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Acronyms and Abbreviations

AC	-	air condition (-ing)
BE	-	building envelope
BEC	-	building energy codes
BEP	-	building energy performance
BES	-	building energy standard
CFL	-	compact fluorescent lamp
CHP	-	combined heat and power
DHW	-	domestic hot water
EE	-	energy efficiency
EPC	-	energy performance certification (certificate)
ESCO	-	energy service company
EU	-	European Union
HP	-	heat pump
HSS	-	heat supply system
HVAC	-	heating, ventilation and air conditioning
NZEB	-	nearly-zero energy building
LED	-	light-emitting diode
MFB	-	multi-family building
PV	-	photovoltaic (cells)
RES	-	renewable energy sources
SFB	-	single-family building
STS	-	solar thermal system
VAC	-	ventilation and air conditioning

Signs and Measures

h	-	hour
m	-	metre
W	-	watt
C	-	Celsius
K	-	Kelvin

Terms and Definitions

Air-conditioning system: a combination of components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity and air cleanliness (EPBD, 2003).

Boiler: combined boiler body and burner-unit designed to transmit to water the heat released from combustion (EPBD, 2003).

Building code: a law or regulation that establishes specifications for the design and construction of residential or commercial buildings. Building codes help ensure that new and existing residential and commercial structures meet minimum health, safety, and performance standards (U.S. DoE, 2019)

Building envelope: integrated elements of a building which separate its interior from the outdoor environment (A.D. McNaught; A. Wilkinson (IUPAC), 1997).

Combined heat and power: simultaneous conversion of primary fuels into mechanical or electrical and thermal energy, meeting certain quality criteria of energy efficiency (EPBD, 2003).

Commercial building: commercial building is that is used for commercial purposes. Types include office buildings, warehouses, retail, hotels, etc.

District heating/cooling: means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling (EPBD, 2010).

Energy audit: systematic procedure to obtain knowledge of existing energy consumption profile of building (group of buildings), of industrial operation and/or installation or of a private or public service, identify and quantify cost-effective energy savings opportunities, and report the findings (ESD, 2006).

Energy code: subset of provisions in building code that establishes the criteria for the building's thermal envelope; heating, ventilation, and air-conditioning; service water heating; lighting; and other areas related to energy usage and performance. Energy codes are developed as a baseline from which homes and all other buildings will achieve a minimum level of EE (U.S. DoE, 2019).

Energy consumption: amount of energy consumed in form, in which it is acquired by user. The term excludes electrical generation and distribution losses.

Energy need for domestic hot water: heat to be delivered to the needed amount of DHW to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point without the losses of the domestic hot water system.

Energy need for heating or cooling: heat to be delivered to or extracted from a thermally conditioned space to maintain the intended space temperature conditions during a given period.

Energy performance certificate: a certificate recognised by country or legal person designated by it, which includes the energy performance of a building calculated according to a methodology based on the general framework set out.

Energy performance requirement: minimum level of energy performance that is to be achieved to obtain a right or an advantage: *e.g.*, right to build, lower interest rate, quality label (CEN, 2005).

Energy service company: a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria (ESD, 2006).

Final energy: energy supplied that is available to the consumer to be converted into useful energy (IPCC, 2019).

Gross floor area: total area of all floors of a building, including intermediately floored tiers, mezzanine, basements, etc., as measured from exterior surfaces of outside walls of a building.

Harmonization: adoption of strategic principles based on recognized best international practices, applicable to national building energy code and facilitating advancement in the field of buildings energy efficiency, taking into account particularities of country, without attempting to apply a uniform approach.

Heat pump: a device or installation that extracts heat at low temperature from air, water or earth and supplies the heat to the building (EPBD, 2003).

Living floor space/area: total area of rooms falling under the concept of rooms (OECD, 2019).

Nearly zero energy building: a very high energy performance building, in which 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 energy sources produced on-site or nearby (EPBD, 2010).

Net floor area: Interior Gross Area less the areas of interior walls (used in International Organization for Standardization standard).

Panel building: building constructed of large, prefabricated concrete slabs/panels.

Primary energy: energy which has not undergone any conversion or transformation process.

Public building: building owned or occupied by any public body (public offices, hospitals, and educational buildings, etc.).

Residential building: structure used primarily as dwelling for one or more households, including single-family houses and multi-family residential buildings (multi-apartment houses).

Standards: documents based on voluntary compliance, established by consensus, and approved by a recognized body. They provide, for common and repeated use, rules, guidelines or characteristics for activities or their results. Standards are aimed at the achievement of the optimum degree of order in a given context, and should be based on the consolidated results of science, technology and experience, and aim to promote community benefits (ISO, 2019).

Useful floor space/area: floor space of dwellings measured inside outer walls, excluding cellars, non-habitable attics and common areas (OECD, 2019).

U-Value: rate of heat loss through a material.

White certificates: certificates issued by independent certifying bodies confirming the energy savings claims of market actors as a consequence of energy efficiency improvement measures (ESD, 2006).

Subregions

Subregion A: Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom;

Subregion B: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia;

Subregion C: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan;

Subregion D: Canada, United States of America;

Subregion E: Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia;

Subregion F: Turkey.

Israel and San Marino, the UNECE member States, are not in the list due to insufficiency of data required for this study.

EXECUTIVE SUMMARY

Existing building energy standards in the UNECE region vary from voluntary guidelines to mandatory requirements, which apply to different building types. Their development is typically a complex decision-making process that involves variety of stakeholders.

Standards that are stringent for one country may be ineffective in another, depending on climate conditions, occupant behavior, existing building stock, and construction practices. Active work is conducted by ministries, regional and municipal level authorities, local and international financial institutions, international organizations and other interested counterparts, resulting in EE improvements and reduction of carbon dioxide emissions.

While many UNECE member States have now technical requirements in place in their building energy codes, there are still those yet to implement requirements on heating, cooling, lighting, ventilation, etc. There are also inconsistencies on the choice and design of the assessment methodology that hinder process of implementation of energy performance certificates, which is also constrained by lack of enforcement, training and monitoring mechanisms. There is also a lack of knowledge, incompleteness of statistics and lack of studies on assessing energy performance gap. This suggests that either calculation methods are flawed, or enforcement regime is not being undertaken sufficiently rigorously, or designers and builders fail to deliver on the intended outcome. Closing the gap between design intent and regulatory requirement is likely to become an important issue over the next decade if countries are to deliver on climate and environmental targets related to buildings.

This publication is prepared in response to the outlined challenges and for a better understanding of the status of deployment and implementation of EE standards in buildings in the UNECE region, based on data gathered through desk research and stakeholder outreach (UNECE, 2018) (UNECE, 2019) (UNECE, 2019), and is set forth as follows:

In Chapter 1 “Energy Efficiency Standards and Technologies”, the analysis of comprehensiveness, stringency, technical requirements and energy efficiency materials and products requirements of the building energy codes and energy performance certificates, and analysis of enforcement mechanisms, including incentive packages and penalties are conducted, and energy efficiency technologies in buildings in relation to the existing standards are initially assessed.

Chapter 2 “Mapping of the Existing Technologies” analyses the actual (as opposed to perceived) prevalence of specific types of energy-efficient technologies in the building stock in the UNECE region, along with levels and types of public policy interventions supporting their deployment. The objectives are to evaluate the adoption of these technologies and appraise the gaps between the existing energy-efficient technologies in buildings and their application and adoption, with assessments undertaken at national levels.

In Chapter 3 “Best practices on standards and technologies for energy efficiency in buildings”, the research is aimed to identify and highlight best practices on adopting, implementing and enforcing energy efficiency standards and energy-efficient technologies for buildings in the UNECE region. It serves as a basis to improve the knowledge of member States concerning best practices in energy efficiency related to existing standards and technologies. The selected best practices are organized in different sections: legislative and regulatory framework; management of multi-family housing stock; awareness raising and behavior change; technical measures; and financial mechanisms.

The report concludes with recommendations arising from the conducted analysis.

1. ENERGY EFFICIENCY STANDARDS AND TECHNOLOGIES

The status of energy efficiency (EE) standards and technologies in buildings in the UNECE region was assessed based on data collected through a Questionnaire survey available from the previous study (UNECE, 2018). This Chapter focuses on analysis of the received responses; it tests elements related to implementation of building energy standards (BES) and assesses EE technologies in buildings in relation to these standards.

1.1. Gap analysis of the status of energy efficiency standards

Gap analysis of the status of EE standards in buildings has been undertaken using a number of specific metrics (to demonstrate the countries' performance in each category) in the following categories:

1. Comprehensiveness and stringency of building energy code (BEC);
2. Technical requirements of BEC;
3. Comprehensiveness and stringency of energy performance certification (EPC);
4. Enforcement mechanisms, including incentive packages and penalties;
5. EE materials and products requirements in BEC.

The analysis intends to determine which countries are embracing EE through effective BES. To this end, it showcases the status and implementation of BEC across the Subregions, highlighting the existing gaps.[1]

1.1.1. Comprehensiveness and stringency of building energy codes

Different BES cover different regions or climatic conditions and different types of buildings (IEA, 2008). Countries can implement codes with various levels of stringency: voluntary, mandatory, or some mixture depending on the region or state (Young, 2014). This stringency metric is a basic reporting of the status of BEC in a country. Table 1 provides an overview of legal status and coverage of BES in selected countries, and shows the stringency of adherence to BEC and the types of buildings.

1 While every attempt was made to ensure accuracy of information and analysis presented, data gaps exist. It is noted that a few participating countries do not presently have mandatory BEC, yet many have a federal form of governance. In these countries, only subnational jurisdictions can adopt and enforce BEC (while not all have BEC). In other countries, BEC may be nominally mandatory, but enforcement may be dependent on self-certification. This presented difficulty in assigning scores for several metrics.

Table 1. BEC coverage in individual countries

Sub-region	Selected countries	Coverage				Stringency	Points max 5
		New build	Existing	Residential	Commercial		
A	Germany	R; NR	R; NR	SF; A	C; P	Mandatory	5
	France	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Italy	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Portugal	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Switzerland	R; NR	R; NR	SF; A	C; P	Mixed	4.5
	Spain	R; NR	R; NR	SF; A	C; P	Mixed	4.5
	United Kingdom	R; NR	R; NR	SF; A	C; P	Mixed	4.5
B	Bulgaria	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Croatia	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Czech Republic	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Slovakia	R; NR	R; NR	SF; A	C; P	Mandatory	5
C	Belarus	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Turkmenistan	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Uzbekistan	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Kazakhstan	R; NR	R; NR	A	C; P	Mandatory	4.5
	Armenia	R; NR	R; NR	SF; A	C; P	Mixed	4.5
	Russian Federation	R; NR	R; NR	SF; A	P	Mixed	4.5
	Ukraine	R; NR	R; NR	SF; A	P	Mixed	4.0
	Azerbaijan	R; NR	R; NR	A	C; P	Voluntary	4.0
	Republic of Moldova	NR	R; NR	SF; A	P	Mixed	3.5
	Georgia	R				Mandatory	1.5
D	United States	R; NR	R; NR	SF; A	C; P	Mixed	5.0
	Canada*	R; NR		SF; A	C; P	Mixed	4.0
E	Bosnia and Herzegovina	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Montenegro	R; NR	R; NR	SF; A	C; P	Mandatory	5
	Serbia	R; NR	R; NR	SF; A	C; P	Mixed	4.5
	North Macedonia	R; NR	R; NR	SF; A	C; P	Mixed	4.5
	Albania	R; NR	R	SF; A	C; P	Mixed	4.0

** – No national model energy code that applies to existing buildings. Federal, provincial, and territorial Governments work to develop a model code for existing buildings by 2022, with the goal that provinces and territories adopt this code.*
Note: Each country was awarded points to provide an indicative score on how well it performs against specific criteria included in the metric. Out of 5 possible points, countries were awarded 1 if their BEC are mandatory, 0.5 for mixed and voluntary, and 0 for no code, giving a total possible 1 point allocation for stringency (in Canada and the United States, national governments do not have authority to pass mandatory building codes; yet, many provinces and states have adopted some; to reflect these countries' specifics in the scoring, 1 point was awarded for 'mixed'.). Countries also earn up to 2 points for BEC coverage (the more comprehensive the code, the more types of buildings the code applies to). For example, for residential, 1 point is allotted for coverage for both single- and multi-family buildings (SFB and MFB respectively). For commercial, the code must include all commercial and public buildings to receive 1 point. If the coverage is partial in either commercial or residential, countries get 0.5 points.
Abbreviations: R – Residential; NR – Non-Residential; SF – Single Family; A – Apartments; C – Commercial; P – Public

The analysis suggests that BEC in Subregions A and B provide greater coverage and stringency compared to Subregions C and D, although it is noteworthy that countries of Subregion C made considerable progress to ensure that BEC apply to different types of buildings. The average scores for this metric do not differ significantly across Subregions: countries in Subregions A and B have an average score 4.9, followed by Subregions E (4.6), D (4.5) and C (4.2).

1.1.2. Technical requirements in building energy codes

For technical requirements, different energy uses and functions covered by the country's BEC were analyzed. The elements selected to evaluate technical requirements for each country are as follows: thermal insulation; heating and hot water; air conditioning (AC) systems; natural and mechanical ventilation; solar gains (G-values); lighting efficiency; design, position and orientation; air-tightness; thermal bridging; renewable energy sources (RES); indoor and outdoor climatic conditions; passive solar systems and solar protection.

Nearly all EE standards incorporate provisions for building envelope (BE) which influence design choices for roof, walls, floor and windows. While several BEC include energy consumption of installed equipment and appliances and lighting, other do not (*e.g.*, Kazakhstan, Serbia, Turkmenistan, North Macedonia). The treatment of RES in BEC also varies: RES are referenced more often in BEC of the countries of Subregions A and B, compared to the countries of Subregions C, D and E. Table 2 demonstrates examples of the RES requirements in selected countries.

Table 2. Examples of RES requirements in the selected countries' BEC

Country	RES in BEC
Norway	Buildings >500m^2 shall be designed and constructed so that minimum 60 percent of net energy need for space and water heating may be met by energy supply other than electricity or fossil fuels. For buildings <500m^2 the requirement is minimum 40 percent.
Spain	Solar thermal energy or other RES for water heating.
Denmark	Solar heating systems must be provided when the expected hot water consumption exceeds 2000 liters per day and able to meet 95 percent of demand.
Sweden	The building's specific energy use may be reduced by solar energy.
Greece	60 percent of domestic hot water (DHW) from solar energy.
Montenegro	Obligation for new buildings in climate zone I to cover 30 percent of annual energy needs for DHW with solar thermal systems (STS). In case of open swimming pools, percentage is increased to 100.

Many countries have requirements associated with minimum performance of boilers and AC systems. In Germany, *e.g.*, boilers that do not meet minimum efficiency levels are banned. Additionally, many BEC require minimum levels of daylight, whilst ensuring that solar gains do no result in overheating and/or AC need (Economidou, 2012).

Most countries introduced requirements to ensure minimum levels of ventilation. These are generally based upon metabolic rates and activity within a building. Given increased use of mechanical ventilation systems, fan power requirement in low-energy buildings is becoming an increasingly important issue. Austria, Bosnia and Herzegovina, Czech Republic, Denmark, Estonia, France, Poland, Spain, and Turkmenistan introduced minimum requirements for fan power. Non-quantitative requirements also exist in Hungary and Latvia. As excessive or insufficient ventilation lead to considerable energy wastage and uncomfortable conditions, many countries introduced requirements to limit air permeability/air-tightness of buildings. Most countries (with exception of Slovakia and Turkmenistan) also include requirements for air-tightness in BEC.

