB	101.0	98.4	105.0	104.1	104.4
PE_{nren} (balance - PV export))	EX PV export	279.5	242.7	223.1	214.3	315.8
	CO (2013)	128.1	158.3	164.8	156.0	164.4
	NZEB	49.9	90.8	102.8	94.0	86.2
FINAL energy	EX	261.5	193.1	177.6	177.6	261.5
	CO (2013)	149.1	134.8	137.1	137.1	149.1
	NZEB	64.6	60.5	65.3	65.3	64.6
PV production		-31.6	-8.4	-3.8	-7.7	-15.8
PV auto-consumption	EX	-16.1	-8.3	-3.8	-6.0	-12.0
	CO (2013)	-8.7	-5.3	-2.6	-2.9	-7.4
	NZEB	-9.3	-5.1	-2.9	-3.3	-7.8
FINAL energy (with PV auto subtracted)	EX-PV auto	245.4	184.8	173.8	171.6	249.5
	CO(2013)-PV auto	140.4	129.5	134.5	134.2	141.7
	NZEB-PV auto	55.3	55.4	62.4	62.0	56.8
FINAL energy savings	EX-PV auto	6%	4%	2%	3%	5%
	CO(2013)-PV auto	46%	33%	24%	24%	46%
	NZEB-PV auto	79%	71%	65%	65%	78%
Energy needs	EX	160.4	113.9	97.5	97.5	160.4
	CO (2013)	82.0	69.2	65.7	65.7	82.0
	NZEB	50.7	47.8	45.4	45.4	50.7

Figure 52 Results from testing the scale and reference for hotel buildings in moderate climate (Bratislava)

Reference (Ref)	310					
		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	D	D	C	C	D
	CO (2013)	D	C	C	C	D
	NZEB	B	B	B	B	B
PE_{nren} (PV auto-consumption only)	EX	D	C	C	C	D
	CO (2013)	D	C	C	C	D
	NZEB	A	A	A	A	A
PE_{nren} (balance - PV export))	EX	D	C	C	C	D
	CO (2013)	C	C	C	C	C
	NZEB	A	A	A	A	A

Cold (Helsinki)

		B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
PE_{nren}	EX	290.1	226.4	200.4	200.4	290.1
	CO (2013)	245.4	216.0	208.0	208.0	245.4
	NZEB	122.0	110.3	111.9	111.9	122.0
PE_{nren} (PV auto-consumption only)	EX PV auto	261.2	209.7	192.9	187.0	266.1
	CO (2013)	228.9	205.1	202.7	201.7	230.9
	NZEB	102.8	99.1	105.3	104.0	105.3
PE_{nren} (balance - PV export))	EX PV export	227.5	209.7	192.9	185.3	258.8
	CO (2013)	182.8	199.3	200.4	192.8	214.1
	NZEB	59.4	93.6	104.3	96.7	90.7
FINAL energy	EX	210.1	162.0	152.1	152.1	210.1
	CO (2013)	192.5	171.1	170.4	170.4	192.5
	NZEB	65.1	61.0	65.7	65.7	65.1
PV production		-27.2	-7.3	-3.3	-6.6	-13.6
PV auto-consumption	EX	-12.5	-7.3	-3.3	-5.8	-10.4
	CO (2013)	-7.2	-4.7	-2.3	-2.7	-6.3
	NZEB	-8.3	-4.8	-2.9	-3.4	-7.2
FINAL energy (with PV auto subtracted)	EX-PV auto	197.6	154.7	148.8	146.3	199.7
	CO-PV auto	185.3	166.4	168.1	167.7	186.2
	NZEB-PV auto	56.8	56.2	62.8	62.3	57.9
FINAL energy savings	EX-PV auto	6%	4%	2%	4%	5%
	CO-PV auto	12%	-3%	-11%	-10%	11%
	NZEB-PV auto	73%	65%	59%	59%	72%
Energy needs	EX	121.2	90.0	75.2	75.2	121.2
	CO (2013)	102.8	85.4	80.4	80.4	102.8
	NZEB	50.4	48.7	45.4	45.4	50.4

Figure 53 Results from testing the scale and reference for hotel buildings in cold climate (Helsinki)

A6 Renovation strategies – identification of relative building targets for step-by-step renovation towards NZEB

The NZEB level is a target of ALDREN renovation strategies in the recommendations for improvement of energy performance. Renovation to the ALDREN NZEB level is proposed in the energy performance certificate with a potential reference to the roadmap RenoMap.

Different system boundaries and energy uses cause large variations within the definitions of NZEB. In particular, the requirements provided by EU Member States in terms of primary energy show a significant variability due to ambition level, different national and regional calculation methodologies and energy flows [21].

Deep renovation and energy classes

The EPBD [2] requires that the energy performance certificate contain recommendations for improving the energy performance of the building, unless there is no reasonable potential for such improvement compared to the energy performance requirements in force. Public authorities which provide support measures of a financial nature are encouraged to link the application of such measures to the indicated recommendations from energy performance certificates. More detailed renovation strategies could be provided in an optional building renovation passport, which complements energy performance certificates.

The recommendations for improvement in ALDREN EVC refer to the renovation roadmap RenoMap (T2.6.3), that is a part of ALDREN renovation passport (T2.6).

The packaged solutions for deep renovation strategies were tested on ALDREN model buildings against the ALDREN energy classes, taking into account the appropriate sequence of renovation steps to avoid the lock-in effect and considering different pre-renovation stages.

The intermediate states (steps) are defined from old one existing building to the NZEB building. The assessment of energy performance of these renovation steps illustrates the energy rating process and the energy classes achieved are tested.

Three intermediate steps are considered from a typical old existing building for a given climate zone. Step 1 is related only to the replacement of windows and doors and installed shading devices. Step 2 assumes a total improvement of building envelope (windows, insulation and thermal bridges) in the past. Step 3 is the renovation of envelope and all energy systems to the NZEB level without PV production. The final step towards the NZEB level is the PV electricity production plant installed. The details of various states and steps are described in Table 36. These renovation steps are just examples assumed for scale testing.

Some individual renovation steps are also considered to be a different pre-renovation state as illustrated in Figure 54. Partly renovated buildings with only windows replacement (Step 1) are often the current situation, especially in the Eastern EU countries.

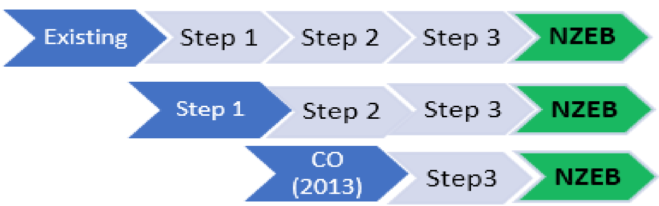


Figure 54   Renovation steps and different pre-renovation stages analysed

A specific methodology has been developed in ALDREN task 2.6.3 in order to support decision-making for step-by-step renovation. The RenoMap outcome is part of ALDREN Building Renovation Passport (BRP). Various stages (steps) were simulated for testing the "energy classes transition" towards deep renovation and to identify the renovation actions needed. Characteristics of buildings and systems applied to model buildings for testing the relative building targets for step-by-step renovation are presented in Table 36.

Table 36 Characteristics of buildings and systems for testing step-by-step renovation

Renovation Stage		Description
EX	**Existing building** (old, before renovation)	Pre-renovation stage: **Baseline for savings calculation** **Old not renovated building from 1970-1980.** The building envelope and systems properties are estimated on the basis of typical national existing buildings as defined in the national reports from the CO level calculation by Member States in 2013 [22], which are required by the EPBD and Reg. 244/2012 [4].
Step 1	Windows replacement	**Pre-renovation stage** Windows replacement and shading devices are installed to the NZEB level.
Step 2	The whole envelope improvement	Thermal envelope improvement to NZEB level (windows, shading, insulation of walls, roof, ceiling, ground floor, thermal bridges).
Step 3	NZEB without PV production	Thermal envelope and change of all technical systems to the NZEB level without PV electricity production.
NZEB	**NZEB** with PV production	**Final target** Thermal envelope and replacement of all technical systems to the NZEB level with the PV electricity production plant installed.
CO (2013)	**Cost optimal** level in 2013	**Pre-renovation stage**. **Reference point on the scale** Approximation to the cost optimal level identified in the national reports from the CO level calculation by Member States in 2013 [22].

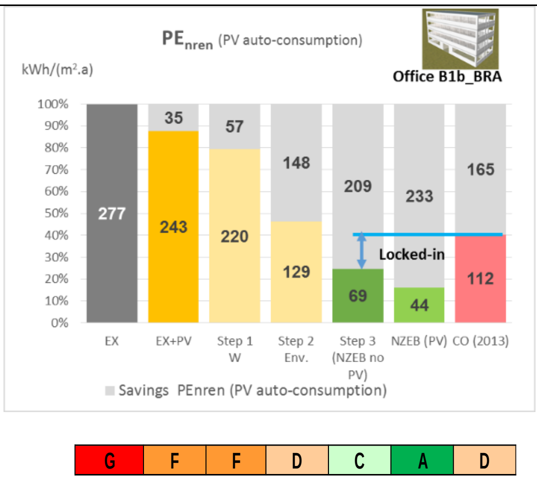
Conclusions

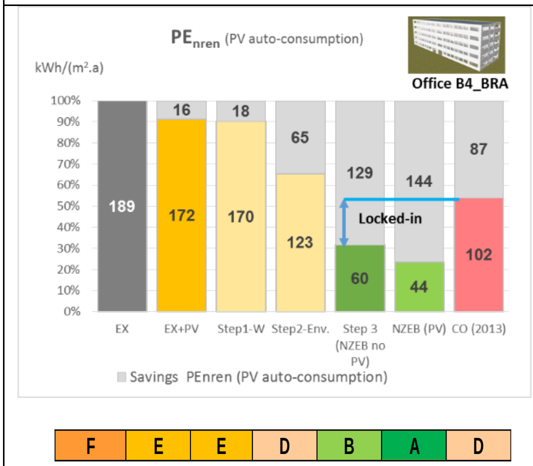
The results of step-by-step renovation modelling towards the NZEB level for two model buildings (B1b and B4) are presented in Figures 55 to 57 together with the transition of energy classes. It is visible that:

- Energy classes transition and the reference point on the scale, both fit to the renovation steps according to Table 36. **The changes in energy classes for renovation stepa are visible**;
- The renovation **from an existing building** to the properties of **NZEB** without PV is sufficient to reach the deep renovation targets;
- The impact of building envelope improvements is higher for smaller building (B1b),
- Deep renovation (60% savings) cannot be achieved just by improving the building envelope alone, renovation step 1 and 2 are not sufficient;
- Improvement of an old **existing building to a cost optimal level (2013)** provides energy savings of almost 60% for small building (B1b), but it is not sufficient for larger building B4 (only 46% savings). The risk of a lock-in effect is evident, as renovation to a cost optimal level (2013) will prevent further improvement to the NZEB level for decades (Figure 55);

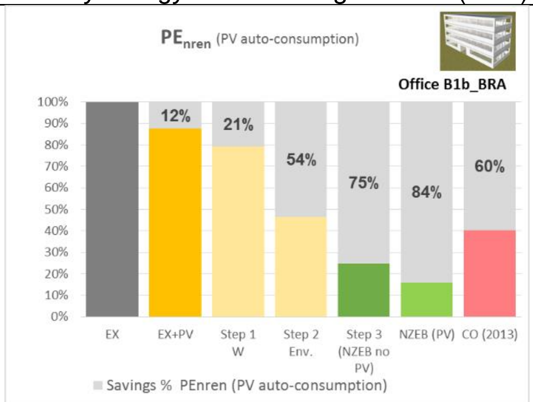
- **Step 1** (replaced windows only), as a pre-renovation state in Figure 56, is often the case for the current building stock. The improvement of building from Step 1 to the properties of NZEB can be regarded as a deep renovation (savings of more than 60%) even without PV;
- **The cost optimal level (2013),** as a pre-renovation state towards NZEB with the PV plant installed, is presented in Figure 57. Savings of 60% can be achieved for a small building (B1b), but not for a large building (B4). Cost-effectiveness has to be examined in the case of renovations from the CO level (2013) to the NZEB level.

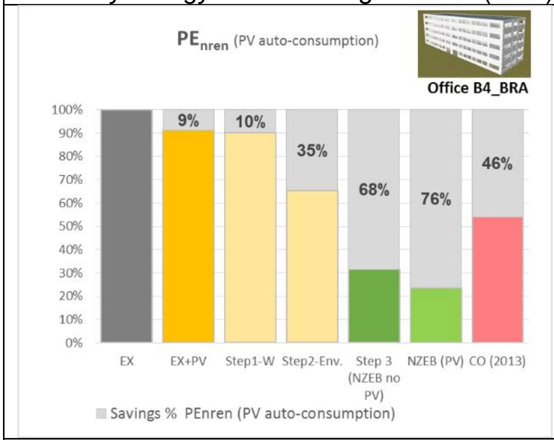
Model office building B1b		Model office building B4	
Total floor area	1 440 m²	Total floor area	5 400 m²
Volume	4 752 m³	Volume	17 820 m³
Shape factor	0.446 1/m	Shape factor	0.327 1/m





Primary energy PEnren savings in kWh/(m².a) | Primary energy PEnren savings in kWh/(m².a)

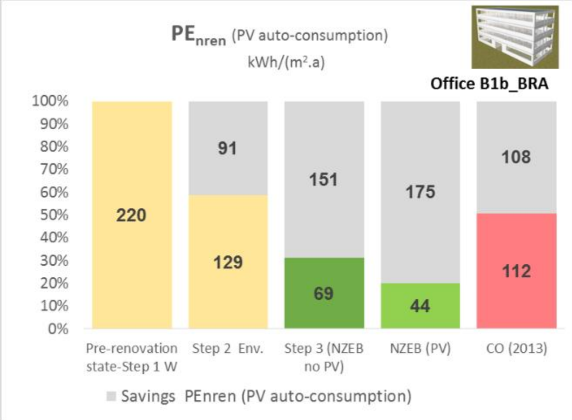




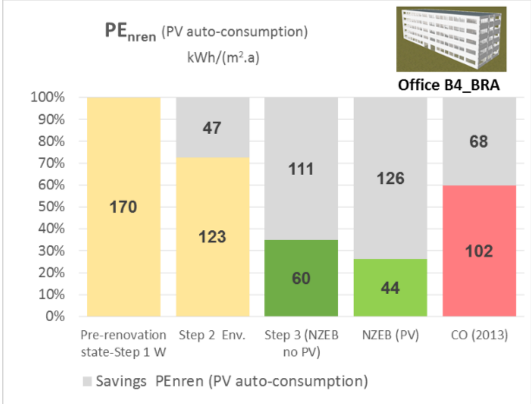
Primary energy PEnren savings in % | Primary energy PEnren savings in %

Figure 55 Energy savings by step-by step renovation from the existing building (EX) to NZEB or CO(2013) level and change of energy classes – office buildings in Bratislava

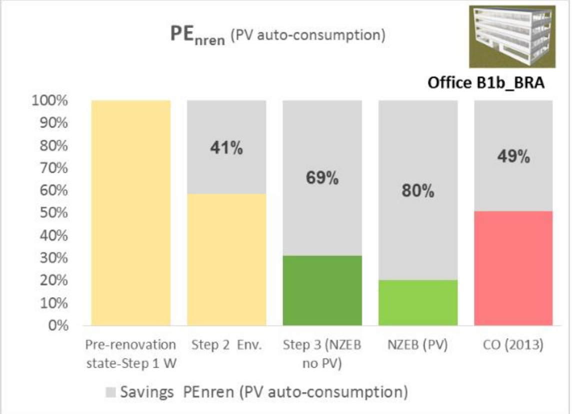
Model office building B1b	**Model office building B4**
Total floor area 1 440 m² Volume 4 752 m³ Shape factor 0.446 1/m	Total floor area 5 400 m² Volume 17 820 m³ Shape factor 0.327 1/m



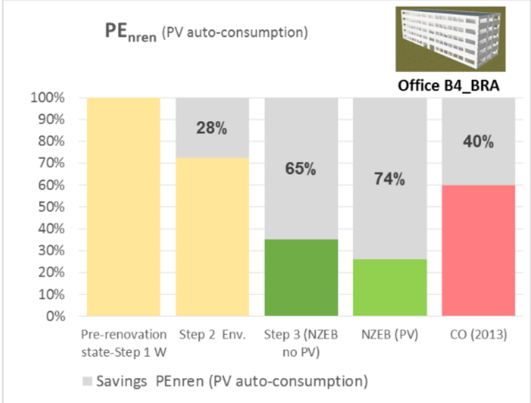
Primary energy PE_{nren} savings in kWh/(m².a)



Primary energy PE_{nren} savings in kWh/(m².a)



Primary energy PE_{nren} savings in %

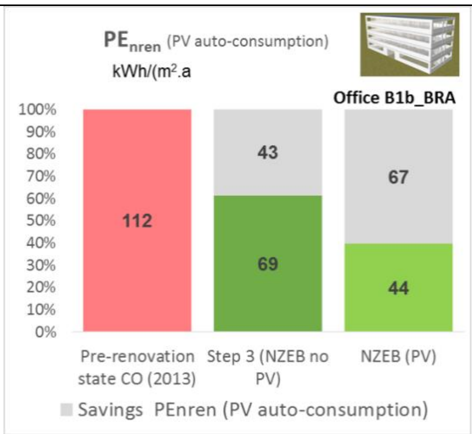


Primary energy PE_{nren} savings in %

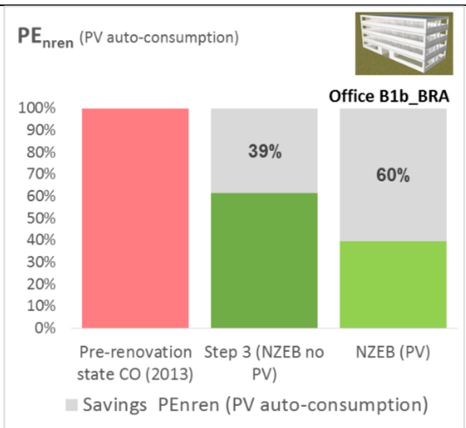
Figure 56 Step-by step renovation from partly renovated building (windows replacement) to NZEB or CO(2013) level

Model office building B1b

Total floor area	1 440	m²
Volume	4 752	m³
Shape factor	0.446	1/m



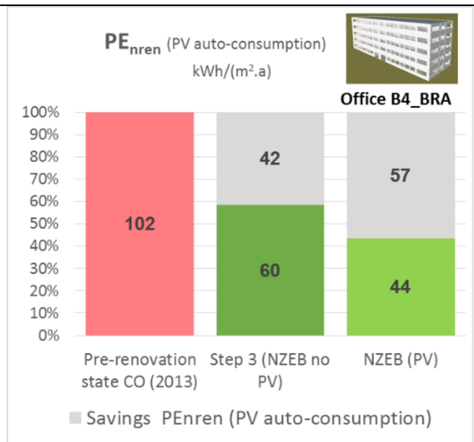
Primary energy PEnren savings in kWh/(m².a)



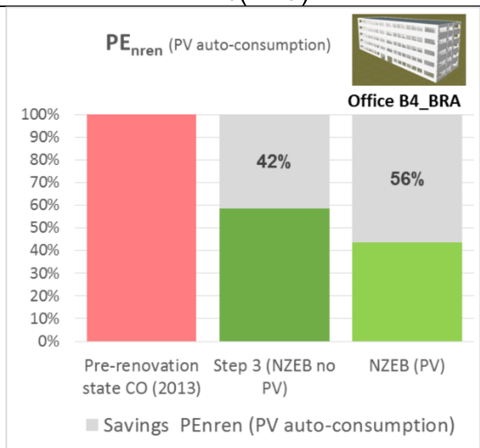
Primary energy PEnren savings in %

Model office building B4

Total floor area	5 400	m²
Volume	17 820	m³
Shape factor	0.327	1/m



Primary energy PEnren savings in kWh/(m².a)



Primary energy PEnren savings in %

Figure 57 Renovation from cost-optimal level CO(2013) to NZEB level

ANNEX B

Annex B Methodological integration of the EVC in ALDREN procedures

B1 Proposal for methodological integration of the indictors in property managers' decision process (Task 2.1)

Energy ratings and targets are included in the decision-making process, among the various criteria of building assets evaluation (including the attractiveness and technical state), in the following two project outcomes:

a) EVC, a harmonised energy performance certificate compliant with the amended EPBD, which can stand alone, focusing on energy performance as an input in the decision-making process (T2.1),
b) EVC+, extended EVC in T2.1, which contains the EVC, but is completed by the additional optional pages (e.g. measured energy from T2.3, health&well-being from T2.4, financial valuation from T2.5).

The EVC has the ambition to be taken over by Member States (Article 11 of the EPBD), by the Commission (Article 11(9) of the EPBD) or by existing voluntary certification schemes. EVC improves the current practice by at least the following features:

- The local climate is used instead of one climate for the whole country or region for energy performance calculation. This will reduce the gap between calculated and actual energy consumption;
- Hourly step for energy performance calculation is used, which provides a more correct consideration of indoor comfort and a correct estimate of the impact of some technologies e.g. PV electricity production and auto-consumption in building, heat pumps;
- Common harmonised calculation methodology is used based on the new CEN standards developed under mandate M/480, that improves a level playing field for products across the EU and comparability of energy performance EU wide;
- All potential indicators are reported, making the EVC applicable to national and existing voluntary certification schemes;
- The thermal comfort score is reported together with the energy performance of the building in order to make visible the relation between a better energy performance and thermal comfort (e.g. building without a cooling system installed);
- The typology for describing systems should be in line with common EU databases (e.g. EU Building Stock Observatory[6]).