Although most countries have inspection schemes for boilers and/or AC systems, data collection on the number of inspections done is still at a very low level. Insufficient data makes it difficult to formulate an appropriate evaluation on effectiveness of these schemes. Finland, France, Ireland, the Netherlands, Slovenia, Sweden and the United Kingdom do not have requirements for inspections of boilers in place.

Table 3 shows technical requirements in each country's BEC. It is evident that the coverage is comprehensive across member States. Out of maximum 3 points, Subregion A has an average score of 2.9, followed by Subregion B (2.7) and Subregions D, E and C with average scores of 2.6, 2.5 and 2.3 respectively.

Table 3. BEC technical requirements

Sub-region	Selected countries	Thermal insulation	Heating and hot water	AC systems	Natural and mechanical ventilation	Solar gains (G-values)	Lighting efficiency	Design, position and orientation	Air-tightness	Thermal bridging	RES	Indoor and outdoor climatic conditions	Passive solar systems and solar protection	Points max 3
A	France	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Germany	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Portugal	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Spain	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Switzerland	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Italy	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	United Kingdom	X	X	X	X	-	X	X	X	X	-	X	X	2.5
B	Bulgaria	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Czech Republic	X	X	X	X	X	X	X	X	X	-	X	X	2.8
	Slovakia	X	X	X	X	X	X	X	-	X	X	X	X	2.8
	Croatia	X	-	X	X	-	X	X	X	X	-	X	X	2.3
C	Ukraine	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Armenia	X	X	X	X	X	X	X	X	X	-	X	X	2.8
	Azerbaijan	X	X	X	X	-	X	X	X	X	X	X	X	2.8
	Belarus	X	X	X	X	X	X	X	X	X	-	X	X	2.8
	Republic of Moldova	X	X	X	X	-	X	X	X	X	X	X	X	2.8
	Uzbekistan	X	X	X	X	X	X	-	X	X	X	X	X	2.8
	Russian Federation	X	X	X	X	X	X	X	X	X	-	X	-	2.5
	Kazakhstan	X	X	-	X	-	-	X	X	X	-	X	-	1.8
	Turkmenistan	X	X	X	X	-	-	X	-	X	-	X	-	1.8
	Georgia	-	-	-	-	-	-	-	-	-	-	-	-	0
D	Canada	X	X	X	X	X	X	X	X	X	-	X	X	2.8
	United States	X	X	X	X	X	X	X	X	X	X*	-	-	2.5
E	Albania	X	X	X	X	X	X	X	X	X	X	X	X	3.0
	Montenegro	X	X	X	X	-	X	X	X	X	X	X	X	2.8
	North Macedonia	X	X	X	X	X	-	X	X	X	X	X	X	2.8
	Bosnia and Herzegovina	X	-	X	X	X	X	X	X	X	-	X	-	2.3
	Serbia	X	X	-	-	X	-	X	X	X	-	X	-	1.8

** – In 2018, California became the first State in the United States to mandate solar panels on new homes and apartment buildings built after 1 January 2020.*

Note: Each country is allotted 0.25 points per technical requirement. Due to data constraints, this list and scoring does not investigate stringency of technical requirements.

1.1.3. Comprehensiveness and stringency of energy performance certificates

EPC are an important instrument to enhance building energy performance (BEP). EPC serve as an information and market tool for building owner, occupiers and real estate actors, *i.a.*, to create demand for EE in buildings by targeting such improvements as a decision-making criterion in real-estate transactions, and by providing recommendations for the cost-effective upgrading of BEP (BPIE, 2014). To measure EPC effectiveness, same metrics as above were selected. An additional metric was included to establish existence of national EPC registry databases, which not only support independent control system, but are also a useful tool to map and monitor national building stock. Table 4 shows the stringency of adherence to EPC and types of buildings subject to EPC coverage for residential and commercial sectors. Often, EPC only apply to specific types of buildings, such as SFB and MFB.

Table 4. EPC in individual countries

Sub-region	Selected countries	Coverage				Stringency	National EPC registry	Points max 6
		New build	Existing	Residential	Commercial			
A	France	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	Portugal	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	United Kingdom	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	Germany	R; NR	R; NR	SF; A	C; P	Mixed	Yes	5.5
	Switzerland	R; NR	R; NR	SF; A	C; P	Mixed	Yes	5.5
	Italy	R; NR	R; NR	SF; A	C; P	Mandatory	No	5.5
	Spain	R	-	SF; A	C; P	Mandatory	No	3.5
B	Czech Republic	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	Slovakia	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	Bulgaria	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6
	Croatia	-	-	SF; A	C; P	Mandatory	Yes	4.0
C	Uzbekistan	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6.0
	Turkmenistan	R; NR	R; NR	SF; A	P	Mandatory	No	4.5
	Russian Federation	R	-	A	C; P	Mandatory	Yes	4.0
	Republic of Moldova	NR	-	SF; A	C; P	Mixed	No	3.0
	Azerbaijan	-	-	A	C; P	Mandatory	No	2.5
	Armenia *	-	-	-	-		No	0
	Belarus *	-	-	-	-		No	0
	Georgia **	-	-	-	-		No	0
	Kazakhstan *	-	-	-	-		No	0
	Ukraine ***	-	-	-	-		No	0
D	Canada	R	R	SF; A	C	Mixed	No	3.0
	United States	R	R	SF; A	-	Mixed	No	2.5
E	Bosnia and Herzegovina	R; NR	R; NR	SF; A	C; P	Mandatory	Yes	6.0
	Serbia	R; NR	R; NR	SF; A	C; P	Mixed	Yes	5.5
	Montenegro	R; NR	R; NR	SF; A	C; P	Mixed	No	4.5
	North Macedonia	R; NR	R; NR	SF; A	C; P	Mixed	No	4.5
	Albania	NR	-	-	P	Mandatory	No	2.0

** – Currently not in use. ** – EPC Law to be enforced in 2019. *** – New rules on EPC became mandatory in July 2018. Note: Out of 6 points: For stringency, 1 is awarded if EPC is mandatory, 0.5 for mixed or voluntary, and 0 for no EPC. Up to 2 points for EPC coverage: for residential buildings 1 point is allotted for coverage of both SFB and MFB (for commercial buildings, the code must include all commercial and public buildings to receive 1 point); if coverage is partial in either commercial or residential, countries get 0.5 points. For national registry database for EPC, 1 point is awarded (otherwise 0). Abbreviations: R – Residential; NR – Non-Residential; SF – Single Family; A – Apartments; C – Commercial; PB – Public*

Table 4 suggests that the use of EPC in Subregions A and B provides greater coverage and stringency with the average score of 5.4 and 5.5 respectively, compared to Subregions E (4.5), D (2.8) and C (2.0). It is noteworthy, however, that some countries in Subregion C made some progress in developing EPC. Most of the countries in Subregions A and B employ mandatory stringency for EPC while countries in Subregion C currently have a much lower level of EPC implementation. The existence of national registry database for EPC is also more prominent in Subregions A and B.

Denmark, Estonia, Hungary, Lithuania, Netherlands, Portugal, Slovakia and Sweden offer access to basic EPC data, such as energy class or BEP, for any building in an online database searchable by its address, while Greece, Norway and Ireland offer this search functionality only by EPC identification number (that is known only to the building's owner). In addition, in the United Kingdom (specifically in England, Wales and Northern Ireland) there is also a feature to search by EPC identification number, postcode, street name and post town. In Italy, the regions of Marche, Emilia Romagna, Sicily and Valle d'Aosta present some EPC information on their websites; in Lombardy, a complete database is publicly available (BPIE, 2014).

Canada

In Canada, EPC are not mandatory, although an Energuide rating system developed by federal government is widely used and supported through incentive programs. Additionally, "Build Smart, Canada's Buildings Strategy 2017" sets the goal for federal, provincial, and territorial governments to work together with the aim of requiring labelling of building energy use by 2019.

The quality of EPC process, however, is not satisfactory in some countries. There are inconsistencies across member States on the choice and design of the assessment methodology which hinders EPC implementation process. Successful implementation of EPC is also hindered by a lack of enforcement and monitoring mechanisms, where national EPC registry database is not deployed. In Belarus, Georgia and Kazakhstan EPC are not in use.

1.1.4. Enforcement mechanisms, including incentive packages and penalties

As efforts to increase EE standards in BEC differ across countries, it is useful to analyze not only which countries have comprehensive BEC, but also which implement and enforce those standards effectively.

BEC and regulations could be one effective way to improve EE, but only if their enforcement can be ensured. Enforcing compliance with BEC and standards will be key to countering the perception that energy saving renovation measures come with a price premium (BPIE, 2011). Additionally, many countries implemented incentives and disincentives to help push contractors and home builders to comply with the codes.

Implementing energy standard involves a network of social systems and human interactions that stretch from officers assigned to administer the standard, to carpenters who apply weather-stripping. Any involved in a building's development, design, and construction process can affect its final energy use, so there are an almost unlimited number of opportunities for building to comply with, or deviate from, the standard's recommendations. The power of implementing agency, the level of training provided, and the effectiveness of compliance mechanisms are all important indicators of the extent to which standard is likely to be followed. This invites further study of these issues.

An attempt to capture these, and highlight some robust policy packages, was made. This metric is meant to document whether countries' BEC have enforcement and penalties for non-compliance. BEC enforcement was examined in 3 ways:

1. Financial incentives: some countries have specific policy packages and incentives that complement or motivate compliance with building codes.[2]
2. Occupancy and construction permissions: if building does not comply with code, then it is refused permission for occupancy or construction.
3. Fines: enforcement of building codes includes fines and fees for non-compliance.

2 For example, there are subsidies, which can only obtained if certain EE requirements are fulfilled. These are based on either pure compliance with requirements in the codes, or on measures stricter than the EE requirements in these codes.

Regulations that require detailed monitoring of energy consumption in buildings drive energy-saving changes in practices and behaviors. Advanced metering and monitoring solutions are vital for enabling data-driven EE, and landlords and commercial building managers now concern themselves with monitoring and metering solutions as a way of gaining detailed view of energy use. This supports EE and cost-reduction efforts by detecting inefficiencies, benchmarking BEP, improving load planning and energy usage, and managing demand to ensure there is minimum exposure to volatility, and thus identifying costs reduction opportunities.

To reflect importance of monitoring, 2 additional metrics were included: requirements for monitoring and its stringency. In total, 5 metrics, as laid out in Table 5, were examined to investigate the status of enforcement mechanisms; Table 5 also presents information whether a country has incentives or disincentives for compliance. Country can have more than one in place, and the most robust packages are in countries that have all 3 elements. Stringency of enforcement approaches is not considered. Countries were awarded 1 point for each of 5 metrics (5 points maximum).

Table 5. BEC enforcement standards

Sub-region	Selected countries	Specific incentive	Refusal for occupancy or construction permit	Fines for non-compliance	Requirements for energy performance monitoring	Stringency of monitoring	Points max 5
A	France	X	X	X	X	-	4.0
	Portugal	X	X	X	X	-	4.0
	Germany	X	X	X	-	-	3.0
	Italy	X	X	X	-	-	3.0
	Switzerland	X	X	X	-	-	3.0
	United Kingdom	X	X	X	X	-	4.0
	Spain	-	X	-	X	-	2.0
B	Czech Republic	X	X	X	X	Mandatory	5.0
	Slovakia	X	X	X	X	Mandatory	5.0
	Bulgaria	X	X	X	X	Mandatory	5.0
	Croatia	-	-	X	X	-	2.0
C	Uzbekistan	X	-	X	X	Mandatory	4.0
	Russian Federation	-	X	-	X	Mandatory	2.0
	Armenia	X	-	X	-	-	2.0
	Azerbaijan	-	-	-	X	-	1.0
	Georgia	X	-	-	-	-	1.0
	Republic of Moldova	-	-	-	X	-	1.0
	Turkmenistan	-	X	-	-	-	1.0
	Kazakhstan	-	-	-	-	-	0
	Ukraine	-	-	-	-	-	0
	Belarus	-	-	-	-	-	0
D	United States	X	X	X	X	-	4.0
	Canada	X	X	X	-	-	3.0
E	Montenegro	X	X	X	X	Mandatory	5.0
	Serbia	-	X	-	X	Mandatory	3.0
	Albania	-	-	X	X	-	2.0
	North Macedonia	-	X	-	X	Mandatory	2.0
	Bosnia and Herzegovina	-	X	-	-	-	1.0

Specific policies and incentives that complement or motivate compliance with BEC are in place in Subregions A, B, and D. These include green loan programmes, financial schemes and public incentives (including tax credits). Specific incentives and mechanisms are currently not widely used in BEC of the countries of Subregions C and E.

Ukraine

While there are no incentives for building owners to undergo energy audits and get EPC, work is underway to introduce Energy Efficiency Fund where the state will provide financial support to partially compensate the costs of modernization and implementation of EE measures.

1.1.5. Energy efficiency materials and products requirements in building energy codes

To facilitate compliance, it is essential to develop and harmonize testing, ratings and certification of building materials, and to improve the knowledge base. The quality of building materials is a critical factor in BEP, aside from design and construction practice. To assure design performance of buildings, materials must be tested and certified as meeting design specifications (The World Bank, 2015). Many low- and middle-income countries lack network of accredited materials testing laboratories necessary to certify the quality of building materials: steel, concrete, and importantly more complex building assemblies. Table 6 provides an overview of how countries meet each criteria for building materials.

Table 6. Building materials and products requirements

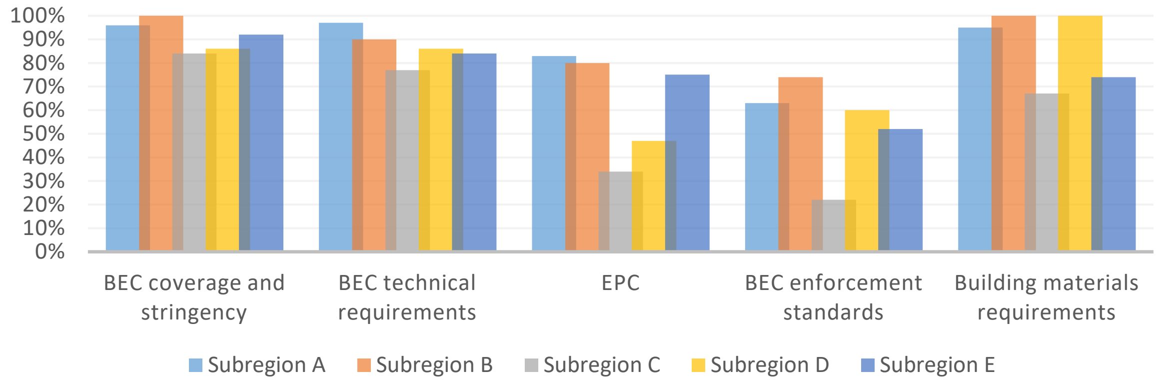
Sub-region	Selected countries	Building materials certification	Harmonization with CE Marking or ISO	Materials testing by certified laboratories	Points max 3
A	France	X	X	X	3.0
	Portugal	X	X	X	3.0
	Spain	X	X	X	3.0
	Switzerland	X	X	X	3.0
	United Kingdom	X	X	X	3.0
	Germany	X	X	-	2.0
B	Slovakia	X	X	X	3.0
	Bulgaria	X	X	X	3.0
	Croatia	X	X	X	3.0
	Czech Republic	X	X	X	3.0
C	Armenia	X	X	X	3.0
	Kazakhstan	X	X	X	3.0
	Uzbekistan	X	X	X	3.0
	Russian Federation	X	X	X	3.0
	Azerbaijan	X	-	X	2.0
	Belarus	X	-	X	2.0
	Republic of Moldova	-	X	X	2.0
	Turkmenistan	X	-	-	1.0
	Ukraine	X	-	-	1.0
	Georgia	-	-	-	0.0
D	Canada	X	X	X	3.0
	United States	X	X	X	3.0
E	Bosnia and Herzegovina	X	X	X	3.0
	Montenegro	X	X	X	3.0
	Serbia	X	X	X	3.0
	Albania	-	X	-	1.0
	North Macedonia	-	X	-	1.0

It can be concluded that countries of Subregions A and B perform consistently across all 3 criteria. The Subregion C countries shown a lower level of consistency in implementing these, with some countries being more stringent when it comes to materials certification and testing. In Subregions C and E, Albania, Georgia, Turkmenistan, Ukraine and North Macedonia showed a relatively low level of implementation for this metric, while Armenia, Bosnia and Herzegovina, Kazakhstan, Montenegro, Russian Federation, Serbia and Uzbekistan exhibited greater commitment to implement EE materials and products in their BEC. Overall, Subregions A, B, D are leading with an average score 3, followed by Subregions E (2.2) and C (2.0).