The potential ways of overtaking the EVC by Member States:

- EVC fulfils all requirements for energy performance certificate defined in Article 11 of the EPBD so that it can **replace** the national EPC for some specific cases (e.g. subsidies);
- EVC could be complementary to the national EPC as it provides comparability at EU level, while the mandatory EPCs provide comparability with the national building stock.

[6] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eubuildings

Possible ways to take over the EVC with existing certification schemes:

- Market study carried out by Triple E Consulting [20] recommends for the market uptake of the EU voluntary certification scheme “a modular scheme addressing energy first and complemented by other modules on different sustainability issues later on, or to combine these modules with existing schemes, thereby allowing existing scheme operators to use part of the new EU voluntary scheme. Uptake would be increased if it was integrated into existing schemes or if it replaces other mandatory schemes”. The potential ways of implementation of EVC identified are in Figure 58.

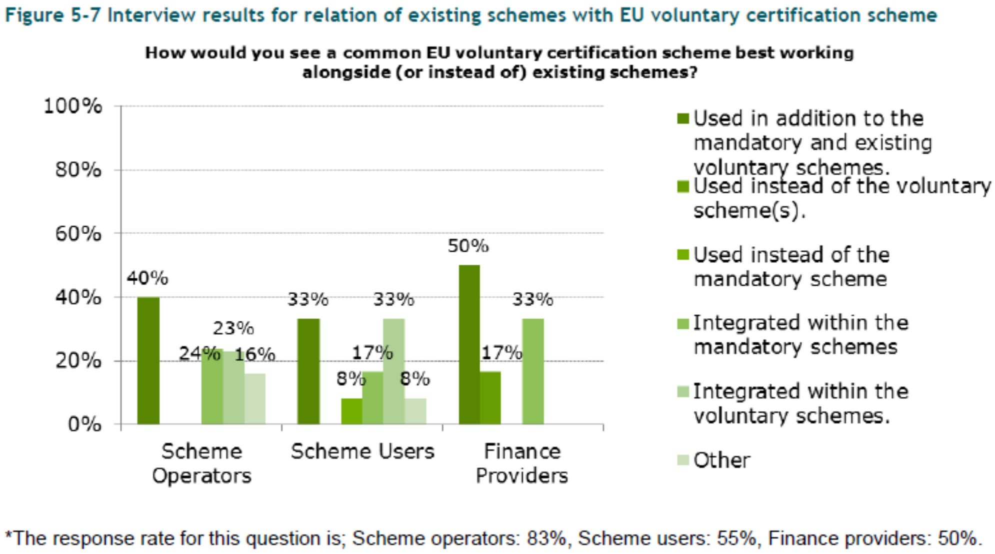


Figure 58 Relation to existing schemes, Source: Triple E Market study [20]

Proposal for content of EVC

Pages 1 and 2

provide the main results of the energy performance assessment with the main indicators, energy ratings (reference values, energy classes) on Page 1, which is also intened to be **displayed** in the building to be visible to the public.

Page 2 provides additional information on the energy needs and delivered energy per service and per energy carrier that is needed e.g. to calculate energy costs calculation and to identify potentials for improvement.

Pages 3, 4, 5

are dedicated to the description of building and technical systems and recommendations for improving energy performance. The EPBD [2] states that the energy performance certificate contains **recommendations** for the cost-optimal or cost-effective improvement of the energy performance of a building or building unit, unless there is no reasonable potential for such improvement compared to the **energy performance requirements in force.**

Recommendations for improvement in the ALDREN EVC should not go to a cost optimal level, but to the NZEB level, in order to achieve the EU's goals towards decarbonisation. After 2020, the requirements in force will be for NZEB.

It is recommended in ALDREN procedures that a detailed renovation roadmap RenoMap to be developed for a specific building. In this case, the recommendations on EVC pages 3, 4, 5 should refer to the detailed information in RenoMap. Details on energy savings are reported on Page 5.

Additional optional pages on measured energy consumption aim to provide:

- support for the EPBD implementation (Article 11 (1)) by providing in the energy performance certificate an additional information on the annual energy consumption for non-residential buildings that reflects typical energy use;
- potential link with SRI and smart measurement equipment and sensors;
- support for existing voluntary certification schemes (all interviewed voluntary schemes provide an optional verification of energy performance after construction);
- promotion of EPB standard EN 15378-3:2017 that provides standardised procedures for heating and DHW measured data collection, normalisation and reporting.

The additional pages for measured energy are described in Table 37.

Table 37 Description of optional ELDREN EVC pages for measured energy

Page	Description	Notes
Page 1 **Measured energy for heating and DHW (optional)**	Energy signature for heating, based on EN 15378-3:2017[7]	The procedures for data collection, data quality verification, normalization is set for heating in EN 15378-3:2017. Method can be used for verification of energy performance after construction (option in some national and voluntary schemes). The design energy signature is built using the procedure of EN 15378-3 with calculated data.
Page 2 (alternative 1) **Measured energy – buildings with specific measurements provisions (optional)**	Ideal presentation of measured energy per service, that can be used for all buildings with adequate measurement and reporting capabilities (e.g. some new **“smart” new buildings**)	Measured energy as defined in Table B.9 Clauses 6 and 9 in EN ISO 52000-1:2017 Assessment is possible only in case the proper measurement and BACS are installed, that allow to allocate the delivered energy per carrier to each service. Use sheet “Measured energy – buildings without specific measurements provisions (optional)” if such provisions are not available.
Page 2 (alternative 2) **Measured energy – buildings without specific measurements provisions (optional)**	Alternative for page 2 for all other buildings (will be the most common for new and existing buildings)	Normalization methods for all influence factors are not available and consolidated for all services. Only average from minimal 3 years measurements is used to reduce the impact of influence factors.

[7] EN 15378-3:2017 - Energy performance of buildings - Heating and DHW systems in buildings - Part 3: Measured energy performance, Module M3-10, M8-10

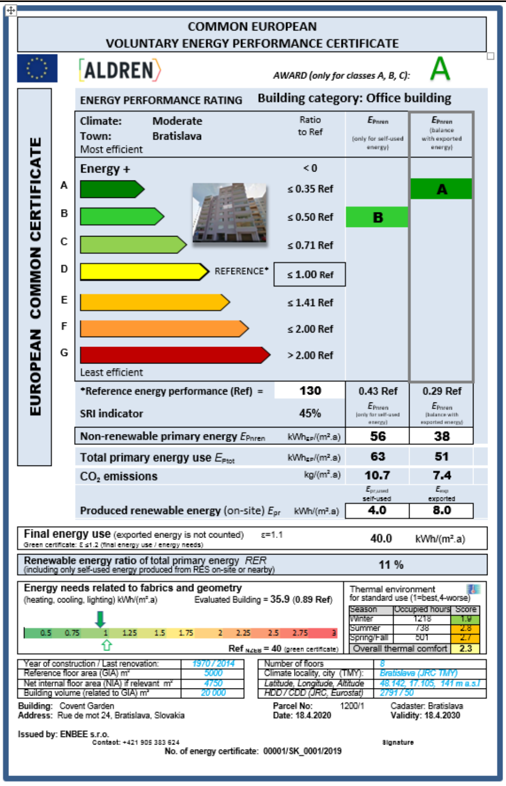
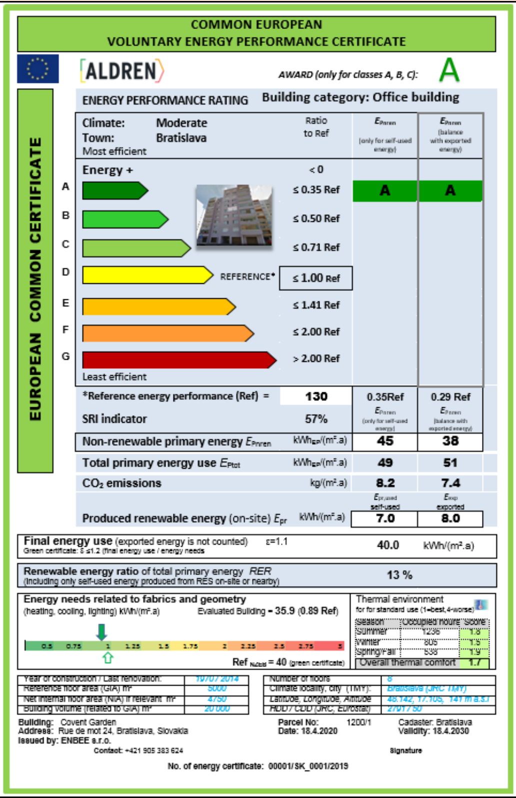
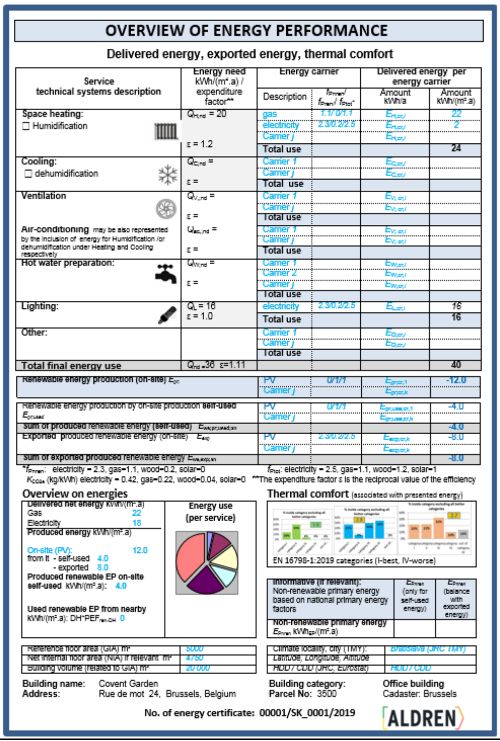
THE MAIN RESULTS, ENERGY PERFORMANCE AND RATINGS	
	
Page 1 – Energy performance certificate and Energy label	Page 1 (optional) – Energy performance certificate – **only for ALDREN NZEB** - **h**ighlighting the high **performing (green) building**
	