1.1.6. Overview of gap analysis results

Figure 1 illustrates overall effectiveness of BEC by Subregions across all 5 metrics (previously calculated average scores were converted into percentages).

Figure 1. Effectiveness of BEC, by Subregion



In Europe, (EPBD, 2003) was a step forward, through which Subregions A and B introduced EE requirements in buildings. This explains a greater level of consistency across the countries that fall under it in reporting BES stringency, coverage, technical requirements, energy-efficient materials and enforcement measures with just few exceptions noted in some countries.

Figure 1 reveals that, although codes stringency and coverage and technical requirements do not indicate high level of disparity in their application in Subregions, metrics on EPC requirements, incentives, enforcement mechanisms and building materials and products suggest an area of focus for further harmonization, and an opportunity for improvement in some countries, particularly in Subregion C.

1.2. Assessment of technologies in relation to the existing standards

In most regions globally, heating and cooling loads represent the largest buildings' energy end-use. BE can be significantly improved to reduce (or even avoid) energy needed to heat and cool buildings – with use of such EE technologies as high energy-efficient windows, insulation, well-sealed structures, cool roofs in hot climates, etc. BE improvements are critical to achieve transition to sustainable buildings, but most countries have still not made them an explicit policy priority. According to (IEA, 2013), in most of the world, energy performance of BE is significantly neglected.

Increasing EE of heating and cooling equipment is an important step towards reducing energy consumption and emissions in buildings sector. Effort is needed on both technical and market maturity. Advanced products that were commercialized but only serve niche markets need to be improved to become market viable, requiring a combination of efforts related to cost reduction, ease of installation and market conditioning (IEA, 2013). Yet while there is substantial success in improving EE of heating and cooling equipment, many buildings are still constructed with no insulation or exterior shade control, have leaking issues, and have single-glazed clear glass windows.

The analysis covers the main BE components, photovoltaic (PV) systems, selected space and water heating as well as cooling equipment. It does not cover combined heat and power (CHP), lighting, cooking, plug loads, appliances, metering and building automation or control systems which require separate analysis.

1.2.1. Overview of global trends

Existing buildings in cold climates with little or no insulation offer the greatest potential for energy saving by installing insulating products and devices. There is also significant potential for energy savings in developing countries, where insulation is often not installed. Advanced insulation materials are also beginning to enter the market in various niche applications.

France

Heating equipment market includes: fossil fuel (gas, heating oil); RES (wood, geothermal, heating pump, solar thermal), and; electricity markets (S-GE, 2014). Heating systems with high energy performance (condensing boilers, heat pumps (HP) and wood fired boilers) represented only 52 percent of hot water heating boilers in 2011 (Uniclima, 2014); that is far less than those in Sweden and the United Kingdom (99 percent), the Netherlands (98 percent) and Germany (77 percent) (EHI, n.d.). RES heaters market is dominated by wood-fired, STS and HP, yet wood and pellets are most popular in residential retrofits as cost per kilowatt-hour of wood-fired generation is among the lowest. The market is correlated to tax credit rates. STS market is dominated by collective residential equipment (51 percent).

Eco-construction material remains an emerging market in France: *e.g.*, timber frame buildings in individual housing represented 8 percent of total in 2011, while it was 90 percent in Canada and US, 60 percent in Scandinavia and 30 percent in Germany. Since enforcement of RT2012 (requires buildings to use maximum 40-65kWh/m^2/year depending on locality and altitude of the building) (RT2012, n.d.), mandatory air-tightness tests are performed when building is finished. While 400,000 air-tightness tests are performed annually, about 100,000 are mandatory and require a certified Qualibat tester – over 800 of those are certified in France.

Russian Federation

Relatively cheap energy sources discouraged improvement of buildings EE, resulting in, *i.a.*, poor thermal insulation, for which the following materials are used: mineral wool, glass wool, expanded polystyrene foam and extruded polystyrene (most are produced locally) (PMR, 2010). The potential for insulation materials' use remains huge.

Russian BEC has strengthened in the past 15 years, and demand for efficient windows has grown. The market, where local producers hold 70 percent (though using imported technologies), is competitive (Vira, n.d.).

Although heat dominates the Russian indoor environmental comfort market, demand for ventilation and air conditioning (VAC) has also increased driven by the growth of average income (particularly in large cities) (PNNL, 2012).

With a variety HP systems, their use is associated with difficulties owing to climatic conditions and properties of low temperature heat sources (Trushevskii & Mitina, 2012). There is much scope for installing HP systems, yet currently their use is at an early stage.

Cost is a primary barrier to greater application, and in some cases, there are also concerns about long-term performance: *e.g.*, advanced foam insulation can be difficult to install at low ambient temperatures.

For the vast majority of buildings that require heating or cooling, air-sealing with mechanical ventilation result in large energy savings. While air-sealing methods during new construction are widely available, validation testing can still be expensive, especially in large buildings (IEA, 2013).

Most cold-climate developed countries make a significant effort to promote high-performance windows. Yet triple-glazed windows, available for many decades, have not achieved significant market share. Triple glazing with clear glass was more prevalent in Northern European countries, but then diminished as manufacturers were able to achieve comparable performance using modern double-glazed low-e coated windows. This trend is changing, however, with more stringent BEC.

Austria, Germany and Switzerland have the highest – 54 percent of total window sales – market share for triple glazing, usually with two low-e surfaces for new constructions and residential sector. The majority of windows sold in the European Union (EU) remains double-glazed (Interconnection, 2013). More effort is needed to research, develop, deploy and expand market for high performance window technology in all building applications.

United Kingdom

Biomass for energy used in small wood stoves a have experienced a popularity upsurge in the past decade. In 2017, more than 1 million homes were using those, and their sales reach 175,000 units/year (SIA, 2018).

Sales of low-carbon heat technologies have steadily increased, backed by Renewable Heat Incentive (RHI). Around 22,000 HP were installed in 2017 (18 percent increase compared to 2016, while after 5 years of almost continuous decline caused by economic slowdown, relatively low oil price, uncertainty around the Incentive, 'Brexit', and concerns pound-euro exchange rate) (Open Access Government, 2018). Nowadays, 120,000 electric HP are installed (TheCCC, 2015, p. 80), with 19,000 accredited in 2014.

STS capacity grew 4-fold in 2003-2010, and since then has been declining despite the fIncentive. PV installations dropped from 26,000 (December 2015) to 2,422 (January 2018) after 2016 policy shift away from rebate incentive scheme – feed-in tariff, which was cut by 60 percent (DECC, 2015).

Solar energy is promoted in many countries as a substitute for conventional, currently used to produce hot water. Solar water heaters represent a good economic and environmental solution to save commercial energies, especially in southern countries with good solar radiation. Recently, PV have become the focus of RES application discussions for buildings as they generate electricity and often have greater versatility than STS technologies. However, STS are a valuable resource that needs to be expanded in buildings. STS heat production already has a global capacity and could be expanded significantly given the right policy discussions and incentives.

HP for cooling and space and water heating are mature, highly efficient technologies that take advantage of RES and play an important role in heat decarbonization. HP have the advantage of providing both heating and cooling with a single unit offering an opportunity to lower initial costs. Sales of HP and RES heating equipment have continued to increase by around 5 percent annually since 2010, representing 10 percent of overall sales in 2017 (IEA, 2019). Yet despite this progress, significantly greater attention is needed to increase sales of high-performance HP and STS heating in buildings.

In recent years in many countries, condensing gas boilers, with efficiencies higher than 90 percent, have gradually displaced coal, oil and conventional gas boilers with efficiencies less than 80 percent.

1.2.2. Analysis of energy-efficient technologies deployment

Building envelope components

The analysis of BE is complicated by global diversity of building materials, climates, and standards and practices of building design and construction (IEA, 2013); similarly, suitability of EE technologies depends on economy, climate and whether the materials are being used for new buildings or retrofits. Thus, policies need to be devised and implemented at the city, regional and country levels.

To achieve large energy savings through efficient BE, full market saturation (deployment) of materials is essential. Yet data on current market share are difficult or expensive to obtain in developed countries, and are often not available in emerging markets.

Table 7 presents assessment of the status of market saturation for high-priority BE components by the Subregions. Generally, deployment of energy-efficient BE components progressed most in Subregions A, B and D. From technology perspective, deployment of typical insulation has been successful with full maturity in most Subregions, followed by low-e glass with some established markets. However, more work is needed, especially in Subregion C, to promote market saturation for advanced building materials (IEA, 2013). For example, air-sealing is an initial market for Subregion C, and is a key way of increasing EE during new construction and deep renovation. Therefore, it is important to validate the results of air-sealing by carrying out standardized tests of its effectiveness in individual markets.

Table 7. An assessment of market saturation for high-priority BE components

Sub-region	Double-glazed low-e glass	Window films	Window attachments (shutter, shade, storm panel, etc.)	Highly insulating window (*e.g.*, triple-glazed)	Typical insulation	Exterior insulation	Air sealing
A	Mature	Established	Mature	Established	Mature	Mature	Mature
B	Mature	Established	Mature	Established	Mature	Mature	Established
C	Established	Initial	Initial	Initial	Mature	Initial	Initial
D	Mature	Established	Established	Initial	Mature	Mature	Established
E	Mature	Established	Established	Initial	Mature	Established	Established

Note: Three levels of market saturation are considered: mature (>50 percent), established (5-50 percent), and initial market (available, but <5 percent).
Source: Adapted from (IEA, 2013) (results of this market assessment may have changed).

The majority of countries have air-tightness included in their BEC technical requirements, while some (*e.g.*, Slovakia and Turkmenistan) currently do not have these. Mandatory requirement for air-tightness tests are absent in several countries, the majority of which represent Subregion C.

Table 8 presents data on sales of some BE components in selected countries in 2013.

Table 8. BE components' annual sales in selected countries, 2013

Countries	Sales of expansible polystyrene, kg/1000 capita	Sales of polyurethane, kg/1000 capita	Sales of biomass based (wood wool), kg/1000 capita	Annual share of buildings with new multiple-walled insulating units of glass, percent	Sales of shading devices area, m^2/capita
Austria		3.4			
Denmark	4.4		0.80	0.50	1.05
Germany				0.36	
Luxembourg	0.87	2.1	0.10		0.44
Netherlands		3.4	0.26		
Norway					
Poland			0.11	0.83	0.37
Czech Republic		3.3			
Portugal	0.86	1.3	0.02	0.36	0.66
Belgium		67.2		0.76	0.05
Slovakia	6.0	2.0		0.86	
Spain	0.76	1.5	0.14		0.80
Sweden	3.5	1.2	0.04	0.29	
Italy	2.6	4.8	0.96	0.34	0.72
France	1.4		0.09	0.48	
UK		2.2	0.07	0.48	

Source: Adapted from (ZEBRA2020)

Slovakia (6.0 kg per 1,000 capita), Denmark (4.4 kg per 1,000 capita) and Sweden (3.5 kg per 1,000 capita) were top-3 countries in Europe with the highest sales of expansible polystyrene, while Belgium took a distinctively leading position in sales of polyurethane (67.2 kg per 1,000 capita) in 2013. Italy and Denmark had the highest sales of biomass-based (wood wool) BE components (sales 0.96 and 0.80 kg per 1,000 capita respectively), while Slovakia, Poland and Belgium had the highest number of annual share of buildings with new multiple-walled insulating units of glass. At the same time, sales of shading devices were more prominent in Denmark, Spain and Italy with 1.05, 0.80 and 0.72 m^2 per capita respectively in 2013, mainly due to mandatory requirements for solar shading in these countries' BEC.

Heating, cooling and other technologies

Deployment level of heating and cooling technologies is influenced by awareness of the technology's benefits among consumers, builders and policymakers, implementation of financing mechanisms to mitigate up-front costs, availability of performance standards and certification programmes, etc. Given well-documented non-market barriers that energy-efficient and low/zero-carbon technologies face, active government policy developed in partnership with consumers, building developers, architects, manufacturers, industry associations and local and regional governments is essential to unlocking the potential these technologies have to reduce energy consumption and CO_2 emissions (IEA, 2011).

Table 9 provides an analysis of market saturation of heating, cooling and other EE technologies.

Table 9. Assessment of market saturation of heating, cooling and other EE technologies

Sub-region	Countries	Condensing boilers	Biomass boilers (wood chip and pellet)	Pellet stoves	HP	STS	PV	Other
A	France	X	X	X	X	X	X	
	Germany	X	X	X	X	X	X	
	Italy	X	X	X	X	X	X	
	Portugal	X	X	X	X	X	X	X *
	Switzerland	X	X	X	X	X	X	
	Spain	X	X	X	X	X	X	
	United Kingdom	X	X	X	X	X	X	
B	Bulgaria	X	X	X	X	X	X	
	Croatia	X	X	X	X	X	X	
	Czech Republic	X	X	X	X	X	X	X **
	Slovakia	X	X	X	X	X	X	X ***
C	Armenia	X	X	-	X	X	X	
	Azerbaijan	X	X	X	X	X	X	
	Belarus	X	X	-	X	X	X	
	Georgia	X	-	-	X	-	-	
	Kazakhstan	-	X	X	X	X	-	
	Republic of Moldova	-	X	X	X	X	X	
	Russian Federation	-	X	X	X	X	X	
	Turkmenistan	-	-	-	-	-	-	
	Ukraine	X	X	X	X	X	-	
	Uzbekistan	X	X	X	X	X	X	
D	Canada	X	X	X	X	X	X	
	United States	X	X	X	X	X	X	
E	Albania	-	X	X	X	X	X	
	Montenegro	X	X	X	X	X	X	
	Bosnia and Herzegovina	X	X	X	X	X	X	
	Serbia	X	X	X	X	X	X	
	North Macedonia	X	X	X	X	X	X	

*Note: * – Cogeneration, trigeneration, district heating and cooling; ** – Forced ventilation with heat recovery; *** – CHP*

The assessment shows that Subregions A, B and D have made significant progress in deploying advanced EE technologies, while their further marketing is needed in Subregion C. For example, in Portugal solar water heaters in new buildings are mandatory, and there is also regulation favoring other RES and high efficiency cogeneration (higher rating EPC is warranted by existence of RES installations). Germany, instead, is witnessing an increase in gas condensing boilers, HP and biomass heating, while STS slightly decrease after peaking in 2008. In Czech Republic (Subregion B) there are financial instruments that support energy-efficient technologies that meet stricter requirements, such as highly-efficient boilers, forced ventilation systems with heat recovery, and HP. In Bulgaria, HP gain popularity; there are still obstacles in introducing individual PV systems, so gas installations for SFB are also expected to rise. Switzerland has applied strong incentives to encourage distributed building mounted PV systems and HP. Most Central Asian countries and Azerbaijan have limited market availability of EE products. An evolving market with EE products (yet of limited variety) is present in Georgia; automatic heat control for heat supply system (HSS) is being developed in Turkmenistan. Belarus, Moldova and Ukraine are more harmonized with EU processes and have more EE products (and, except for Moldova, even manufacture locally). In Canada, market is also transforming rapidly, with industry recognizing codes and standards changing dramatically. Armenia has a law giving strong impetus for PV plants.[3] Both PV and STS are well-represented on local market, with over 10 companies importing and a few locally producing PV modules. Furthermore, local financial institutions developed loan products for financing installation of both systems. Finally, in Montenegro, biomass boilers and stoves have become more popular in recent years, mostly thanks to the implementation of ENERGY WOOD project (interest-free credit line for installation of modern biomass-fueled (pellets, briquettes) heating systems for households). Biomass boilers and condensing boilers, along with STS and HP, were promoted through Municipal Energy Efficient Programme and Energy Efficiency Program in Public Buildings (refurbishment of educational and health care buildings). Use of decentralized PV systems was initiated through project SOLARNI KATUNI (installation of PV solar systems in summer pasture lands).

The advanced EE technologies have significant technical and economic considerations relating to climate (Table 10). The complexity can exist not only in a regional and global context, but also within a specific country: *e.g.*, addressing large global residential heating load requires marketing of advanced BE technologies and heating equipment to populated locations with colder climate. Milder weather locations will have lower energy savings, thus leading to diminished cost effectiveness (IEA, 2013).

Table 10. Technology complexities with climate considerations

Technology	Climate		
	Cold	Mixed	Hot
Gas absorption HP for heating	High priority, most cost effective	With cooling capability. Could be cost effective	Less cost effective
Solar cooling	Not recommended	Harder to justify	High priority. Most cost effective
STS: water and heat	Freeze protection, less resource	Freeze protection, good demand	Low-cost options for water heating
HP water heater (air)	Cold ground water, but cold ambient air	High priority, decent ambient air and cold ground water	Great ambient air temperatures but warmer ground water

Source: Adapted from (IEA, 2013)

Table 11 presents data on annual installations and sales of heating and cooling EE technologies in selected countries in 2013.

3 On 12 May 2016 and 21 December 2017, Parliament adopted amendments to the laws “ On Energy” and “On Energy Saving and Renewable Energy”.

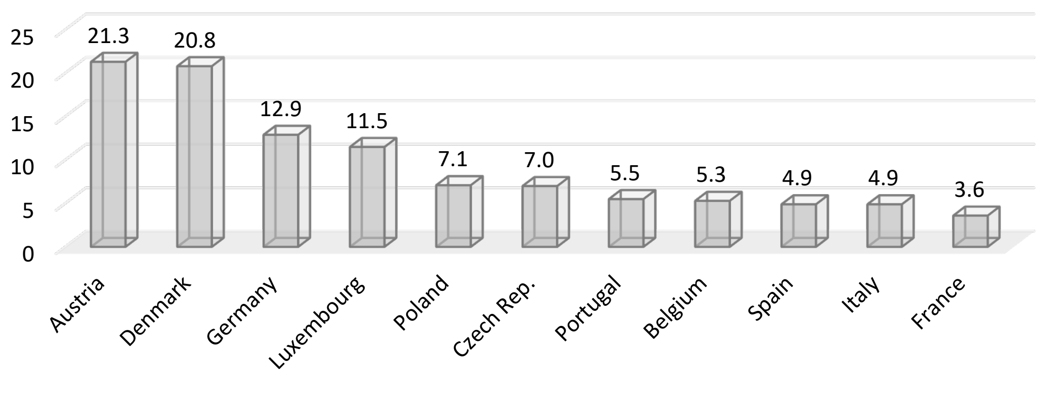
Table 11. EE equipment annual sales and installations in selected countries, 2013

Countries	STS	PV systems,	Condensing boilers	Biomass boilers (wood chip and pellet)	Pellet stoves	HP
	m²/1000 capita	kW/1000 capita	per 1000 dwellings			
Austria	21.3	42.8		3.5	0.67	5.2
Denmark	20.8	0.89	4	1.7		1.8
Germany	12.9			0.48	0.39	
Luxembourg	11.5					2.9
Netherlands			56.6			4.3
Norway						22.5
Poland	7.1	0.04	7.2	0.57	12.7	
Czech Republic	7		2.4	0.61	0.12	1.7
Portugal	5.5					18.2
Belgium	5.3	17.1		0.09	0.64	
Slovakia			3.8			
Spain	4.9	41.4		0.07	0.76	2.8
Sweden		0.07		0.78		8.6
Italy	4.9	12.8	10.2		7.8	34.8
France	3.6	5	12	0.32	3.3	11.1
UK			53.1			

Source: Adapted from (ZEBRA2020)

The benchmark on STS installations for most countries with medium solar radiation is Austria with 21.3 m^2 per 1000 capita, followed by Denmark (20.8) and Germany (12.9) (Figure 2). In most EU countries, financial (subsidies or soft loans) and fiscal incentives (tax credit) exist to encourage households to install solar water heaters in dwellings. Furthermore, regulations on mandatory installation of solar heaters in new construction in Portugal and Spain are in place (Enerdata, 2012).

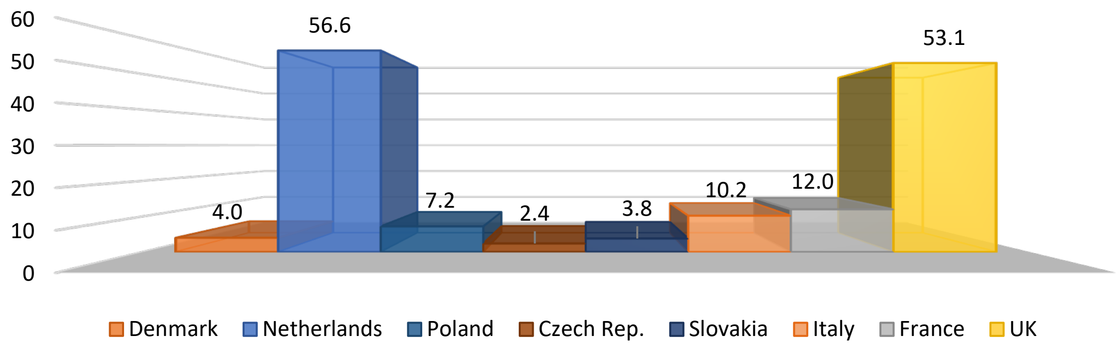
Figure 2. Annual installation of STS per capita, m^2/1000 capita, 2013



Source: Compiled from (ZEBRA2020)

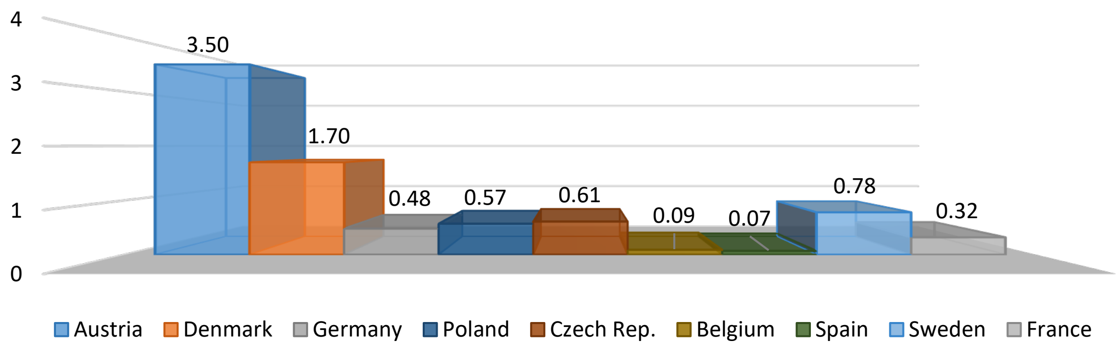
The largest sales of condensing boilers were in the Netherlands (56.6 units per 1000 dwellings) and in the United Kingdom (53.1 units per 1000 dwellings) (Figure 3), possibly due to stringent requirements and favorable market conditions. Noteworthy, the current policy in the Netherlands bans use of natural gas as major heating fuel – reflecting the need to significantly reduce CO_2 emissions, and to reduce domestic gas production while not boosting energy dependency; additionally, the electricity (kWh) and natural gas (m^3) price ratio became a game changer for new and renovated buildings, leading to wider deployment of HP, which became the most used intermediate solution (used in combination with low-temperature heat emission systems and high temperature cooling emission systems, which became feasible due to better thermal insulation and air-tightness and use of ventilation heat recovery).

Figure 3. Annual sales of condensing boilers per 1000 dwellings, 2013



In 2013, Austria, Denmark and Sweden had the largest sales of biomass boilers with 3.5, 1.7 and 0.78 units per 1,000 dwellings respectively (Figure 4).

Figure 4. Annual sales of biomass boilers (wood chip and pellet) per 1000 dwellings, 2013



The installed base of wood heating systems in Germany is estimated 9 million units. For instance, 1 in 5 German households use wood heating (ADEME, 2013). Annual sales are estimated at 400,000 units for all wood systems. Germany has a general EE loan scheme for home improvements with up to 75,000 euro with the loan amount reduced based on achieved improvement and subsidised interest rates. Grants for up to 20 percent are also available. This was introduced in 2001 and is managed by KfW (INSPIRE, 2016).

Austria

With 46 percent forest coverage and significant rural population in the country, biomass-fueled central heating systems dominate. The 2013 domestic sales reached 10,281 pellet boilers, 5,754 wood log boilers and 3,477 wood chip boilers, as well as 2,454 pellet stoves, 7,411 cooking stoves and 14,923 wood log stoves. The turnover of Austrian biomass boiler producers and domestic stove manufacturers was 952 and 131 million euro respectively, and resulted in 5,043 jobs (CEBC, 2017). As of 2012, there were 1.5 million 50kW domestic biomass boiler systems installed, compared to only 26,000 stoves (Audigane, et al., 2012). Almost 80 percent of new homes in Austria have a biomass boiler installed with a 25kW typical size.

Incentives schemes to support biomass heating systems to reduce reliance on heating oil are in place since 1980s. The Environmental Aid Act provides for general support of schemes to protect the environment, within which there are special investment incentives for STS installations, HP, geothermal energy and biomass heating plants, especially for businesses. Schemes vary per province but grants are available for up to 30 percent of investment cost (ResLegal, 2019).

1.3. Conclusions

The study demonstrates that a number of countries achieved significant progress in EE technologies deployment, resulting from holistic and consistent policy approach to developing and implementing BEC with support of effective financial and enforcement mechanisms. Significant improvements are noted in increasing EE of heating and cooling equipment. Yet, many new buildings still have no insulation or exterior shade control and have single-glazed clear glass windows. The market maturity for high-priority BE components varies significantly between the countries of the UNECE region.

Many countries, particularly of Subregion C, experience difficulties in increasing market deployment of EE technologies. This may stem from wrong signals sent by incoherent polices in regard to financial incentives, lack of consumers awareness on benefits of such technologies, insufficiently developed BEC, and/or lack of technical expertise, all of which have negative impacts on EE technology cost reduction, ease of installation and market conditioning.

While it is difficult to generalize, research provides a basis for further inquiry into the development, structure, and implementation of BES. This information may be particularly useful to countries at similar stages of development, with common cultural roots, and/or those in comparable climates. The intention was to draw attention to the need to further define the field for research in the area of BES.

Based on the analysis, countries' climate-specific recommendations of EE technologies deployment are presented in Table 12. Best practices identified through gap analysis are presented in Table 13 below.

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Table 12. Overview of countries' specific recommendations according to climate condition

<table>
<tr><th rowspan="2">Sub-region</th><th rowspan="2">Climate</th><th rowspan="2">BEC recommendations</th><th colspan="4">EE technology</th><th colspan="2">BE</th></tr>
<tr><th>STS</th><th>HP</th><th>Air sealing</th><th>Boilers</th><th>New Build</th><th>Retrofit</th></tr>
<tr><td rowspan="2">A
B
D</td><td>Warm</td><td rowspan="2">- Facilitate harmonization of EPC through integration of ventilation, cooling and lighting
- Make mandatory requirement for inspection of boilers and AC systems
- Make mandatory air-tightness test</td><td>Advanced STS</td><td></td><td rowspan="4">Implement market-validated air-sealing requirements for new construction and apply to retrofits</td><td rowspan="2">Upgrade standards for condensing boilers to >95 percent efficiency</td><td>- Architectural shading;
- Very low solar heat gain coefficient windows (or dynamic shades/windows)
- Reflective walls/roofs
- Advanced roofs (integrated design/building-integrated PV)
- Optimised natural/mechanical ventilation</td><td>- Exterior window shading and dynamic glass/shading
- Reflective roofing materials and coatings
- Reflective wall coatings
- New windows and/or window films with low solar heat gain coefficient</td></tr>
<tr><td>Cold</td><td></td><td>Advanced cold climate HP</td><td>- Highly insulated windows
- Passive heating gain (architectural feature/dynamic glass/shades)
- Passive house (Passivhaus) equivalent performance based on life cycle costing limitations</td><td>- Highly insulated windows
- Low-e storm or interior panels
- Insulated shades and other insulating attachments (films)
- Exterior insulating wall systems
- Interior high-performance insulation</td></tr>
<tr><td rowspan="2">C
E</td><td>Warm</td><td rowspan="2">- Draw from Energy Passport experience (EU, Russia), expand beyond code compliance at design stage to use Energy Passport to record energy consumption during operation
- Include lighting, AC, DHW and ventilation in Energy Passports
- Improve supply of domestic EE products, materials and skills, and materials certification capacities
- Promote prices for energy that reflect its social and environmental costs; set prices to increase consumers' motivation
- Improve access to information on consumers' options to improve EE and related benefits
- Create incentives for companies for improving EE through appropriate policies, tax incentives and low-interest loans for EE projects</td><td>Affordable STS and innovative cooling</td><td></td><td rowspan="2">Promote low-cost, high efficiency fireplaces and stoves with incentives; upgrade standards for condensing boilers to >95 percent efficiency</td><td>- Exterior shading and architectural features
- Low solar heat gain coefficient windows
- Reflective roofs and wall coatings
- Optimised natural/mechanical ventilation</td><td>- Exterior shading
- Reflective coatings (roof and wall)
- Low-cost window films
- Natural ventilation</td></tr>
<tr><td>Cold</td><td>Affordable STS</td><td>Advanced cold climate HP</td><td>- Highly insulated windows (possibly double-glazed with low-e storm panel)
- Passive heating gain (architectural feature)
- Optimised low-cost insulation and air sealing
- Develop affordable windows with U-value <0.6 W/m^{2}K</td><td>- Low-e storm or interior panels
- Insulated shades and other insulating attachments (films)
- Exterior insulating wall systems
- Cavity insulation, lower-cost interior insulation (e.g., expanded polystyrene)</td></tr>
</table>