	Page 2 – Overview of energy performance

Figure 59 The main results, energy performance and ratings

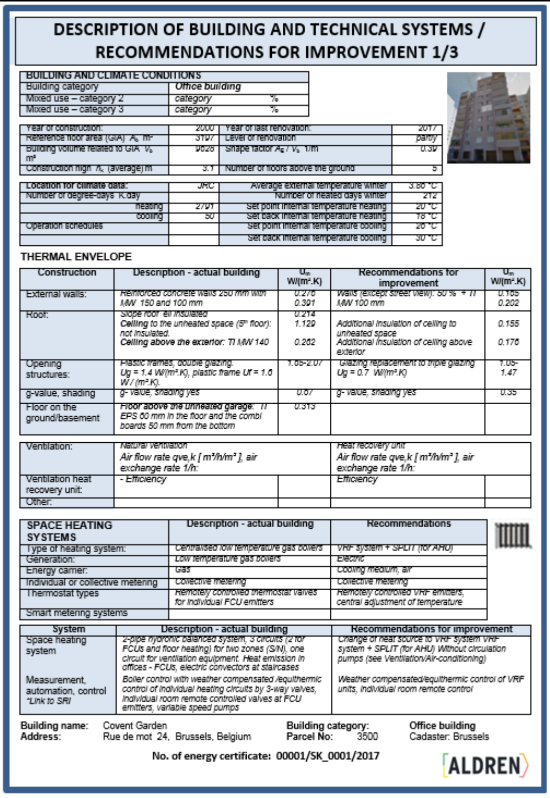
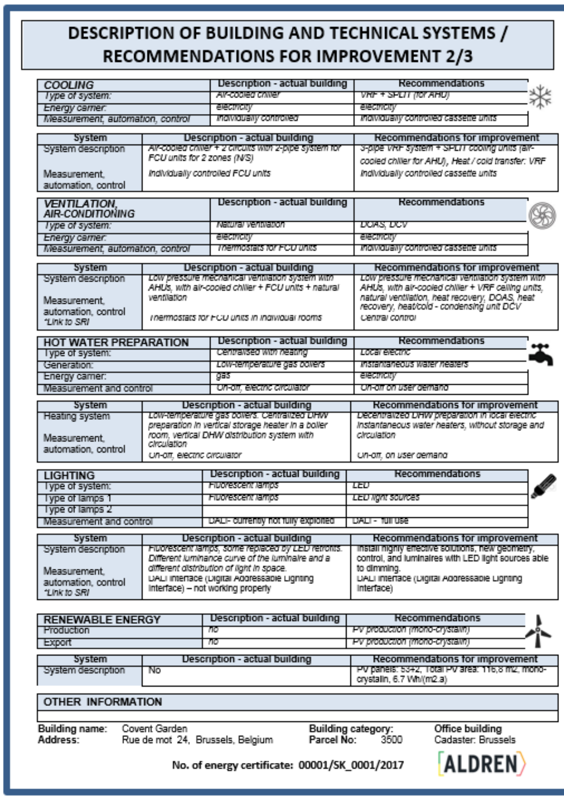
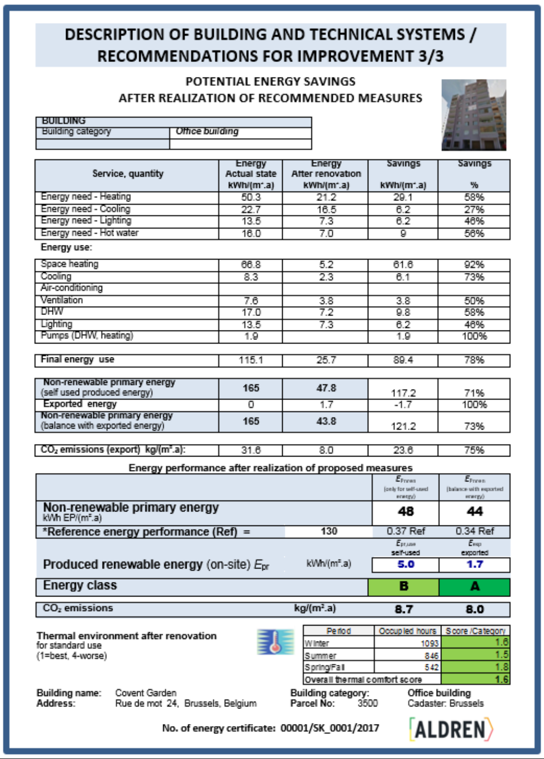
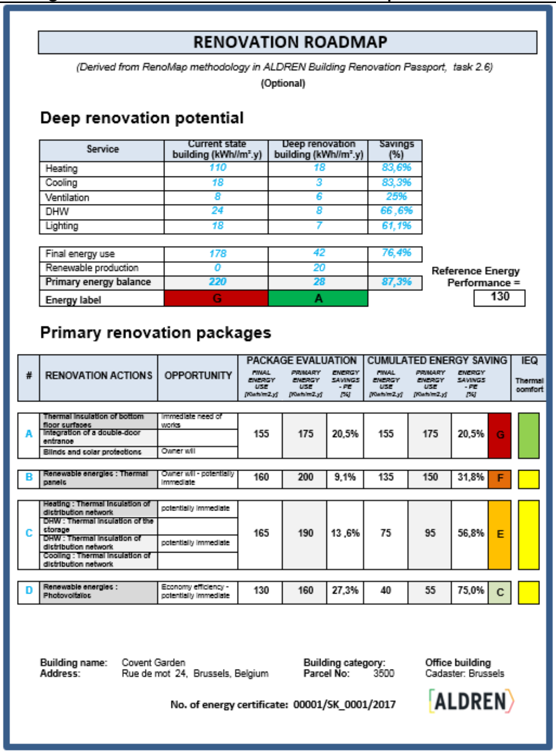
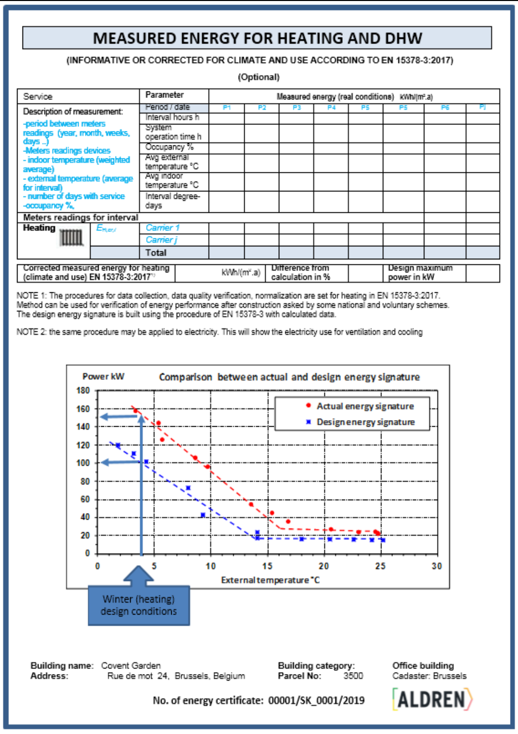
DESCRIPTION / RECOMMENDATIONS FOR IMPROVEMENT OF BUILDING AND TECHNICAL SYSTEMS	
	
Page 3 – Recommendations for improvement 1/3	Page 4 – Recommendations for improvement 2/3
	
Page 5 – Recommendations for improvement 3/3 **Calculation of potential energy savings**	Page 6 - Detailed renovation roadmap RenoMap **towards NZEB to avoid lock-in effect**

Figure 60 The pages for recommendation for improvement of EP

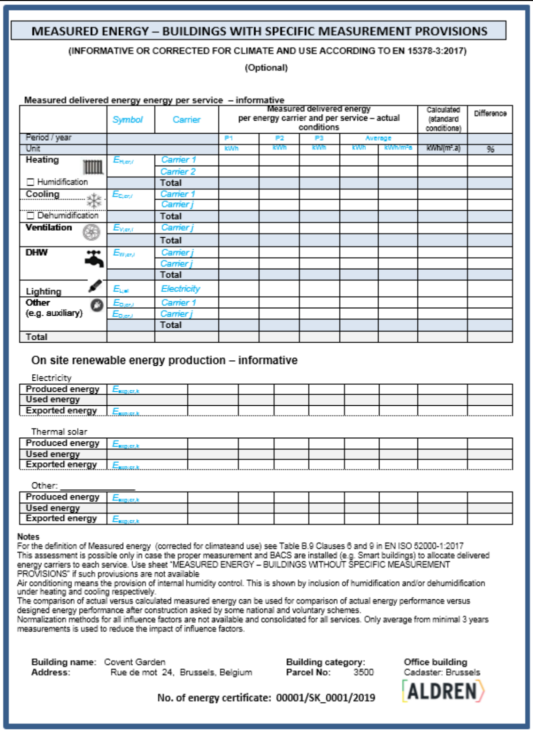
MEASURED ENERGY - OPTIONAL


MEASURED ENERGY FOR HEATING AND DHW

(INFORMATIVE OR CORRECTED FOR CLIMATE AND USE ACCORDING TO EN 15378-3:2017)

(Optional)

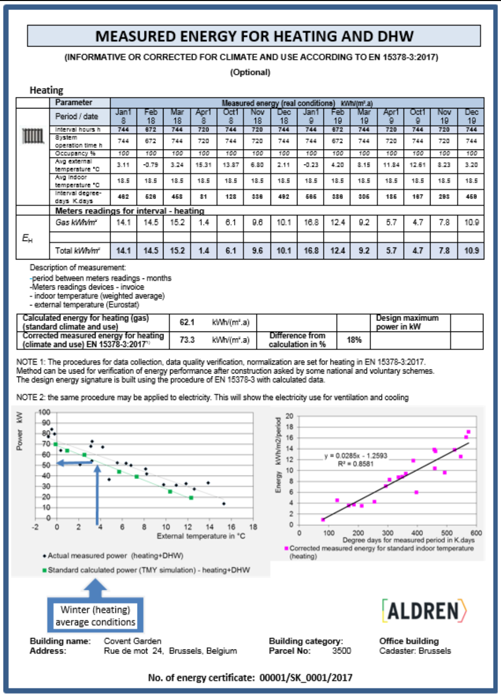
Page 7 – Measured energy for heating and DHW **(optional)**


MEASURED ENERGY – BUILDINGS WITH SPECIFIC MEASUREMENT PROVISIONS

(INFORMATIVE OR CORRECTED FOR CLIMATE AND USE ACCORDING TO EN 15378-3:2017)

(Optional)

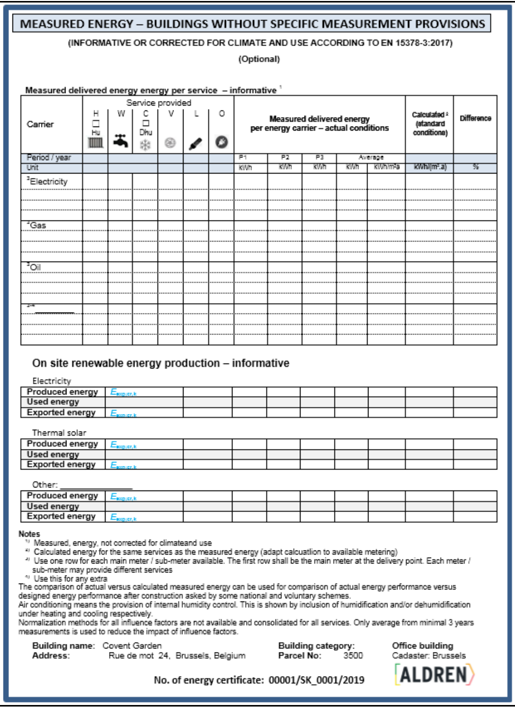
Page 8 (alternative 1) – Measured energy – buildings **with** specific measurements provisions **(optional)**


MEASURED ENERGY FOR HEATING AND DHW

(INFORMATIVE OR CORRECTED FOR CLIMATE AND USE ACCORDING TO EN 15378-3:2017)

(Optional)

Page 8 – Measured energy – example of reporting (pilot building)


MEASURED ENERGY – BUILDINGS WITHOUT SPECIFIC MEASUREMENT PROVISIONS

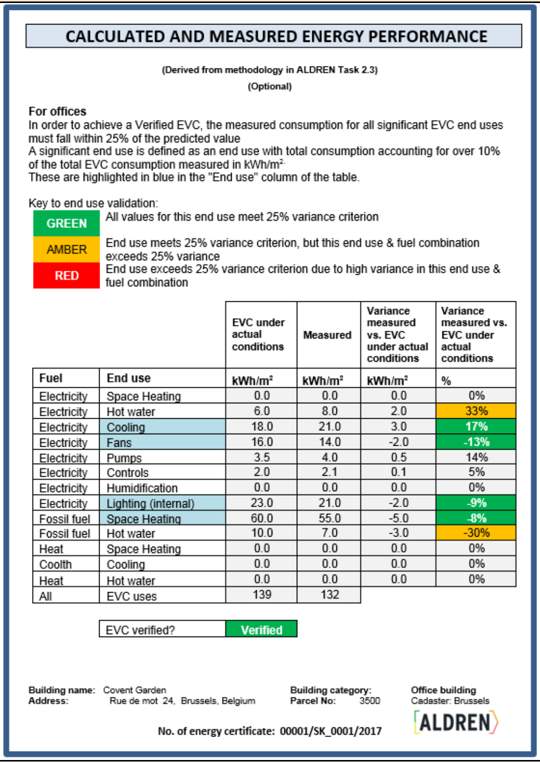
(INFORMATIVE OR CORRECTED FOR CLIMATE AND USE ACCORDING TO EN 15378-3:2017)

(Optional)

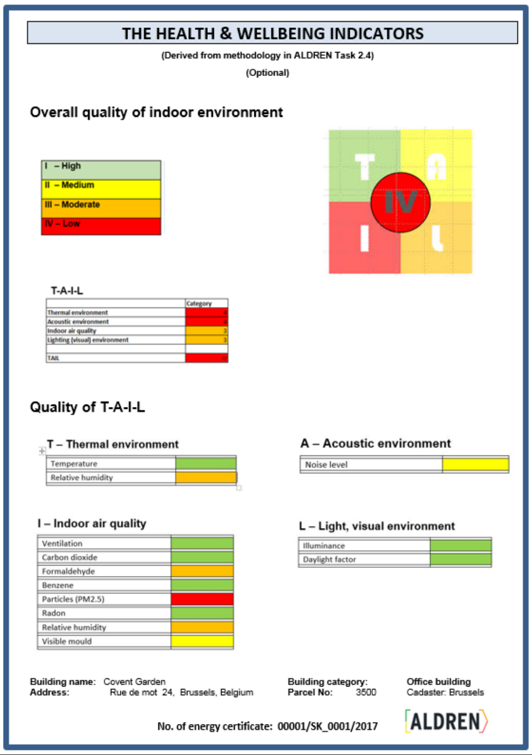
Page 8 (alternative 2) – Measured energy – buildings **without** specific measurements provisions **(optional)**

Figure 61 The pages for measured energy

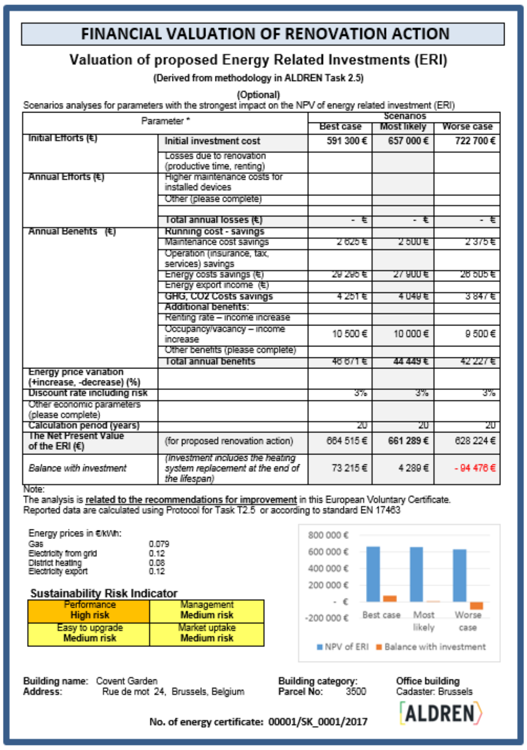
ADDITIONAL ALDREN INDICATORS



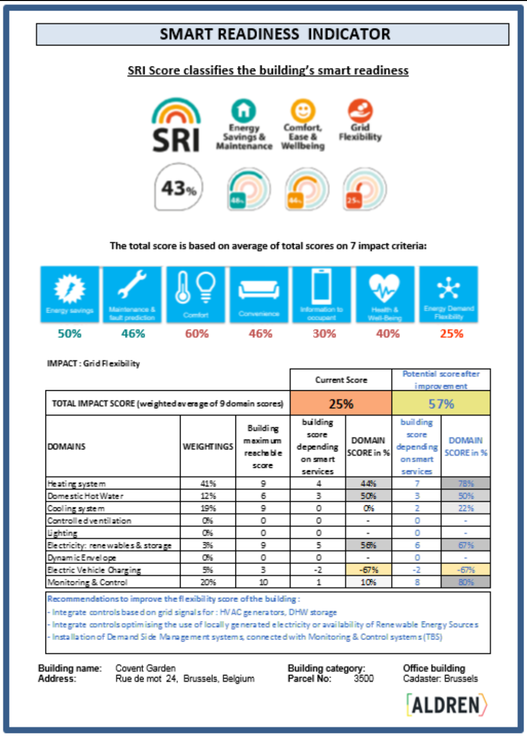
Page 9 – Gap between Calculated and measured energy performance



Page 10 - The health & wellbeing indicators



Page 11 - Financial valuation of renovation action



Page 12 - Smart readiness indicator (page can be repeated for next aspects)

Figure 62 Additional ALDREN indicators for EVC + (verification by measured energy, financial valuation, Health&Wellbeing, SRI)

B2 Integration of energy performance indicators in building passport (Task 2.6)

All relevant information should be collected in one place for future use as an decision making tool by owner or building manger or as a pool of information for designers, energy auditors or energy assessors on a specific building.

Data from all EVCs should be collected in the database for:

- Research, statistics, monitoring the building stock and issued EVCs by scheme operator
- Publicly available information
- Input for EU Building Stock Observatory[8].

The minimum recommended energy performance indicators to be collected in building passport are presented in Table 38.

Table 38 Proposal for integration of EP indicators in the building passport

INDICATORS	VALUE	UNIT	SOURCE
Geometry			
Reference floor area for EP indicator			EVC ALDREN (GIA-Gross internal area)
Shape factor Ae/V		1/m	EP calculation
Standard building use (for EP assessment)			
Building category			EP calculation, ALDREN - office/hotel
Use patterns (hours of use, week, weekend)		hours	EP calculation
Set point temperature - heating		°C	EP calculation
Set back temperature - heating		°C	EP calculation
Set point temperature - cooling		°C	EP calculation
Set back temperature - cooling		°C	EP calculation
Climate data (for EP assessment)			
Reference year - Locality - name (JRC)			EP calculation, JRC, Eurostat
Reference year - Locality - latitude		°	EP calculation, JRC, Eurostat
Reference year - Locality - longitude		°	EP calculation, JRC, Eurostat
Reference year - Locality - altitude		m	EP calculation, JRC, Eurostat
Reference year - HDD		K.day	EP calculation, JRC, Eurostat rules
Reference year - CDD		K.day	EP calculation, JRC, Eurostat rules
Building thermal protection			
Walls - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
Roof - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
Basement/ground floor - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
Windows - average U-value		$W/(m^2.K)$	EP calculation, Renovation roadmap
Windows - Shading		yes/no	EP calculation, Renovation roadmap
Windows-average g-value of glazing			EP calculation, Renovation roadmap
Building Technical systems			
System description – space heating	EU BSO typology		EU BSO typology
System description – cooling	EU BSO typology		EU BSO typology
System description - air-conditioning	EU BSO typology		EU BSO typology
System description - ventilation	EU BSO typology		EU BSO typology
System description – DHW	EU BSO typology		EU BSO typology

[8] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eubuildings

System description – lighting	EU BSO typology		EU BSO typology
System description – other services	EU BSO typology		EU BSO typology
Energy production - electricity - system description	EU BSO typology		EU BSO typology
Energy production - thermal - system description	EU BSO typology		EU BSO typology
Individual or collective metering	EU BSO typology		EU BSO typology
Thermostat types	EU BSO typology		EU BSO typology
Smart metering systems	EU BSO typology		EU BSO typology
Calculated Energy performance			
Non-renewable primary energy balance (with export)		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Non-renewable primary energy (auto consumption of production)		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Total primary energy		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Exported primary energy		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
CO2 emission		kg/ (m^2.a)	EVC, CEN standards M480 (hourly step)
Ratio of renewable		%	EVC, CEN standards M480 (hourly step)
Reference energy performance (non-ren. primary energy)		kWh_{EP} /(m^2a)	ALDREN scale
Ratio to reference		-	ALDREN scale
Energy use for space heating		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use for cooling		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use for air-conditioning		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use for ventilation		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use for DHW		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use for lighting		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy production - electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy production - thermal		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy export - electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy export - thermal		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Delivered energy per energy carrier (calculated)			
Name for energy carrier 1	EU BSO typology		EU BSO typology
Name for energy carrier 2	EU BSO typology		EU BSO typology
Name for energy carrier 3	EU BSO typology		EU BSO typology
Name for energy carrier 4	EU BSO typology		EU BSO typology
Sum for energy carrier 1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Sum for energy carrier 2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Sum for energy carrier 3		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Sum for energy carrier 4		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Sum for electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Space Heating			
Heating - delivered energy for carrier 1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Heating - delivered energy for carrier 2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Heating - delivered energy for carrier 3		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Heating - delivered energy for carrier 4		kWh /(m^2a)	
Heating - delivered electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Cooling			
Cooling - delivered energy for carrier 1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Cooling - delivered energy for carrier 2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Cooling - delivered electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Ventilation			
Ventilation - delivered energy for carrier 1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Ventilation - delivered energy for carrier 2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Ventilation - delivered electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Air-conditioning			
Air-conditioning - energy carrier 1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)