Table 13. Best practices on EE standards in buildings in UNECE

Comprehensiveness and stringency of BEC	
Armenia	In 2016, mandatory BEC was introduced with adoption of "Thermal Protection of Buildings" regulation (based on ground of Russian BEC of 2003, updated 2012), with application of some methodologies and approaches of European standards (EN 15217:2007; EN15316-1:2007; EN15603-1:2007; ISO 16818:2008; ISO 23045-2008). It links BE components and heat losses with established energy limits, taking into account climatic differences. It also includes a requirement for issuing a building energy passport and an EE label with EE classes. Armenia has developed two National Standards AST 362-2013 "Energy conservation. Building energy passport. Basic rules. Standard form" and AST 371-2016 "Methodology for performing energy audit in residential and public buildings" (CCIC, n.d.).
France	To comply with (EPBD, 2002), the Directive on National Building Regulation was implemented in 2005. It set a 15 percent efficiency rate, and a 40 percent efficiency rate goal to be met by 2020, as well as minimum standards for existing buildings, and defined the necessary renovations. Additionally to mandatory BEC, complementary categories for efficient buildings and "White Certificate Trading" were established.
United States	In the State of California, BEC development is characterised by continuous increase in stringency and enforcement. Its building standards set net-zero energy requirements for all new residential buildings by 2020, for new state buildings and half of major retrofits by 2025, and for new commercial buildings and half of existing commercial buildings by 2030. The standards include: basic set of mandatory requirements for all buildings, set of performance requirements that vary by building type and climate zone, and set of prescriptive packages as an alternative to the performance-based approach (GABC, 2016).
Technical requirements in BEC	
Spain	Building EE requirements have both prescriptive and performance-based elements. Codes require performance-based reference building calculation (manual or simulation) for compliance. A prescriptive path (technical requirements, *e.g.*, thermal envelope and EE standards for heat, ventilation and air conditioning (HVAC), DHW, lighting, auxiliary systems) is used for buildings in specific locations. Additionally, code covers design, position, and building orientation and technical installations' requirements (Young, 2014).
Comprehensiveness and stringency of EPC	
Ireland	EPC scheme came into effect in 2009 and became mandatory information for sales and leases. By mid-2014, 25 percent of homes had Building Energy Ratings and certificates. A one-step increase in this rating has been valued at a 2.8 percent increase in sale price, and 1.4 percent of rent (IEA, 2015).
Russian Federation	Decree 399, which sets rules for EE classes of apartment buildings, was adopted in August 2016. EE class is determined based on comparison of actual (for existing buildings) or estimated (for new buildings) energy use with base energy use value set depending on heating degree-days and building height. Certification includes 9 classes (A++ to G) and requires the building class to be presented in energy passport and on building facade. A++ class presumes 60 percent energy savings in comparison to base-level. High EE classes cannot be given to a building that is not equipped with an individual heat-supply station with automatic indoor temperature regulation, energy-efficient lighting of common areas and energy meters in each apartment. This certification system is envisioned to be mandatory; however, it is not yet enforced, and measures to stimulate compliance have not been developed yet (GABC, 2016).
Slovakia	Ministry of Transport and Construction is responsible for EPC system and open-source database (established 2010). Data for issued EPC must first be uploaded by qualified expert to the database in order to be approved and validated (allows for automatic basic quality control for entered data and calculations). To allow registered assessors access the database, an online system was also implemented (it also allows any user to access aggregated statistics from 2009 on, with information on year of EPC issuance, energy class, building type, exact address, and name of qualified assessor). In 2014 (Q2), the database included 44,000 EPC, of which 92 percent for residential buildings. The system seems uses a very modest annual budget of 19,200 euro. Operation of database and quality checks of EPC are financed by the Government, and are controlled by the above Ministry and by Trade Inspection (BPIE, 2014).

Enforcement mechanisms	
Albania	National Energy Efficiency Action Plan set 9 percent energy use reduction by 2018. Residential building sector is expected to account for 22 percent of this target. To achieve it, EE standards for new building construction were introduced: Law No. 8,937 (defines minimal thermal efficiency standards for new construction), and Law No. 10,113 (mandates compliance with EE standards). The Law on Energy Efficiency, which will build a framework for enforcement and implementation of national EE priorities that previously remained unenforced, is under development (Clean Energy Solutions Center, 2019).
Canada	Both residential and commercial codes have all 3 kinds of enforcement mechanisms. The most advanced building code (yet unevenly implemented across the country), contains some comprehensive EE policies, incentives, and disincentives. On-site inspections throughout construction process are required. Specifically, the Ontario Building Code's enforcement includes on-site inspection during and after completion of building. Certification and inspection of boilers and HVAC systems is also required. Enforcement, as with nearly all building codes, is performed by localities, but the Ontario code also requires a third-party inspection, and provides training for inspectors (Young, 2014).
Penalties for non-compliance	
Belgium	In Flanders, fines around 2,500 euro are set for owners, builders, constructors or installers who fail compliance on U-values for surface area (WEC, 2016).
Declaration of EE before construction	
Portugal	A building's EE must be declared by architect or contractor before construction. After construction, certificate must be issued by independent consultants and include a review of self-declaration. If building fails to comply with the regulations, occupancy permit may be rejected until required efficiency level is maintained
Denmark	Additionally, such independent consultant also conducts on-site visual inspection (actual insulation, glassing and installed products checks) of new buildings, and occupancy permit is issued only once compliance with building codes is validated.
Incentives	
France	Initiatives beyond BEC, which improve energy performance, secure supporting measures (grants, subsidies, loans, tax incentives, and trading schemes). The aim by 2020 is to reduce energy consumption by 26 percent. France provides a successful example of implementing tax incentives for homeowners; due to a tax credit scheme providing tax credits for homeowners adopting measures which improve energy performance of their dwellings, a 26 percent reduction in energy consumption of residential buildings is expected (Hilke & Ryan, 2012).
United States	Tax incentives were given in the last years to increase the level of insulation and to encourage constructor and building owners to go further than the minimum requirements. These incentives probably also helped to increase compliance with national codes (WEC, 2016).
EE materials and products requirements in BEC	
Armenia	Technical regulation on EE (of 12 April 2018) is applicable to MFB under construction and to objects constructed/reconstructed/repaired) at the State's expense. The building code on "Thermal Protection of Buildings" was adopted in July 2016. Total 17 EU and ISO EE standards were developed/adopted and registered. Database of insulation and construction materials and lighting equipment (produced locally or imported), was created. An Advisory Handbook on Technical Solutions in Insulation was adopted in 2013. In addition, a full package of replicable design documents for 5 energy-efficient residential houses has been available publicly since 2014. A modern thermal physics laboratory was established for testing and certification of building insulation materials and lighting equipment in addition to more than 13 types of insulation materials that were tested and certified since then. An educational EE laboratory was established for students studying architecture and civil engineering (Harutyunyan & Jalalyan, 2016).

2. MAPPING OF THE EXISTING TECHNOLOGIES

This Chapter analyses actual (as opposed to perceived) prevalence of specific types of energy-efficient technologies in buildings in the UNECE region, along with levels and types of public policy interventions supporting their deployment. The objectives are to evaluate adoption of these technologies and appraise the gaps between the existing energy-efficient technologies in buildings and their application and adoption, with assessments undertaken at national levels. It focuses on how and where energy is consumed in building during its operational life, and on relevant existing EE technologies.

Graphic and tabulated data and country-specific narratives are documented in (UNECE, 2019).

This Chapter is based on the principles of the UNECE Framework Guidelines for Energy Efficiency Standards in Buildings (UNECE, 2017), and thus transcends the incremental, components-based approach of existing building standards analyses.

2.1. Existing energy-efficient technologies

BEC provide guidelines both for new construction and retrofitting to create high-performance buildings by applying an integrated, holistic design process, which increases building life-span, adaptability, durability, and resilience, supports sustainability, reduces energy consumption, operating costs and environmental impacts, and contributes to better, healthier, more comfortable environment for people. Some of the basic EE measures are described below.

2.1.1. Building envelope: insulation and glazing

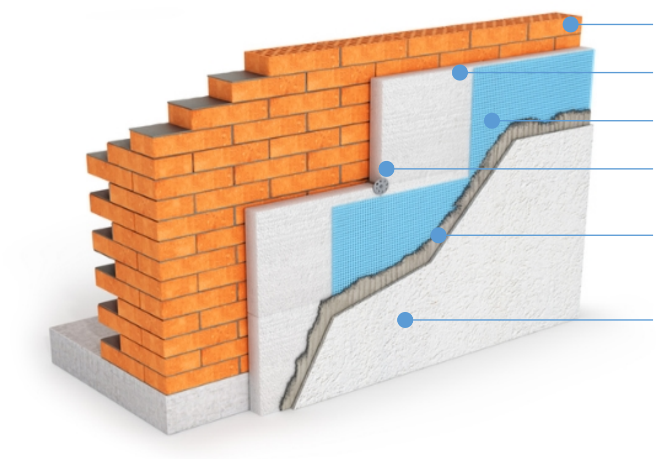
Insulation of building envelope, air-tightness, thermal bridging

BE has the greatest impact on BEP and is a prime area to consider when planning EE measures. It is imperative to optimize BE design and functions (*i.e.*, security, comfort, shelter, privacy, aesthetics, ventilation, etc.) to meet the occupants' requirements while reducing energy consumption and heat loss.

The importance of thermal insulation, air-tightness, and reducing thermal bridging in buildings is equally relevant for countries in both hot and cold climates. Both heat loss (due to poor insulation) and cool air loss (due to high heat gain) occur through walls, roofs, floors, in addition to glazing, sealing joints, and thermal bridges, etc., and result in increased energy consumption and higher CO_2 emissions. Adequate insulation and reduction of thermal bridging are critical measures for improving thermal performance and comfort, as well as to ensuring building durability.

Selection of insulation layer thickness is based on the requirements of the construction and regulatory criteria, climate conditions, current thermal, and other necessary parameters, which all should be considered at architectural design stage. Some technical solutions for, *e.g.*, external walls and attic/ground floors or basement slabs insulation are illustrated in Figure 5. The selection of a wide range of thermal insulation materials used in buildings in the UNECE region is shown in Table 14.

Figure 5. Technical solutions for insulation



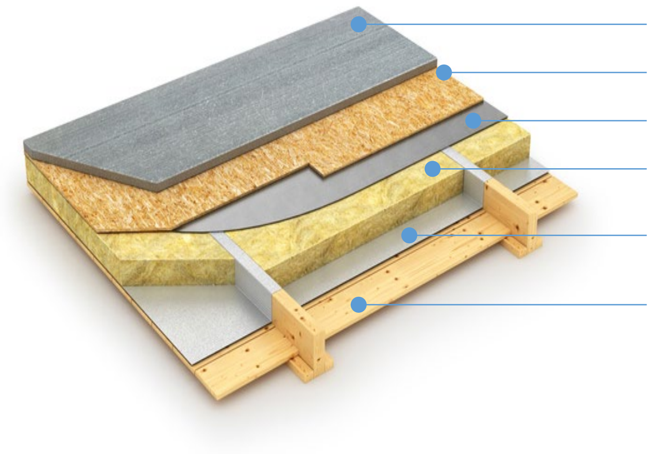


Table 14. Insulation materials applied in the UNECE region

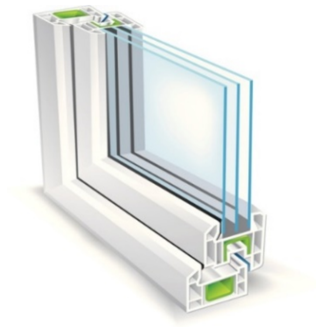
		Fiberglass	Rock wool	Slag wool	Expanded polystyrene (frothed non-pressed)	Extruded polystyrene
View						
Characteristic	Raw material	Sand, soda, limestone, drill (or etibor), cullet	Rocks	Domain slags	Foam plastic (98 percent air)	Granules of polystyrene formed by extrusion
	Heat conductivity, W/mK	0.038-0.046	0.035-0.042	0.04-0.07	0.036-0.050	0.028-0.034
	Max. operational temperature, °C	450	up to 1000 (if no deformation)	300	70	75
	Min. operational temperature, °C	-60	-	-	-50	-50
Advantages		Lightness, elasticity, good sound-proofing properties, non-flammable, high compression for easy transport	Non-flammable, high elasticity, immunity to mould and fungus, resistance to short-term moisture influence (can be mounted during rain), fibers are not caustic	Low water absorption – is ideal for work under the open sky in any weather	Low price, excellent flexibility, high durability on compression at the low density, simplicity of installation	High durability on compression at the low density, low water absorption, low vapor permeability, low coefficient of heat conductivity
Disadvantages		High fragility of fibers, high water absorption	Inconvenient for transport (low compression), high cost	High fragility of fibers, low heat conductivity	Flammability, high water absorption, repeated 0ºC crossings lead to destruction	Combustible, high cost
Restrictions		Need to use coveralls made of dense material, gloves, respirator, and safety glasses during installation	Requires careful transport and protection against mechanical impacts	Not recommended to use with metallic facade elements	Prohibited to use without covering – requires cement and sand or plaster protection from open environment	Prohibited to use without covering – requires cement and sand or plaster protection from open environment

Installation of modern windows with higher thermal characteristics

Replacement of windows with those using latest insulation technologies is more efficient than repairing them. Building standards in several countries require installation of energy-efficient windows with high thermal characteristics thanks to multi-chamber glazing profile. These consist of sheets of glass divided by a spacer which is hermetically sealed on each end. Glass panes are separated by air, or filled with insulating gas, to reduce heat transfer.

As well as having advanced thermal characteristics, multi-chamber windows better resist deformation and are more durable. A broad range of materials is used to produce such windows made of are available; comparison of main technologies is shown in Table 15.

Table 15. Energy-efficient window profiles

	Profile		
	Wooden	Aluminium	Polyvinylchloride (PVC)
View			
Raw material	Oak, pine, ash tree or larch	Aluminium*	Polyvinylchloride
Advantages	Attractiveness; good thermal insulation and frost resistance; sound insulation; possibility of changing color either inside or outside	Lightness; durability; resistance to weather conditions; possibility to customize the configuration and complexity	Good thermal insulation; excellent sound insulation; resistance to various atmospheric actions; simple operation and maintenance
Disadvantages	Combustibility and hygroscopicity; ongoing maintenance or finishing required	Possibility to electrochemical corrosion; high thermal conductivity of aluminium – requires thermally broken frames to achieve high performance	Mechanical damages cannot be corrected

Note: two types of aluminium windows exist: light (for buildings which do not require significant sound and heat isolation) and warm (consist of external part – cold, and internal – warm; these are produced separately and assembled directly onto the building).

Depending on thermal and technical requirements, window profiles can be specified in accordance with building regulations (*e.g.*, acoustic insulation could be included). In many countries, windows have energy-saving glazing, *i.e.*, a glass panel coated with a thin layer of silver to decrease glazing emissivity. This type of single-chamber double-glazed window is warmer than simple double-chamber ones. Moreover, it weighs about 30 percent less, contributing to longer lifespan. Due to silver coating, these also exhibit mirror effect (enhanced reflectivity), which helps room stay cooler during summer, and warmer in winter.

The important aspect is installation of windows by qualified specialists, which ensures reduction of thermal bridging and proper air-tightness.