Air-conditioning - energy carrier 2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Air-conditioning - delivered electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Domestic hot water			
DHW - energy carrier1		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
DHW - energy carrier2		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
DHW - energy carrier3		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
DHW - energy carrier4		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
DHW - delivered electricity		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Lighting			
Lighting - delivered electricity		kWh /(m^2a)	EVC results - CEN standards M480 (hourly step)
Produced - auto consumed energy			
Produced - auto consumed energy - electricity		kWh /(m^2a)	EVC results - CEN standards M480 (hourly step)
Produced - auto consumed energy - thermal energy		kWh /(m^2a)	EVC results - CEN standards M480 (hourly step)
ENERGY RATINGS			
Obligatory energy performance certificate (last issue)			
No. of EPC			optional, if exists, external document from owner
Date of issue			optional, if exists, external document from owner
Date of validity			optional, if exists, external document from owner
Country			optional, if exists, external document from owner
Energy class			optional, if exists, external document from owner
Main indicator - description			optional, if exists, external document from owner
Main indicator value		kWh /(m^2a)	optional, if exists, external document from owner
Reference (Minimum requirement for new buildings) for main indicator		kWh /(m^2a)	optional, if exists, external document from owner
ALDREN EVC - rating			
Software commercial name used for EP calculation			EVC, CEN standards M480 (hourly step)
ALDREN Energy class 1 (non-renewable primary energy balance with export)			EVC, CEN standards M480 (hourly step)
ALDREN Energy class 2 (non-renewable primary energy auto-consumption)			EVC, CEN standards M480 (hourly step)
Reference value Ref (non-renewable primary energy)		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Main indicator 1 (non-renewable primary energy balance with export) kWh/(m².a)		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Main indicator 1 - Ratio to reference			EVC, CEN standards M480 (hourly step)
Main indicator 2 (non-renewable primary auto-consumption) kWh/(m².a)		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Main indicator 2 - Ratio to reference			EVC, CEN standards M480 (hourly step)
Total primary energy		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Energy use kWh/(m².a)		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Exported primary energy		kWh_{EP} /(m^2a)	EVC, CEN standards M480 (hourly step)
Share of renewable %		%	EVC, CEN standards M480 (hourly step)
CO2 emissions		kg CO_2/(m².a)	EVC, CEN standards M480 (hourly step)
Renewable energy generation - total			
Renewable electricity generation by PV panels		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable heat generation by biomass		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable heat generation by heat pumps		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable heat generation by solar		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable electricity generation by wind (small size turbines)		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable energy generation - auto consumed			

Auto consumed-Renewable electricity generation by PV panels		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Auto consumed-Renewable heat generation by biomass		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Auto consumed-Renewable heat generation by heat pumps		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Auto consumed-Renewable heat generation by solar		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Auto consumed-Renewable electricity generation by wind (small size turbines)		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Renewable energy generation - exported			
Export-Renewable electricity generation by PV panels		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Export-Renewable heat generation by biomass		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Export-Renewable heat generation by heat pumps		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Export-Renewable heat generation by solar		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Export-Renewable electricity generation by wind (small size turbines)		kWh /(m^2a)	EVC, CEN standards M480 (hourly step)
Measured energy - operational rating			
Measured corrected energy consumption - heating		kWh /(m^2a)	EVC optional page, CEN standards M480 (hourly step)
Measured corrected energy consumption - cooling		kWh /(m^2a)	EVC optional page, CEN standards M480 (hourly step)
Measured corrected energy consumption - DHW		kWh /(m^2a)	EVC optional page, CEN standards M480 (hourly step)
Measured corrected energy consumption - lighting		kWh /(m^2a)	EVC optional page, CEN standards M480 (hourly step)
Measured corrected energy consumption - ventilation, air conditioning		kWh /(m^2a)	EVC optional page, CEN standards M480 (hourly step)

B3 Integration of energy performance indicators in asset evaluation (Task 2.5)

Increased attractiveness and better technical state have an impact on potential of a building for commercialisation. The aim of financial valuation is to present the economic benefits to motivate building owner towards investment in deep renovation.

The focus of ALDREN project is on old obsolete buildings with poor energy performance, which are able to achieve 60% energy savings. Such buildings have often a poor indoor air quality and comfort and therefore the renovation is urgently needed,

The economic benefits from renovation of commercial building could be:

- **direct benefits** - costs savings (e.g. energy costs, maintenance costs) – direct link to T2.2
- **indirect benefits** – increased attractiveness, Health & Wellbeing and technical state.

The economic benefits due to deep renovation of existing commercial non-residential buildings (offices, hotels) are the subject of task T2.5 including the attractiveness and technical state.

Different valuation methods for asset valuation are codified in European countries, which can be based on:

- sales comparable approach - suitable for stable big markets or for buildings that do not produce income (e.g. residential buildings),
- cost approach – suitable for special cases only when no cash flow is produced,
- income approach - market value for non-residential buildings is mainly based on rational considerations, capitalisation and income, Discounted Cash Flow (DCF) or Net present value (NPV).

The income approach, based on the net present value (NPV), can show explicitly the benefits for building owner that result from deep renovation integrating several aspects during building commercialisation, as building technical quality / obsolescence, energy performance, Health & Wellbeing and attractiveness for occupants. The inputs in income approach for asset valuation are:

- net income during calculation period → all future cash flows (incomes, costs)
- discount rate → influenced by risk, type of building, attractiveness and technical state
- end value for subsequent sale (value at the end of calculation period) → influenced also by attractiveness and technical state

Variables for NPV calculation influenced by renovation are:

- Energy costs
- Maintenance costs
- Replacement costs
- Renting rate
- Occupancy rate
- Discount rate with risk consideration

The definitions of energy performance related costs are in Regulation No. 244/2012 [4] and in European standard EN 15459-1:2017 [14].

Examples of energy savings as results from energy performance calculation (T2.2), that can be directly used for NPV method, are in Figures 63 – 69. Energy and costs savings from step-by step renovation for model **office buildings** are in Figures 63.

The costs savings from simulation of **office buildings** in different climates are in Figures 64 – 66.

The costs savings from simulation of **hotel buildings** in different climates are in Figures 67 – 69.

The renovation actions considered in examples are:

EX - NZEB – renovation from old existing building quality to ALDREN NZEB level
EX - CO – renovation from old existing building quality to cost optimal level in 2013
CO - NZEB – renovation from cost optimal level in 2013 to ALDREN NZEB level

The energy prices from Eurostat for electricity[9] and gas[10] were used for these examples.

Conclusions on direct savings for asset evaluation

The main findings from investigation on model buildings are:

- It is more difficult to reach 60% savings for bigger buildings (envelope has less influence)
- It is difficult to reach 60% savings for hotel buildings even with PV installed
- Renovation from cost optimal level CO (2013) to ALDREN NZEB does not reach 60% savings if PV is not installed

In Helsinki the average old existing buildings are very close to the CO (2013) level. So even if there are energy savings in the final energy, there could negative savings in terms of primary energy and costs savings due to change from gas to electricity.

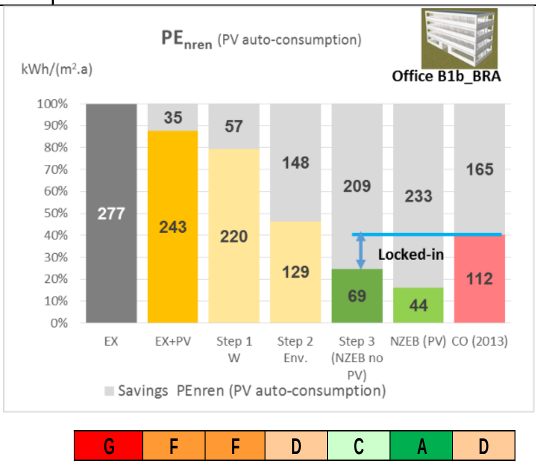
In case the ALDREN RenoMap (Task 2.6.3) is not developed for building it is recommended to perform a global costs analysis for different options how to get to NZEB level based on EPB standard EN 15459-1:2017 [14] or Regulation 244/2012 [4] for big investment in deep renovation decision.

[9] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

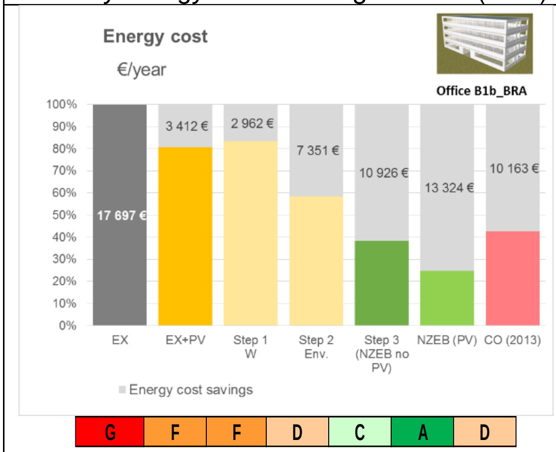
[10] https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics

Model office building B1b

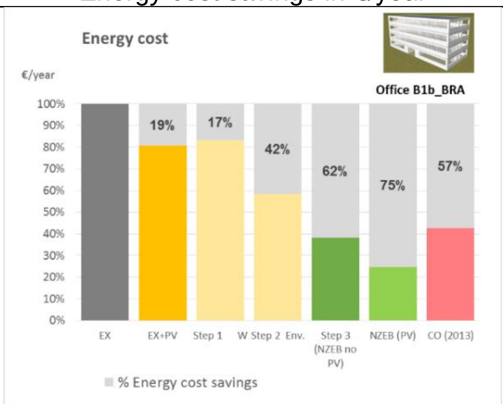
Total floor area	1 440	m²
Volume	4 752	m³
Shape factor	0.446	1/m



Primary energy PEnren savings in kWh/(m².a)



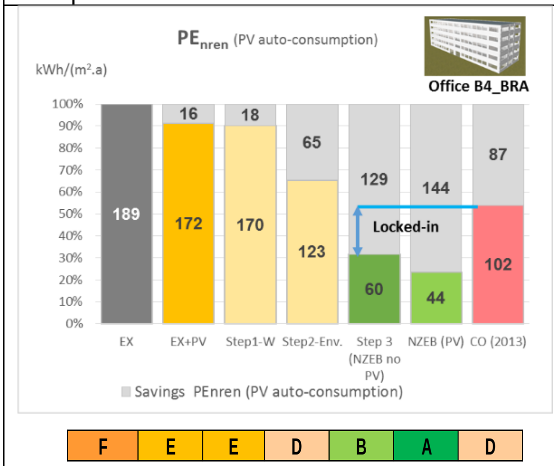
Energy cost savings in €/year



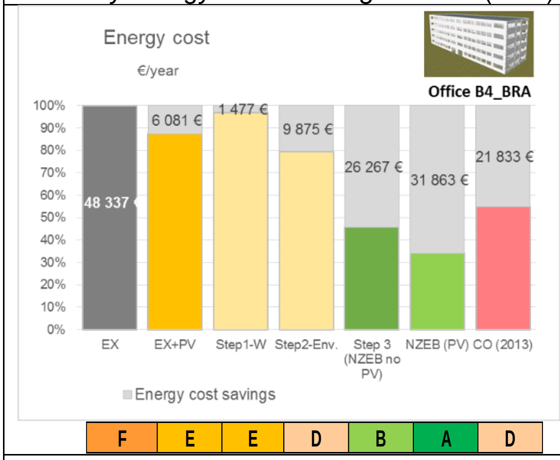
Energy cost savings in %

Model office building B4

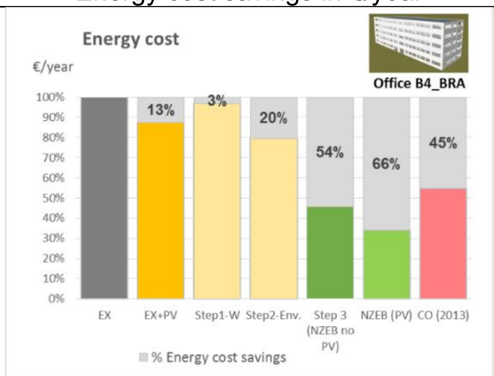
Total floor area	5 400	m²
Volume	17 820	m³
Shape factor	0.327	1/m