2.1.2. Heating, domestic hot water supply

Different approaches to the design of building heat supply system (HSS) depend largely on availability of energy resources, fuel prices, infrastructure, technological development, and relevant energy policy. HSS technology is in a transition phase in the countries of the UNECE region, and there are significant technological advancements being made to include RES as a source of heat supply. This strongly relies on development of proper legal framework and related policies; establishment of targets for promoting

RES for use in electricity or heating; provision of financial/fiscal incentives for investment in RES; adoption of medium-term feed-in tariff for the purchase of RES energy; imposing obligation on power companies to secure a certain percentage of RES in their supply.

The implementation of RES solutions can be applied to both centralized and decentralized HSS.

Improvement of decentralized heating supply systems

The principle of decentralized heat supply is based on independently-produced heat energy for internal needs. Decentralized HSS can rely on both RES (*e.g.*, roof-top solar collector systems, HP) non-RES (*e.g.*, boiler equipment using natural gas, diesel, coal, electricity or biomass).[4]

Installation of the boiler equipment

One of the most widespread measures for modernizing decentralized HSS is replacement of outdated boilers with more efficient ones. Boiler efficiency is determined by its energy output from fuel combustion, and modern ones use less fuel of same type for equal energy performance. There are also technologies that allow switching boilers to fuels with higher calorific value, along with automatic heat regulation systems coupled with weather compensation control. Figure 6 depicts modern gas-fired boilers as an example.

Figure 6. Examples of modern gas-fired boilers

Condensing boilers, which capture additional heat from water vapor, are nowadays considered most efficient, innovative, and environmentally-sound. Sales of non-condensing gas-fired boilers are forbidden in EU (with a few exceptions) by (European Parliament, 2009), and all European manufacturers are obliged to produce only condensing gas-heating equipment for sale in EU countries.

Solar collector solutions

Solar collectors for DHW and internal heating generate temperatures 60-100°C and is a widely-used RES-based technical solution in buildings. There are two types of solar collectors: flat and vacuum (Table 16).

4 A heat pump can be truly renewable only when the electricity used to drive the pump comes from a non-fossil fuel source. Additionally, according to the EU Directive 2009/28/EC, point 31: “Heat pumps enabling the use of aerothermal, geothermal or hydrothermal heat at a useful temperature level need electricity or other auxiliary energy to function. The energy used to drive heat pumps should therefore be deducted from the total usable heat. Only heat pumps with an output that significantly exceeds the primary energy needed to drive it should be taken into account.”

Table 16. Types of solar collectors

Flat solar collectors	Vacuum tube collectors
Advantages	
- Low cost - Easy to install and maintain - Simple to operate with generally no other equipment (pumps, etc.) required - Proven technology, durable (>25 years) - Ideal for intermittent loads (*e.g.*, houses, restaurants, small businesses) - Transparent insulation can be equipped for flat collectors to achieve higher efficiency. It can be used to reach higher temperatures and is applicable in cold climates to protect collector against freeze. Also has overheating prevention at the collector level.	- Higher efficiency compared to flat collectors - Ideal for high and constant loads (hotels, spas, swimming pools, gyms) - Ideal for solar cooling and heating; temperatures can range from 50°C in winter to 120°C in summer - Cover winter load, except in extreme conditions - Not prone to damage from heavy snow or hail
Disadvantages	
- Lower efficiency compared to vacuum tube collectors - Temperature range not ideal for solar cooling; during extended winter periods, cannot accommodate DHW load - Sensitive to damage from extreme snowfall or hail	- Relatively expensive - Not ideal for small DHW loads - Hot summer conditions may cause glycol pyrolysis if there is no constant consumption or water circulation (temperatures may rise above 130°C) - Prone to damage if used for intermittent loads - Low electricity consumption due to the need for forced recirculation, especially during summer

Solar systems can be passive and active (Figure 7). Passive are installed as rooftop units comprised of solar collector and water tank (system is relatively less expensive but is inappropriate for cold climates). Active solar water heating and HSS include a range of engineering equipment: solar collectors, controllers, circulation pump, broad tank, main storage container, and connecting pipes. Active systems are more expensive but give more benefits and can be used during winter season. In general, these consume less electricity annually, and can be used not only for DHW, but also for HSS. Further, it is possible to adjust the capacity of active solar systems (within specified limits) by adding more collectors.

Figure 7. Examples of solar heating systems

Passive solar system with flat collectors

Active solar system with vacuum-tube collectors

Heat pumps

HP operates on the principle of vapor-compression cooling. Heat power is carried by means of condensation and evaporation of coolant (generally, freon circulating within closed contours). HP consume electricity to operate coolant compressor and secondary circuit circulation pumps.

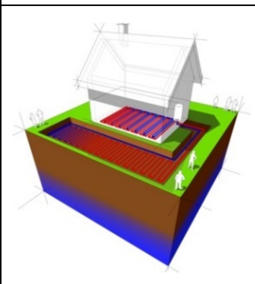
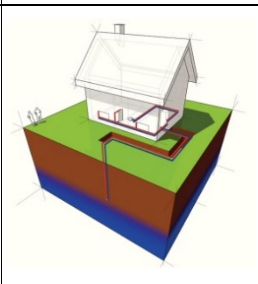
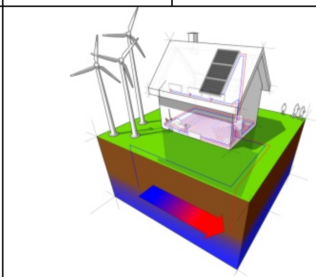
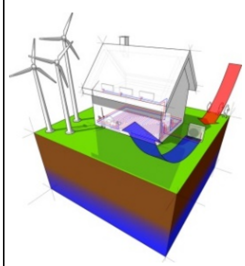
HP demonstrate outstanding efficiency when daytime temperatures fluctuate drastically. In cold climates and warm seasons, HP using a water source can work more effectively than air-based HP. In areas where drilling is relatively cheaper, geothermal systems with a vertical soil heat exchanger are the most attractive. Yet, flat geothermal systems (low depth, wide area) can also work well if there are large areas on the property which can be used for this purpose.

Installation of HP is most economically feasible at the time of construction, to plan for needed space. Yet it is still possible to also integrate it into existing HSS along with a heat collector during retrofit.

HP are more efficient than electric heating systems and, depending on fuel prices, can also be more affordable than other HSS. In general, HP are economically feasible if natural gas is unavailable or relatively expensive compared to electricity, and are practical when electricity price (per kW) is 3.5 times higher than price of traditional fuel (per production of 1 kW).

HP may be classified according to the source of low-potential thermal power, as shown in Table 17.

Table 17. Types of HP

	Soil – water		Water – water		Air – water
	Horizontal	Vertical	Horizontal	Vertical	
View				*	
Design	Collector is placed in the form of rings or twisting inside horizontal trenches lower than soil frost depth (usually >1.2m)	Collector is placed vertically in a well up to 200 m in depth	Collector is placed in the form of rings or twisting in a water reservoir lower than soil frost depth	Collector is placed vertically in a well, and the second well is located in downstream water 15-20 m underground	Units consist either of 2 blocks placed outside and inside the building, or of a monoblock connected with external space by flexible air duct
Principle of operation	Energy is gained by heat exchanger, which is placed in a vault, and accumulated in carrier; carrier is continually supplied to HP evaporator and returned for additional heat power		Similarly to other systems, except for heat exchanger is in water	Ground waters gained from the first well are supplied to evaporator that gains heat power from water; cooled down for 5 degrees, it returns to the second well	Fans supply air into evaporator, which gains its heat power
Application	Most economically feasible for residential buildings if land area allows to place a horizontal collector	Applied when the land area does not allow to place the contour horizontally, or there is a threat of land damage	Most cost-effective, but requires water reservoir	Applied where there is sufficient ground water, and land area allows for placing two wells	Practical and economical; capacity is reduced, but in return HP of this type operate at up to - 15°C (additional heat energy source is needed if below)

** – Principal diagram of heat pump with vertical collectors*

Improvement of centralized heating supply system

Centralized district HSS consist of heat energy source, distribution network, and individual heat points (which connect the network to building internal heating system) Each component ensures reliability and quality of heat supply.

MFB, public, and commercial buildings are usually equipped with engineering systems, including HVAC and hot water supply, which should seek to provide reliability of supply, and safety and comfort for occupants whilst saving energy and reducing CO_2 emissions.

Implementation of district heating systems requires a complex automation within the buildings' HSS, covering heat points and heat consuming systems. In many countries, automated control for centralized HSS (Figure 8) is an obligatory measure in new buildings in addition to retrofits, as these enable significant energy savings owing to its adjustment and correction functions: hot water temperature depending on outdoor air temperature (weather compensation control); temperature of hot water which returns from the building's internal HSS to district heating network, depending on outdoor air temperature as per the set temperature schedule; accelerated warming-up of building after energy saving mode (reduced heat consumption); heat consumption according to indoor air temperature; constraining hot water temperature in HSS pipelines; heat load in hot water supply system; heat load by ventilation units with freezing protection function; heat consumption within set periods, depending on outdoor air temperature; heat consumption given building's orientation, and its ability to act as a heat sink.

Figure 8. Individual automatic heat point with weather compensation control

Practical experience in modernizing heat points proved effectiveness of this measure in many countries.

System performance optimization measures

Insulation of pipes and equipment

Insulation of supply system pipelines, which is a necessary – and obligatory in many countries – measure in new constructions and retrofits,[5] for which several types of materials are available (Figure 9). Insulating pipelines reduces heat loss in pipelines, and maintains heat carrier temperature at a consistent level, leading to substantial energy savings.

Figure 9. Pipe insulation and insulated distribution pipes of HVAC systems

5 In case of retrofits, pipeline should only be insulated after pipelines are repaired and pressure-tested.

Installation of thermostatic regulators on radiators

Temperature control in rooms is fundamental for rational use of energy. In case of radiator heating, significant heat savings can be achieved by installing thermostatic regulators before radiators, which allow adjustment of indoor temperature (Figure 10). For other types of heating systems (floor heating or fan-coils in offices) the same logic applies.

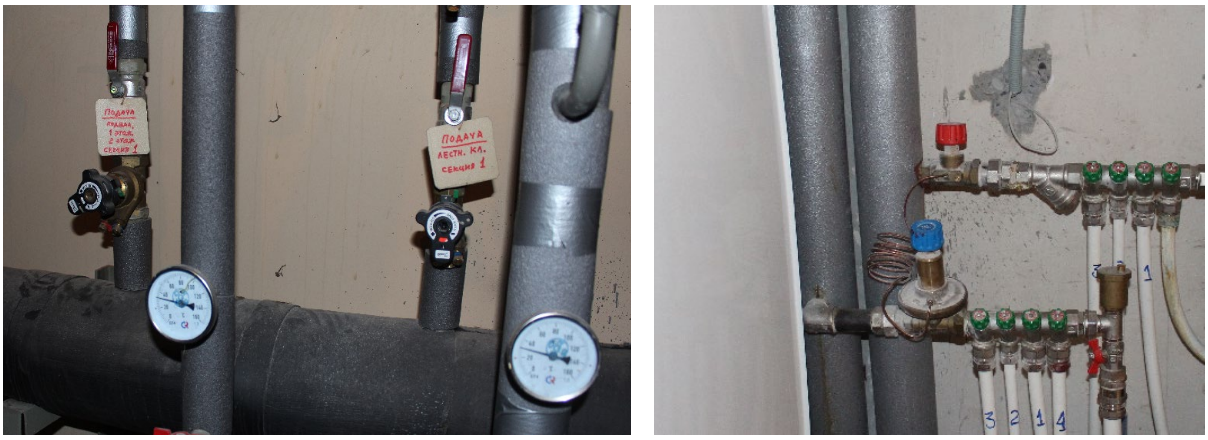
By avoiding excessive heat supply, thermostat prevents over-heating and maintains ambient comfort. Automated regulation help avoiding excessive temperature rise, which is usually vented by opening of windows – a clearly inefficient energy use. Installation of thermostats is usually coupled with installation of HSS with higher thermal performance.

Figure 10. Thermostatic radiator control elements

Installation of balancing valves

Balancing valves are part of clearance pipe fittings, intended for circulation of hydraulic balancing rings (risers, branches) of cold and heat power supply systems (Figure 11). System performance is thereby dynamically optimized based on varying real-life operation conditions (known as 'dynamic balancing'), also providing a range benefits: hydraulic stability and optimal operational conditions of system elements (emitters and their controls, pipe distribution systems, heating/cooling generators); reduction of pipelines' and other elements' noise (by means of automatic maintenance of reduced pressure and restricting maximum heat carrier flow); stabilization of systems during extended continuous operation (by means of compensation, it increases resistance of hydraulic elements to corrosion and scum); simplification of installation and maintenance of systems (by means of combining functions) while often enabling computer diagnostics of systems; possibility to divide heat or cooling system of building into temperature zones, *i.e.*, into floor- or apartment-specific systems; reduction of energy consumption by circulating pumps; additional economic and health benefits by preventing diversion of heat carrier in heating and ventilation systems; etc.

Figure 11. Example of balancing valves



Dynamic balancing is provided by automated balancing valves for risers or for each heat emitter. It is recommended to install them with default values; where solutions for risers are chosen, they should be installed on each riser of heating systems and should only have their settings tuned afterwards. Implementation of this measure should be done after development of design documentation and after heating system is flushed. During repair of heat and cold supply systems, it is reasonable to install balancing valves together with other measures. During installation, it is necessary to consider commissioning work which should be performed by specialized organizations.

Energy monitoring and smart metering systems

These consist of hardware (smart meters) and software (digital telemetry and pulse outputs, pulse counting devices, interface converters, transceivers, and information communication channels infrastructure) components, specifically:

1. Measuring components: system which measures parameters and provides measurement results on quantity and quality of resources consumed; it also provides intermediate storage of received unmodified information for automation objects (measurement, diagnosis, scheduling, etc.).
2. Linking components: devices intended for reception of data and signals of faulty measuring components and transferring them to processing by computing components.
3. Computing components: unified computer centre for data processing, analysis, storage, and distribution of information resources.

2.1.3. Ventilation, air conditioning and cooling

Application of frequency converter drives

Modern building engineering systems have variable operating mode (ability to change parameters or characteristics during operation), allowing for reduction of designed parameters of fresh air, heating, cooling, hot or cold water. These parameters must be optimally set to maintain proper ambient climate conditions, and to ensure rational consumption. Such 'dynamic mode of operation' allows for adjustment to changes of outdoor climate conditions, indoor heat gain from solar radiation, occupancy changes, changes of electricity, hot or cold-water consumption, and other factors.

The use of frequency converter drives (FCD) (Figure 12) for pumps' and fans' electric motors helps optimizing operational parameters of engineering systems (pressure, temperature, flow, CO_2) by reducing spinning rate and hence power consumption.

Frequency converter drives are highly efficient and extensively applied in many countries. As an example, their application for fans of outdoor condenser units of a central cooling system can reduce compressors' power consumption, reduce noise and support floating condensing pressure function.

Figure 12. Frequency converters

Application of heat recovery for centralized mechanical ventilation systems

Heat recovery is a process of extracting heat from air which is expelled from a building via outlet ventilation, and then injecting that heat back into air supplied through inlet ventilation. This reduces energy consumption for space heating due to additional (intermediate) heating of air in recuperator – a heat transfer device that warms cold air by exhaust, without mixing these volumes (Figure 13).

Figure 13. Heat recovery unit for mechanical inlet and outlet ventilation

Application of variable flow cooling systems

Traditional approach in design and operation of cooling systems – based on principle that consumption of coolant is constant, and it is continuously supplied from chiller – implies constant electricity consumption, which is, as a matter of fact, not energy-efficient.