Primary energy PEnren savings in kWh/(m².a)



Energy cost savings in €/year



Energy cost savings in %

Figure 63 Energy and costs savings by step-by step renovation from old existing building to NZEB or CO(2013) level – office buildings in Bratislava

Savings	Warm (Palermo)						
PRIMARY ENERGY nren (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	70%	70%	71%	56%	56%	56%	70%
EX-CO	64%	63%	65%	49%	53%	53%	63%
CO-NZEB	**17%**	**19%**	**17%**	**15%**	**7%**	**7%**	**19%**

PRIMARY ENERGY (PV auto cons for NZEB)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	91%	91%	88%	75%	66%	75%	87%
EX-CO (PV auto)	84%	83%	81%	66%	63%	71%	78%
CO (no PV)-NZEB(PV auto)	**75%**	**75%**	**66%**	**51%**	**29%**	**47%**	**64%**

PRIMARY ENERGY (balance - PV export for N	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	132%	133%	106%	83%	68%	80%	101%
EX-CO (PV export)	126%	125%	100%	75%	65%	77%	94%
CO (no PV)-NZEB(PV export)	**189%**	**187%**	**117%**	**66%**	**32%**	**58%**	**103%**

FINAL ENERGY (PV auto for NZEB)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	94%	93%	92%	80%	74%	81%	91%
EX-CO (2013)	68%	67%	71%	50%	58%	58%	67%
CO-NZEB (PV auto)	80%	81%	73%	61%	39%	54%	72%

Warm (Palermo) € total

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	8 748	8 758	15 365	17 878	37 180	37 180	8 758
EX-CO (2013)	8 260	8 184	14 562	16 494	36 569	36 569	8 184
CO-NZEB	488	574	803	1 384	611	611	574

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	12 057	12 011	20 208	24 890	45 781	52 579	11 362
EX(no PV)-CO (2013) (PV auto)	11 421	11 290	19 023	22 924	45 218	51 407	10 588
CO (no PV)-NZEB(PV auto)	3 797	3 827	5 646	8 396	9 212	16 010	3 178

Warm (Palermo) %

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	65%	65%	65%	52%	51%	51%	65%
EX-CO (2013)	61%	61%	62%	48%	50%	50%	61%
CO-NZEB	9%	11%	9%	8%	2%	2%	11%

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	89%	89%	86%	73%	63%	72%	84%
EX(no PV)-CO (2013) (PV auto)	85%	84%	81%	67%	62%	70%	79%
CO (no PV)-NZEB(PV auto)	73%	72%	63%	47%	25%	44%	60%

Warm (Palermo) €/m2

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	6.1	6.1	6.1	3.3	3.1	3.1	6.1
EX-CO (2013)	5.7	5.7	5.8	3.1	3.1	3.1	5.7
CO-NZEB	0.3	0.4	0.3	0.3	0.1	0.1	0.4

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	8.4	8.3	8.0	4.6	3.9	4.4	7.9
EX(no PV)-CO (2013) (PV auto)	7.9	7.8	7.5	4.2	3.8	4.3	7.4
CO (no PV)-NZEB(PV auto)	2.6	2.7	2.2	1.6	0.8	1.3	2.2

Figure 64 Energy and costs savings by renovation actions – office buildings in Palermo

Savings Moderate (Bratislava)

PRIMARY ENERGY nren (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	75%	75%	74%	68%	66%	66%	75%
EX-CO	60%	60%	59%	46%	48%	48%	60%
CO-NZEB	37%	39%	38%	42%	34%	34%	39%

PRIMARY ENERGY (PV auto consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	84%	84%	83%	76%	71%	75%	83%
EX-CO (PV auto)	68%	68%	66%	53%	54%	57%	66%
CO (no PV)-NZEB(PV auto)	60%	60%	58%	56%	44%	52%	57%

PRIMARY ENERGY (PV export)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	102%	101%	91%	79%	71%	77%	88%
EX-CO (PV export)	87%	86%	75%	56%	54%	59%	73%
CO (no PV)-NZEB(PV export)	105%	104%	77%	61%	44%	55%	71%

FINAL ENERGY (PV auto)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	91%	91%	90%	86%	82%	85%	90%
EX-CO (2013)	62%	61%	61%	47%	50%	50%	61%
CO-NZEB (PV auto)	76%	76%	74%	73%	64%	69%	74%

Moderate (Bratislava) € total

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	10 596	10 926	17 602	26 267	51 322	51 322	10 926
EX-CO (2013)	9 949	10 163	16 312	21 833	45 597	45 597	10 163
CO-NZEB	648	762	1 291	4 434	5 724	5 724	762

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	13 022	13 324	21 261	31 863	58 494	63 649	12 910
EX(no PV)-CO (2013) (PV auto)	12 168	12 345	19 561	26 960	52 769	57 804	11 936
CO (no PV)-NZEB(PV auto)	3 073	3 161	4 949	10 030	12 897	18 052	2 747

Moderate (Bratislava) %

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	61%	62%	61%	54%	53%	53%	62%
EX-CO (2013)	58%	57%	56%	45%	47%	47%	57%
CO-NZEB	9%	10%	10%	17%	11%	11%	10%

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	75%	75%	73%	66%	60%	65%	73%
EX(no PV)-CO (2013) (PV auto)	70%	70%	67%	56%	54%	59%	67%
CO (no PV)-NZEB(PV auto)	42%	42%	39%	38%	25%	35%	36%

Moderate (Bratislava) €/m2

Energy cost savings (no PV)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	7.4	7.6	7.0	4.9	4.3	4.3	7.6
EX-CO (2013)	6.9	7.1	6.5	4.0	3.8	3.8	7.1
CO-NZEB	0.4	0.5	0.5	0.8	0.5	0.5	0.5

Energy cost savings (PV auto-consumption)	B1a	B1b	B2	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	9.0	9.3	8.4	5.9	4.9	5.4	9.0
EX(no PV)-CO (2013) (PV auto)	8.5	8.6	7.8	5.0	4.4	4.9	8.3
CO (no PV)-NZEB(PV auto)	2.1	2.2	2.0	1.9	1.1	1.5	1.9

Figure 65 Energy and costs savings by renovation actions – office buildings in Bratislava

Savings	**Cold (Helsinki)**						
PRIMARY ENERGY nren (no PV)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB	70%	71%	70%	65%	64%	64%	71%
EX-CO	39%	39%	39%	22%	27%	27%	39%
CO-NZEB	**52%**	**52%**	**51%**	**56%**	**51%**	**51%**	**52%**
PRIMARY ENERGY (PV auto cons for NZEB)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB (PV auto)	80%	80%	79%	73%	69%	73%	79%
EX-CO (PV auto)	47%	46%	46%	29%	32%	36%	45%
CO (no PV)-NZEB(PV auto)	**68%**	**68%**	**65%**	**66%**	**58%**	**63%**	**65%**
PRIMARY ENERGY (balance - PV export fo	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB (PV export)	98%	98%	86%	76%	69%	74%	84%
EX-CO (PV export)	67%	66%	55%	32%	32%	37%	52%
CO (no PV)-NZEB(PV export)	**97%**	**96%**	**78%**	**69%**	**58%**	**65%**	**74%**
FINAL ENERGY (PV auto for NZEB)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB (PV auto)	88%	88%	87%	83%	79%	82%	87%
EX-CO (2013)	36%	35%	35%	12%	18%	18%	35%
CO-NZEB (PV auto)	82%	82%	80%	80%	75%	78%	80%

Cold (Helsinki)	€ total						
Energy cost savings (no PV)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB	9 836	10 312	16 690	24 529	47 593	47 593	85 078
EX-CO (2013)	5 089	5 308	8 619	6 929	17 711	17 711	43 789
CO-NZEB	4 747	5 005	8 070	17 600	29 883	29 883	41 289
Energy cost savings (PV auto-consumptior	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX (no PV)-NZEB (PV auto)	11 016	11 483	18 442	27 130	50 906	53 401	92 951
EX(no PV)-CO (2013) (PV auto)	6 017	6 212	10 036	9 217	21 023	23 267	50 130
CO (no PV)-NZEB(PV auto)	5 927	6 175	9 823	20 201	33 195	35 691	49 162

Cold (Helsinki)	%						
Energy cost savings (no PV)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB	74%	74%	73%	68%	67%	67%	74%
EX-CO (2013)	38%	38%	38%	19%	25%	25%	38%
CO-NZEB	57%	58%	57%	61%	56%	56%	58%
Energy cost savings (PV auto-consumptior	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX (no PV)-NZEB (PV auto)	82%	83%	81%	76%	72%	75%	81%
EX(no PV)-CO (2013) (PV auto)	45%	45%	44%	26%	30%	33%	44%
CO (no PV)-NZEB(PV auto)	72%	72%	69%	70%	62%	67%	69%

Cold (Helsinki)	€/m2						
Energy cost savings (no PV)	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX-NZEB	6.83	7.16	6.62	4.54	4.01	4.01	7.16
EX-CO (2013)	3.53	3.69	3.42	1.28	1.49	1.49	3.69
CO-NZEB	3.30	3.48	3.20	3.26	2.52	2.52	3.48
Energy cost savings (PV auto-consumptior	**B1a**	**B1b**	**B2**	**B4**	**B6**	**B6 (2xPV)**	**B1b (0.5PV)**
EX (no PV)-NZEB (PV auto)	7.65	7.97	7.32	5.02	4.28	4.50	7.82
EX(no PV)-CO (2013) (PV auto)	4.18	4.31	3.98	1.71	1.77	1.96	4.22
CO (no PV)-NZEB(PV auto)	4.12	4.29	3.90	3.74	2.79	3.00	4.14

Figure 66 Energy and costs savings by renovation actions – office buildings in Helsinki

Savings Warm (Palermo)

PRIMARY ENERGY nren (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	57%	51%	43%	43%	57%
EX-CO	40%	31%	28%	28%	40%
CO-NZEB	**29%**	**29%**	**22%**	**22%**	**29%**

PRIMARY ENERGY (PV auto cons for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	69%	60%	48%	49%	67%
EX-CO (PV auto)	51%	40%	32%	33%	50%
CO (no PV)-NZEB(PV auto)	**48%**	**41%**	**29%**	**29%**	**46%**

PRIMARY ENERGY (balance - PV export for N	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	104%	67%	52%	60%	81%
EX-CO (PV export)	87%	48%	36%	44%	63%
CO (no PV)-NZEB(PV export)	**107%**	**53%**	**33%**	**45%**	**68%**