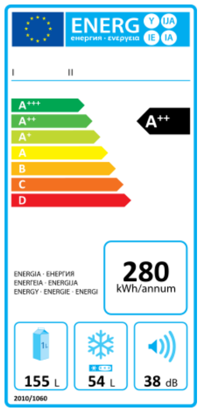
Modern cooling systems with variable coolant consumption are widely applied in public buildings, where centralized AC system includes air handling units as well as fan coils and other appliances. Hydraulic structure of a modern cooling system (divided into primary (chiller) and secondary (fan coils and AC units) contour) also includes circulation pumps and shut-off and balancing valves. Thanks to optimized consumption, this reduces operational costs of coolant pumping, and enables use of circulation pumps in secondary contour that further decrease energy consumed by pump groups.

2.1.4. Energy-efficient appliances labelling

Appliances consume significant proportion of electricity, and use of high EE class appliances EE labelling proves to be an invaluable measure for reducing this, along with decreasing ecological footprint of buildings.

Appliances can be certified according to ISO 9001 and ISO 14001 standards, which indicate that no hazardous substances were used. The majority of large household appliances must be certified in accordance with the European EE class, and have a special label (includes information on title, model, producer; class of EE: color code with alphabetic reference (from A to G), which reflects the level of energy consumption; level of annual energy consumption; additional information on type of appliance, *e.g.*, internal volume of refrigerator in litres, maximum speed of rotation for washing machines, etc.; and noise level expressed in decibels), applied (Figure 14).

Figure 14. EE labelling



2.1.5. Modernization of the existing building lighting systems

Modernization of existing lighting system in residential buildings implies replacing the currently widely-used filament and fluorescent lamps with energy-efficient lamps/modules, including light-emitting diodes (LED) (Figure 15) and compact fluorescent lamps (CFL). These lamps are characterized by lower energy consumption and longer service life; additionally, they do not require any maintenance and thus extra operational cost. Additionally, modernization may include installation of sensor-based lighting management systems. All these actions can be performed both by inhabitants individually, and by building owners in public areas / common spaces (entrances, cellars, laundries, attics, outdoor, etc.).

Nowadays, various types of lighting appliances with various ingress protection classes are available, as well as lighting appliances with built-in devices providing emergency lighting in case of power outage, and many CFL and LED lighting appliances are equipped with motion and thermal sensors (these detect movements/heat and turn lights on and off, as appropriate), as well as ambient light sensors (toggling lights subject to luminance). These may also have automatic dimming and switch scheduling.

The economic attractiveness of sensor-based lighting controls is building-specific, depending on operational hours, occupant behavior, electricity prices, etc. To enhance EE benefits in buildings, it is reasonable to implement a robust lighting management system, preferably automated, or which at least includes dimmers.

Figure 15. LED lighting fixtures

2.2. Current deployment of technologies: data analysis and review

Much progress has been made globally towards improving buildings EE, supported primarily by 3 types of public policy tools: legal requirements (building standards), financial incentives (rebates, reduced-rate debt, tax deductions), and information awareness programmes. In EU, relevant directives played a vital role, with (European Commission, 2019) being key element. Despite these efforts, improvement of buildings EE remains slow.

Analysis of data on technologies available in the UNECE member States, and those actually used in the countries, allowed for understanding the current regional trends and patterns in buildings EE.

2.2.1. Energy efficient technologies in Subregions A, B, and D

Building envelope: insulation and glazing

Adoption of EE technologies in buildings has increased since adoption of (European Parliament and Council, 2018), which amended (EPBD, 2010) and (European Parliament and Council, 2012), even though these had far-reaching consequences: one enabled EPC to generate economic value for building owners (premium for reduced energy consumption and increased economic rents), and another, *i.a.*, conditioned installations of building insulation and energy-efficient windows (in Subregions A and B).

The final major impact throughout EU is the requirement for new buildings to meet the nearly-zero energy building (NZEB) standard, *i.e.*, be designed highly energy-efficient, and use RES to cover those amounts of energy they consume. Notably, Belgium and Germany (Subregion A) surpassed NZEB, and are implementing the Passive house standard – which has more stringent requirements for energy consumption for space heating/cooling, air-tightness, and energy generation – for both new and existing buildings. In Switzerland, a similar standard MINERGIE-P is used. The Passive house concept is further extended in Norway by developing the Powerhouse design concept, where buildings are designed to be net positive for energy over its entire lifecycle (including construction and demolition).

In Subregion B, all countries (except Latvia) made progress in BE improvements, and policies played a key role: *e.g.*, since 2010, Romania has had support measures (bank loans guaranteed by the Government) to finance thermal rehabilitation of residential buildings, including BE and replacement of HSS, for low income households. Yet, apart from commercial buildings, renovation is still lagging. Croatia, Cyprus, Czech Republic, Estonia, Hungary, Malta, Poland, Romania, Slovakia, and Slovenia achieved a remarkably fast penetration of NZEB within the existing building stock.

In Subregion D, both Canada and the United States have extensive building standards at federal, state, and local levels, which set minimum EE requirements for BE. Codes regulating building renovations are also in place in many states of the United States. Cumulatively, residences and commercial buildings can save over 125 billion US dollars in 2012-2040 (corresponding to 1 billion tons of avoided CO_2 emissions) if following the portfolio of model codes, as suggested in (Liu & Bartlett, 2015). In 1993, the U.S. Green Building Council introduced the Leadership in Energy and Environmental Design (LEED) (LEED, 2019) building rating certification programme, which is similar to NZEB in EU, and also requires buildings to meet stringent energy consumption requirements.

Train-to-NZEB project

The 2015-2018 EU-funded project aimed to provide world-class training on EE and RES in buildings, with goals to provide practical trainings, demonstrations and consulting for design and construction of RES-supported NZEB based on Passive House concept, and improve knowledge and skills in construction sector. Combined with 'One-stop shop' consulting services, these were expected to increase interest and capacity for design and construction of such buildings, and stimulate market demand for such solutions for new buildings and retrofits. The tasks included equipment of 5 training centres (Building Knowledge Hubs); adaptation of the existing, and development of new curricula for building professionals; training and certification of 90 trainers, 2,400 construction workers, 480 designers and 720 representatives of public authorities, managers, consumers, media, etc. The project established training facilities and innovative teaching programmes, enabling the next generation of construction professionals. The training centres form a part of a growing international network that combines theoretical lessons with practical hands-on exercises. Train-to-NZEB network concepts will now be further expanded: new EU-funded project, Fit-to-NZEB, has been recently launched, with a focus on energy-efficient building renovation.

Space heating, air conditioning, water heating and cooling

In Subregion A, France has the most diverse mix of heating solutions, followed by Spain and Ireland. Ireland is the only country in the region using coal in both new and existing buildings. Except for Greece, Italy, Luxembourg, and Portugal, countries of Subregion A tend to develop centralized space heating solutions. Belgium, Finland, France, Ireland, Spain, and Switzerland adopted various types of RES for space heating (biomass, solar, HP). Data shows that the United Kingdom, Norway, Italy, and Iceland favor HP and biomass-fired boilers, while Germany uses solar for space heating.

In Subregion B, Slovenia is leading diversification of its technology mix for space heating deploying biomass-fired boilers, solar, and HP, followed by Cyprus, Malta, Poland, and Slovakia. Latvia and Hungary have a large share of gas-fired boilers, though Hungary additionally supports adoption of HP. Croatia and Malta have a diverse mix of technologies, and use diesel and oil boilers in new and existing buildings. Czech Republic is the only to still deploying coal-fired boilers in new and existing buildings.

In Subregion D, Canada has the most diverse mix of technologies for space heating, including coal. The United States tend to rely mostly on decentralized heating.

Ventilation, air conditioning and cooling

The European Commission, in its first plan of 2016 to tackle energy used for heating and cooling in building sector, to curb energy demand, boost RES, reduce energy costs, and decrease CO_2 emissions (European Commission, 2016), requests to improve integration of power grid with district heating and cooling systems, so utility-scale RES could replace fossil fuel generation for district heating and cooling.

Finland and Sweden

Finland is one of the leading countries in terms of CHP: more than 30 percent of electricity is generated in connection with the production of district heat. Almost half of the population lives in residences warmed by district heating.

Sweden, in its effort to improve EE of space conditioning, links district heating systems with industries. In some parts of Sweden, up to 90 percent of MFB rely on district heating that uses waste heat from nearby industrial plants and waste incinerators. Not only does this reduce energy consumption for space heating, but it also reduces industrial waste heat.

Recent years have seen advances in increasing efficiency of space-conditioning equipment. Yet at least 2 issues persist: (1) while there is a variety of fuels and technologies used for heating, natural gas remains the primary source. (2) the current retrofit practices are usually limited to simple maintenance, such as replacing filters, oiling motors, and cleaning burners.

Impressive EE gains in boiler technologies and HVAC systems, along with design improvements in vent dampers, however, can significantly contribute to energy savings. Distribution systems and controls are frequently overlooked opportunities for improving efficiency of space conditioning systems: *e.g.*, unretentive air distribution ducts result in significant energy losses, and such parts shall not be overlooked.

Appliances

Throughout building's lifetime, equipment (appliances, lighting and electronics) is replaced and upgraded. Each occurrence – which apparently is more frequent than a major retrofit – represents an EE improvement opportunity, and its aggregate impact may be comparable to retrofitting. Apart from labelling, adoption of EE is also encouraged through cash rebate programmes.

Overall, the 'low-hanging fruit' of improved EE in appliances has probably already been 'picked': large appliances (refrigerators, freezers, washers, etc.) are nowadays significantly more efficient than their 1990s analogues.

In the United States, (NTIA, 2009) resulted in an unprecedented number of household appliances replaced with energy-efficient upgrades. Other countries with similar programmes include Canada, Denmark, and Germany.

In EU, the binding directives (European Parliament and Council, 2010) and (European Parliament, 2009) require many household appliances to meet minimum EE standards and to carry energy labels, categorizing the expected energy consumption (similarly to voluntary Energy Star programme introduced by the U.S. Environmental Protection Agency). However, labelling programmes yield results only if products are properly promoted. This is proved by the Latvian case, where the expected appliances' EE increase failed, due to insufficient promotion of labelled products.

Another issue with labelling is stringency of requirements – especially when minimum requirements are equal, or very close to market averages. More stringent regulations that drive technological innovation are needed to induce market changes and improve EE.

Lighting

There are 3 main solutions to improve EE of lighting in buildings:

1. Architectural solutions that make inventory of natural daylight;
2. Lighting sensors and controls, and;
3. CFL and LED.

Legal constraints – building codes and technological standards, and information awareness programmes – are predominantly used by policymakers to drive improvements in lighting EE. Many countries have already phased out inefficient lighting technologies, and building codes place requirements on lighting fixtures and control systems to encourage efficiency.

While enhanced standards proved effective, they mostly impact new construction and, less markedly, deep retrofits. For example, daylighting architectural solutions – which have documented social benefits, additionally to reduced energy consumption – involve design that makes maximal use of sunlight for internal lighting, and can obviously be applied only to new construction (even though examples of applying this technology to existing buildings exist Finland, Denmark, Monaco, and Norway. In Subregion A, daylighting technologies in new public buildings' construction is moderately prevalent in Austria, while in subregion B only Estonia and Cyprus use it.

Lighting sensors and controls can have a tremendous impact on lighting energy consumption by ensuring that lights are only used when required, and investing in these technologies pays for itself. Despite this, sensor-based lighting controls are not widely used. The technology is prevalent in less than half of Subregion A countries. In Subregion B, only Cyprus and Estonia use it. Apparently, stronger policies and awareness campaigns are necessary to encourage its adoption.

France

The 2013 energy-saving initiative required all non-residential buildings to turn off the lights at night to reduce light pollution and energy consumption. Indoor lighting, which can be seen from outside, must be switched off at 1 AM or one hour after closing time (whichever is earlier) and can only be switched on after 7 AM or one hour before opening (whichever is earlier). Outdoor lighting of building facades (shops, monuments, schools, city halls, etc.) can only be on between sunset and 1 AM. Sensor-based control systems can better support and enable such initiatives.

The simplest, furthest reaching, and most prevalent technology for decreasing lighting energy consumption is energy-efficient light bulbs. CFL and LED are far superior to traditional bulbs and can be used in any types of new and existing buildings.

The United States began phasing out incandescent bulbs in 2007, and the Canadian Government began banning them in 2014. EU voted in 2009 to ban them taking full effect in September 2018, which was expected to result in significant reduction in waste, and even more importantly – annual energy consumption reduction by 9.4 terawatt-hours (a level of Portugal's 5-year electricity consumption), while avoiding 3.4 million tons of CO_2 emissions annually. However, simply banning is not enough, as proved by earliest adopters' experience: Denmark and the United Kingdom implemented the policy earliest, experienced sharp reductions in incandescent bulbs sales, yet much of market share inadvertently shifted to halogen bulbs, which are only slightly more efficient. Thereby, the energy saving potential – that could be achieved by switching to CFL or LED – was not realized; there is still little sign of LED penetration on domestic lighting markets, possibly because of their higher cost.

Germany, Spain, Switzerland and many other countries of Subregion A, when it comes to reductions in lighting energy consumption, are mainly reliant on bulb replacements with energy-efficient ones. Denmark, Monaco, and Norway exemplify few countries that are more diversified and make attempts to use all 3 types of technological solutions. In Subregion B, Estonia applies them to new constructions, while Cyprus focuses on retrofits.

Energy monitoring and smart metering systems

Smart metering and smart building systems are among technologies that could positively impact building subsystems. One of the primary objectives of EU EE-related directives is to encourage use of information and communication technology and smart technologies to ensure buildings operate efficiently. Denmark, Italy, Switzerland and the United Kingdom in Subregion A, and Estonia, Lithuania and Malta in Subregion B implemented EE policies promoting application of such smart systems. Moreover, nearly all buildings in Finland, Italy and Sweden are equipped with smart meters.

In the United States, cloud-based energy management and control systems are extensively used to avoid necessity for on-site staff to maintain building energy systems. A third-party contractor to monitor building can usually be an effective way to reduce energy consumption, yet split incentives for multi-tenant office buildings may discourage owners from purchasing cloud-based control system if tenants are responsible for their energy consumption.

United Kingdom

The Smart Metering Programme aims to roll-out (by end-2020) over 50 million smart meters (gas and electricity) to all domestic properties and smart/advanced meters to smaller non-domestic sites (businesses) – impacting approximately 30 million premises. This programme is currently in the main installation phase, and there are now over 11 million smart and advanced meters operating.

For office buildings, in which owners are responsible for energy consumption and maintaining systems, there is still more economic incentive to invest in such technology. This suggests that the highest barrier in implementing smart metering and control systems technologies in buildings is the requisite capital expenditure.

2.2.2. Energy efficient technologies in Subregions C, E, and F

Building envelope: insulation and glazing

In the countries of Subregions C and E (partly), similar post-Soviet types of buildings are prevalent, and most residential and public buildings were designed and constructed 30-50 years ago. Back then, policies and norms were stricter in terms of construction material quality and envelope safety levels, but with less emphasis on EE requirements such as insulation and glazing. To that end, retrofit programmes to improve insulation and glazing for existing buildings have recently been introduced.

Most of the countries in subregions C, E, and F updated their building codes for insulation and glazing in both new construction and retrofits by 2018, mandating insulation and glazing from the design stage. Requirements for retrofits are different, and in most cases, necessitate additional external financing and modification of procurement procedures for public buildings and MFB.