FINAL ENERGY (PV auto for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	73%	63%	52%	52%	72%
EX-CO (2013)	36%	26%	21%	21%	36%
CO-NZEB (PV auto)	57%	50%	39%	39%	56%

Warm (Palermo) € total

Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	9 662	24 909	39 806	39 806	9 662
EX-CO (2013)	7 555	17 845	30 705	30 705	7 555
CO-NZEB	2 107	7 064	9 101	9 101	2 107

Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	12 116	30 041	45 836	46 352	11 795
EX(no PV)-CO (2013) (PV auto)	9 934	23 297	36 365	36 867	9 637
CO (no PV)-NZEB(PV auto)	4 561	12 196	15 130	15 647	4 240

Warm (Palermo) %

Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	53%	48%	40%	40%	53%
EX-CO (2013)	42%	34%	31%	31%	42%
CO-NZEB	20%	21%	13%	13%	20%

Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	67%	58%	47%	47%	65%
EX(no PV)-CO (2013) (PV auto)	55%	45%	37%	37%	53%
CO (no PV)-NZEB(PV auto)	43%	36%	22%	23%	40%

Warm (Palermo) €/m2

Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	6.71	4.61	3.35	3.35	6.71
EX-CO (2013)	5.25	3.30	2.58	2.58	5.25
CO-NZEB	1.46	1.31	0.77	0.77	1.46

Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	8.41	5.56	3.86	3.90	8.19
EX(no PV)-CO (2013) (PV auto)	6.90	4.31	3.06	3.10	6.69
CO (no PV)-NZEB(PV auto)	3.17	2.26	1.27	1.32	2.94

Figure 67 Energy and costs savings by renovation actions – hotel buildings in Palermo

Savings	Moderate (Bratislava)				
PRIMARY ENERGY nren (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	65%	58%	52%	52%	65%
EX-CO	43%	32%	25%	25%	43%
CO-NZEB	**39%**	**38%**	**36%**	**36%**	**39%**
PRIMARY ENERGY (PV auto cons for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	71%	62%	55%	55%	70%
EX-CO (PV auto)	49%	37%	28%	28%	48%
CO (no PV)-NZEB(PV auto)	**50%**	**45%**	**40%**	**40%**	**48%**
PRIMARY ENERGY (balance - PV export for N	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	86%	65%	56%	59%	76%
EX-CO (PV export)	64%	40%	29%	33%	53%
CO (no PV)-NZEB(PV export)	**75%**	**49%**	**41%**	**46%**	**57%**
FINAL ENERGY (PV auto for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	79%	71%	65%	65%	78%
EX-CO (2013)	43%	30%	23%	23%	43%
CO-NZEB (PV auto)	63%	59%	54%	55%	62%

Moderate (Bratislava)	€ total				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	12 345	29 778	45 360	45 360	12 345
EX-CO (2013)	10 003	22 639	34 234	34 234	10 003
CO-NZEB	2 342	7 139	11 126	11 126	2 342
Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	14 466	34 146	50 774	51 461	14 126
EX(no PV)-CO (2013) (PV auto)	11 977	27 131	39 118	39 656	11 695
CO (no PV)-NZEB(PV auto)	4 463	11 507	16 539	17 226	4 123

Moderate (Bratislava)	%				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	53%	45%	37%	37%	53%
EX-CO (2013)	43%	35%	28%	28%	43%
CO-NZEB	18%	17%	13%	13%	18%
Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	62%	52%	42%	42%	61%
EX(no PV)-CO (2013) (PV auto)	52%	41%	32%	33%	50%
CO (no PV)-NZEB(PV auto)	34%	27%	19%	20%	31%

Moderate (Bratislava)	€/m2				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	8.57	5.51	3.82	3.82	8.57
EX-CO (2013)	6.95	4.19	2.88	2.88	6.95
CO-NZEB	1.63	1.32	0.94	0.94	1.63
Energy cost savings (PV auto-consumption)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	10.05	6.32	4.27	4.33	9.81
EX(no PV)-CO (2013) (PV auto)	8.32	5.02	3.29	3.34	8.12
CO (no PV)-NZEB(PV auto)	3.10	2.13	1.39	1.45	2.86

Figure 68 Energy and costs savings by renovation actions – hotel buildings in Bratislava

Savings	Cold (Helsinki)				
PRIMARY ENERGY nren (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	58%	51%	44%	44%	58%
EX-CO	15%	5%	-4%	-4%	15%
CO-NZEB	**50%**	**49%**	**46%**	**46%**	**50%**
PRIMARY ENERGY (PV auto cons for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	65%	56%	47%	48%	64%
EX-CO (PV auto)	21%	9%	-1%	-1%	20%
CO (no PV)-NZEB(PV auto)	**58%**	**54%**	**49%**	**50%**	**57%**
PRIMARY ENERGY (balance - PV export fo	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV export)	80%	59%	48%	52%	69%
EX-CO (PV export)	37%	12%	0%	4%	26%
CO (no PV)-NZEB(PV export)	**76%**	**57%**	**50%**	**54%**	**63%**
FINAL ENERGY (PV auto for NZEB)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB (PV auto)	73%	65%	59%	59%	72%
EX-CO (2013)	8%	-6%	-12%	-12%	8%
CO-NZEB (PV auto)	71%	67%	63%	63%	70%
Cold (Helsinki)	€ total				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	10 456	27 166	47 233	47 233	10 456
EX-CO (2013)	2 323	967	- 5 988	- 5 988	2 323
CO-NZEB	8 132	26 200	53 221	53 221	8 132
Energy cost savings (PV auto-consumptior	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	11 470	29 378	50 103	50 676	11 336
EX(no PV)-CO (2013) (PV auto)	3 195	3 126	- 3 687	- 3 234	3 089
CO (no PV)-NZEB(PV auto)	9 147	28 411	56 091	56 664	9 013
Cold (Helsinki)	%				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	61%	54%	48%	48%	61%
EX-CO (2013)	14%	2%	-6%	-6%	14%
CO-NZEB	55%	53%	51%	51%	55%
Energy cost savings (PV auto-consumptior	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	67%	59%	51%	51%	66%
EX(no PV)-CO (2013) (PV auto)	19%	6%	-4%	-3%	18%
CO (no PV)-NZEB(PV auto)	62%	58%	53%	54%	61%
Cold (Helsinki)	€/m2				
Energy cost savings (no PV)	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX-NZEB	7.26	5.03	3.98	3.98	7.26
EX-CO (2013)	1.61	0.18	- 0.50	- 0.50	1.61
CO-NZEB	5.65	4.85	4.48	4.48	5.65
Energy cost savings (PV auto-consumptior	B1b	B4	B6	B6 (2xPV)	B1b (0.5PV)
EX (no PV)-NZEB (PV auto)	7.97	5.44	4.22	4.27	7.87
EX(no PV)-CO (2013) (PV auto)	2.22	0.58	- 0.31	- 0.27	2.15
CO (no PV)-NZEB(PV auto)	6.35	5.26	4.72	4.77	6.26

Note: In Helsinki the existing buildings are very close to the CO(2013) level. So even if there are energy savings in final energy, there could negative savings for primary energy and costs savings due to change from gas to electricity.

Figure 69 Energy and costs savings by renovation actions – hotel buildings in Helsinki

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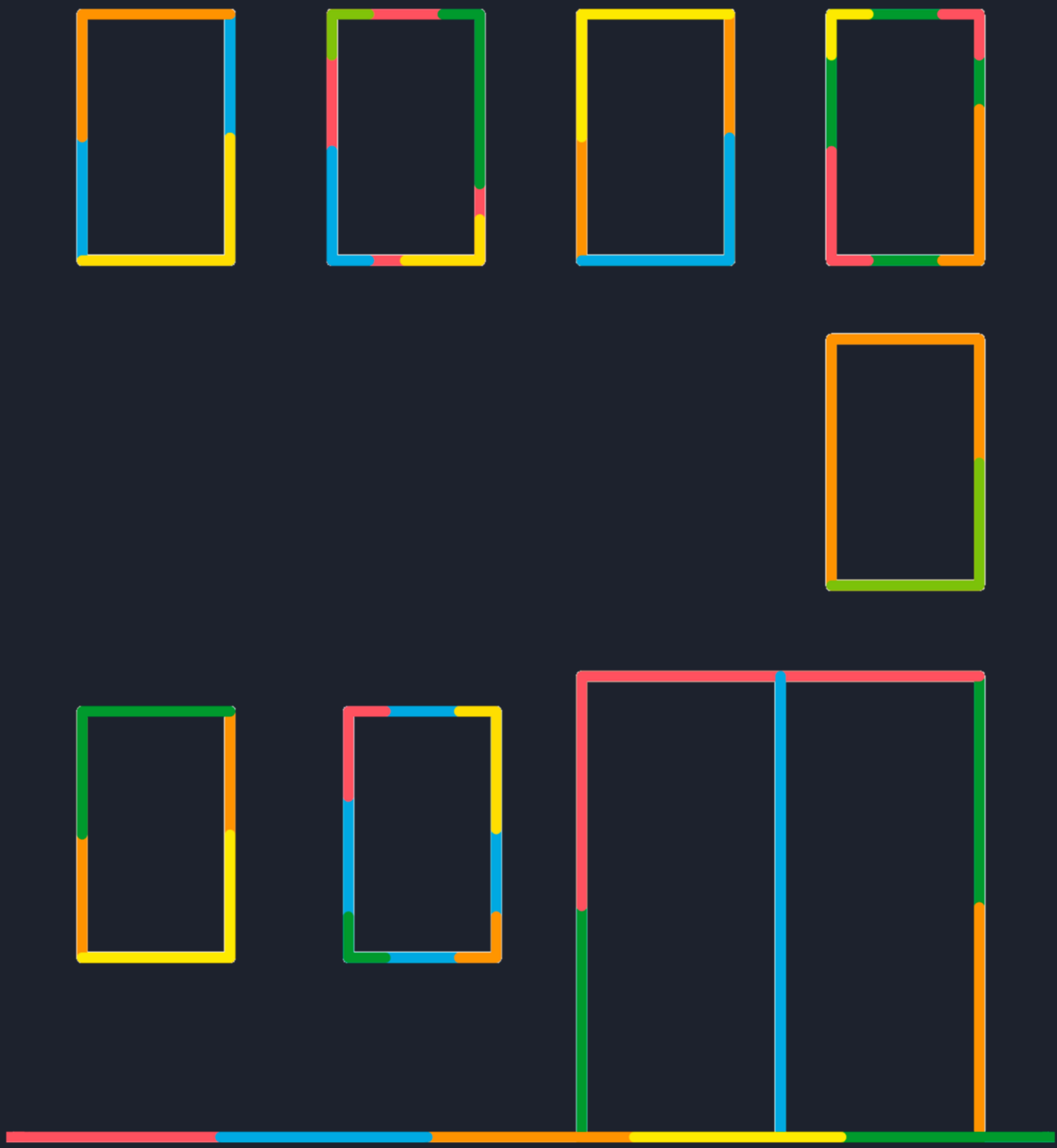

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