In almost all countries of Subregion C, a common approach to addressing EE in MFB and public buildings (reflected in specific laws), is modern insulation and glazing. As in most cases these are considered as long payback period measures (especially if energy price is low, which is the case in Subregion C), different supporting mechanisms exist: subsidized loans, tax incentives, specialized energy efficiency funds, etc. In Kazakhstan, Armenia, Ukraine, the Russian Federation, and several other countries in Subregions C, E, and F, there are requirements to perform specified number of annual insulation and glazing projects for public buildings and MFB, which are included in budgets of regions, departments or municipalities.

Commercial buildings have fewer specified mandatory requirements for insulation and glazing across countries of Subregions C, E, and F, and in most cases, it is a market-driven process, aimed primarily at avoiding financial losses due to energy wastage. However, analysis of insulation technology mix shows generally a good level of BE technologies deployment.

SFB still have lower levels of energy-efficient insulation and glazing implementation. By 2018, as a result of numerous awareness raising campaigns supported by local governments and international organisations across countries of Subregions C, E, and F, there was an obvious shift in individual homeowners' understanding of the potential for savings (UNDP, 2019). For example, micro-finance tools for non-city dwellers were developed and implemented in 2012 by Asian Credit Fund in Kazakhstan and Kyrgyzstan for improving houses' quality. In Uzbekistan, construction of standardized energy-efficient individual houses is supported by state programmes that offer subsidized pricing and mortgage schemes. A similar one is implemented in Armenia.

Armenia

Among countries of Subregions C, E, and F, Armenia is leader in scaling up energy-efficient technologies in buildings. In 2018, the country transposed the EU Directive on BEP and harmonized it with local construction and design standards. This resulted in enforcement of mandatory EE requirements for all building types, and improved technology penetration with an important role of local manufacturers of insulation materials.

Space heating, air conditioning, water heating and cooling

Modern technologies in space heating, DHW and cold water supply are at different levels in the countries of Subregions C, E, and F, presumably due to differences in fuel mix. Kazakhstan and other coal mining countries actively use it for electrical and heat energy generation, from large CHP plants to small-scale boilers, and this trend is likely to continue. In this case it is better to concentrate on deployment of environmentally sound coal burning technologies, rather than to completely ban its use.

Improvement of decentralized heating sources

In coal mining and coal consuming countries of Subregion C decentralised heat and power generation are mainly based on coal, yet modern efficient coal-burning technologies are moderately used. By 2018, some of these countries expressed interest in investing in clean and efficient technologies for coal use. Pilot implementation of high-efficiency boilers and pyrolysis-type back-pressure steam turbine energy generators in the Russian Federation and Kazakhstan show substantial technical and financial potential for cleaner energy generation from fossil fuels or municipal waste (Rosprirodnadzor, 2019).

Biomass-fired boilers are still at early adoption stage, with slightly better implementation rates in Ukraine and Moldova (Subregion C), and Serbia and Bosnia and Herzegovina (Subregion E). In Turkmenistan and Uzbekistan, new energy-efficient boilers' installation (gas-fired) is mandatory for all building types, while other countries focus only on MFB and public buildings – even though deployment levels there are higher.

It might be reasonably concluded that modern gas-fired heat and power generators, produced both globally or locally, are commercially available in countries of Subregions C, E, and F. Yet certain barriers to a broader deployment of modern technologies persist; among others, the following are the most obvious: most Central Asian countries of Subregion C with low population density have low stock availability of spare parts for repairs, which sometimes limits technological options considered at decision-making stage, and; there is a limited professional competence for maintenance locally.

In most countries of Subregions C, E, and F, commercial buildings' (shopping malls, hotels, offices, etc.) owners recognize the benefits of modern energy-efficient generation equipment as this primarily reduces their energy bills. At low internal energy prices, however, investments in EE are normally discouraged; moreover, an issue with access to low-cost funds to finance such measures. These, collectively and discretely, constitute a hardly surmountable EE technologies' implementation barrier.

Electric boilers are used in more than half of the countries of Subregions C, E, and F in various building types. This is sometimes due to scarcity of fuels available for heating and DHW. An imperative in such cases should be installation of efficient power generation units with properly-adjusted waste heat recovery schemes, to increase efficiency of power generation. No single country in Subregions C, E, and F, however, has regulation concerning such installations; neither alternative energy sources uptake is promoted to improve efficiency of electric heating.

Common measures and improvement of centralized heating systems

Subregions C and E have a long history of implementing centralised HSS. In Subregion C, the currently used equipment was principally designed and installed in 1960-1970's, and as this represents a critical issue especially for big cities, it is nowadays being extensively renovated backed by national policies and with support from region-specific incentives and relevant financial tools. These (except for SFB application) are in place in Kazakhstan, the Russian Federation, Turkey, and Ukraine. Other countries with existing centralised HSS are in process of adopting these. Countries not focused on this activity are Albania, Belarus, Bosnia and Herzegovina, Montenegro, North Macedonia, and Uzbekistan.

Insulation of pipes and other equipment solutions are common measures in countries of Subregions C, E, and F. Yet while insulation is mandatory and progresses in Belarus, Moldova, Turkmenistan, and Ukraine, in, Armenia, Georgia, Kyrgyzstan, Montenegro, Turkey, and Serbia the level of its application is relatively low. This issue proves to be recognized by the Governments, and will hopefully be resolved.

Insulation of distribution pipes for cooling networks is a widely implemented solution in Azerbaijan Belarus, Moldova, the Russian Federation, Turkey, Ukraine, and Uzbekistan, and the focus is on increasing the quality. In the last 5-6 years, governmental support and investments into this measure have increased, which resulted in growth of cooling equipment market, with active presence of modern efficient equipment suppliers.

Also, policies and design norms in Belarus, Moldova, the Russian Federation, Turkey, Turkmenistan, and Ukraine request installation of balancing valves, thermostats, energy-efficient pumps, heat exchangers, and other relevant engineering equipment, which improve centralized HSS.

Other modern technologies and measures, including installation of energy-efficient water pumps, water supply sensors, and wastewater heat recuperators, remain at low or medium levels of deployment for most SFB, MFB and public buildings. Several pilot projects on heat recuperation and recovery for building stock, supported by international organisations, were implemented in Belarus, Kyrgyzstan, the Russian Federation, Turkey, and Uzbekistan. To encourage further advancements, especially in public buildings, international organisations and local financial institutions should focus on raising awareness and develop transparent, possibly also municipally-supported, financing schemes.

Ventilation, air conditioning and cooling

From the technical point of view, there are limitations to VAC equipment installation and modernisation during retrofit (due to limited indoor space and absence of VAC system design in the original construction), therefore usually VAC are a focus area only in cases of new construction. Yet while this is predominantly a case for MFB, it is common that other building types enjoy higher implementation rates of modern VAC during retrofits. Relatively high penetration of modern VAC equipment – even for retrofits – is seen in Turkey, stemming from its climate conditions, favorable trade channels and location, product availability, strong governmental support, and also promotion of various packaged "Energy-efficient home" solutions (UNDP, 2019). Yet the countries in concern tend to have certain gaps in implementing energy-efficient VAC technologies, and the hope to address them is linked to the currently observed transposition of EE-related EU Directives at national levels.

Installation of air recuperation units and modern frequency converter drives for fans and pumps in new commercial and public buildings is common in Moldova, the Russian Federation, and Ukraine, where use of these technologies is mandatory, and they are broadly deployed. In the countries of Subregion C, implementation of variable flow cooling systems is a relatively new trend that shows further potential for increasing buildings EE. The technology is mostly used for commercial and public buildings in Georgia, Moldova, Montenegro, and Turkey, and yet MFB remain almost out of focus.

Promotion and implementation of modern absorption-type cooling units and effective individual AC finds strong support in the countries of Subregions C, E and F: *e.g.*, in the Russian Federation, Turkey, Ukraine, and Uzbekistan the technology (being mandatory in some cases) is currently at a high implementation level for both retrofits and new construction of all building types, except commercial.

Appliances

Promotion of energy-efficient appliance use is a relatively new trend in the countries of Subregion C. Nevertheless, analyses of buildings' energy load profile demonstrates that implementation of modern appliances (household and especially commercial) could bring large energy savings to overall energy consumption pattern of a typical building. By 2018, Kazakhstan, the Russian Federation, and Turkey promoted implementation of energy-efficient appliances with the support of international donors, conducting campaigns to raise awareness, covering both public and private sectors. Exemplarily, an increased recognition of benefits of energy-efficient household appliances factored into growth of market demand in the countries of Subregion C. It is unfortunate, though, that most appliance suppliers in these countries attempt to obtain a marketing advantage on better promotion by naming equipment as more efficient than it actually is, which mainly impacts uninformed customers.

> Awareness-raising campaigns, aimed at promoting energy-efficient appliances, take place in almost all countries of Subregions C, E and F. In 2017, Kazakhstan, Kyrgyzstan, and the Russian Federation launched a joint information campaign entitled "Together Brighter" supported by the national Ministries of Energy to encourage installation of energy-efficient appliances. Implementation of energy-efficient appliances and green energy standards are also promoted at annual "Energy Efficiency Day", which takes place early September in all 3 countries.

In the countries of Subregions C, E, and F, installing modern efficient appliances in public and commercial buildings has become common in the last 5-6 years: firstly, this might be due to increased energy prices, and; secondly, most countries have adjusted procurement procedures for new building and retrofitting, with requirements to purchase only equipment with high EE class.

The general European approach to mandatory implementation of energy-efficient appliances for all building types is mainly pursued by all the countries of Subregions E and F. Policies concerning energy-efficient appliances remain voluntary only Turkmenistan (Subregion C) and Bosnia and Herzegovina (Subregion E), though these countries are reportedly making progress in this regard.

Lighting

A global trend to install modern energy-efficient lighting is also seen in all the countries of Subregions C, E, and F, backed by strong promotion. National governments, together with international donors, provided support for improving capacity of local producers focusing on development, in most cases, of modern LED technologies. Noteworthily, design norms were significantly modified to implement LED and CFL, while banning production and distribution of incandescent lamps, and yet, despite signs of an increased LED technologies uptake (in new building and retrofits of all building types, except SFB), no policies on mandatory implementation of LED lamps in Subregions C, E, and F were identified.

Albania, Kazakhstan, and the Russian Federation were found as supporters of occupancy/daylight sensors, exterior lighting control, and daylight architectural solutions, as they are promoting such solutions and aim on reduction of lighting expenses in common areas of MFB (stairwells, entrance halls, etc.). Even though these technologies are still scarcely deployed in almost all countries, their promotion and changes of procurement procedures (for residential and public buildings) resulted in growing interest from energy service companies (ESCO) to finance such projects (UNDP, 2019).

Smart systems and solutions

The primary objectives for implementation of smart metering systems are tracking and verification of energy consumption. Conducting fair calculation of EE gains, and forecasting estimated energy consumption profiles and future energy savings potential are warranted by an established metering system and officially approved control methodology.

One of the biggest challenges in terms of implementation of smart solutions in the countries of Subregions C, E and F is the lack of legislative acts that are focused on regulating methodologies for the analysis of EE results and savings potential, meaning that massive implementation of smart meters and data collection systems would be redundant and provide little value without simultaneous, national-level adoption of properly-developed analytical methodology.

Strong administrative and analytical approach to smart solutions shows good results in Bosnia and Herzegovina and Serbia (Subregion E), Armenia, Kazakhstan, the Russian Federation, and Ukraine (Subregion C), and Turkey (Subregion F). Government-supported implementation of municipal level energy management systems in these countries resulted in higher quality of energy action plans for municipalities, which used such approach, especially for MFB and public buildings (UNDP, 2016).

In 2015, Serbia started national energy management programme on connecting public buildings to a centralized database used by national authorities and municipalities for budget planning and energy consumption forecasting. This practice is now being replicated in Albania and Bosnia and Herzegovina (Subregion E). In Subregion C, Kazakhstan and the Russian Federation are leading in implementation of energy management systems. Since 2012, Russian Energy Agency has been operating the State Energy Information System, which incorporates all energy consumption data from MFB and commercial and public buildings (Russian Energy Agency, 2019). Designed originally for manual data input, since 2017 it enjoys the benefits of digitalization and smart data collection.

Kazakhstan

The first non-European country to introduce in 2012 strict mandatory requirement for nomination of responsible municipal energy managers in charge of implementing relevant smart data collection system for objects consuming over 1,500 tonnes of oil equivalent annually. This approach continued until 2016, when the mandatory requirement was excluded from the law, and positions of energy managers were no longer financed by the state budget. This resulted in immediate freeze of all energy management activities. This example confirms benefits and efficiency of a systematic approach which could be effective – but only with strong governmental support. This is especially true if relevant administrative positions are created and financed as new (as opposed to increasing duties and responsibilities of the existing personnel).

2.3. Conclusions

Data suggests that some aspects and types of EE technologies are consistently deployed in buildings across the UNECE region, while other are characterised by wide disparities in technologies.

The main findings of the analysis conducted in Chapter 2 are as follows:

1. EE in buildings is improving in all Subregions. The Russian Federation, the countries of Eastern and South-Eastern Europe and Central Asia – many of which have traditionally low energy prices – have significantly increased mandatory EE requirements, especially for new builds.
2. EE in buildings is nevertheless improving incrementally and in a disjointed manner, even though recent technological design developments have yielded remarkable advancements.
3. To support EE improvements in buildings, 3 types of public policy tools prove particularly successful: legal regulations (building standards), financial incentives (rebates, reduced-rate debt, tax deductions), and information awareness programmes for various types of energy-efficient technologies. Countries with comprehensive and stringent building standards in place have higher penetration rates of energy-efficient technologies.
4. Effective design and implementation of public policy is key to increasing EE. Gaps between what is available in the market and what is being used testifies that effective governance and use of legal and financial instruments, rather than just technical advancement, are key.
5. Specific technology trends observed are as follows:
   - The EU countries show increased adoption of energy-efficient boilers, along with shifts to cleaner fuels. Yet strong concerns remain regarding coal use for residential space heating.
   - With implementation of labelling and eco-design regulations, adoption of energy-efficient appliances is on upward trend.
   - Most countries in the UNECE region have banned, or are phasing out, incandescent light bulbs in favor of CFL and LED technologies. However, lighting sensors and controls are being implemented less frequently.
6. EPC have accelerated retrofitting of existing buildings, but much remains to be done.
7. In addition to environmental benefits associated with decreased energy consumption and increased RES-based power generation, many technologies referenced above offer social benefits. Examples include boosting economic growth, developing local competitive markets, increasing employment, promoting implementation of lower-cost and accessible EE technologies, and developing international markets.

3. BEST PRACTICES ON STANDARDS AND TECHNOLOGIES FOR ENERGY EFFICIENCY IN BUILDINGS

This Chapter aims to identify the best practices on adopting, implementing and enforcing EE standards and technologies in building sector in the UNECE member States.[6]

Desk research, stakeholder outreach and expert contributions and submissions (UNECE, 2019) yielded in a range of national case studies, which were organized by the below thematic sections and presented in tabular form in Tables 18-22.

3.1. Legislative and regulatory framework

The case studies (Table 18) present various aspects of enforcement for EE-oriented legislative and regulatory frameworks, including establishment of institutions responsible for their implementation and regulation.

Supportive governmental activities and clear guidelines for promotion of EE can support regional economic growth, develop local competitive markets, and increase employment. Better cooperation between governments, industry and energy programme administrations is needed, especially when it comes to new technologies which may be not fully economically feasible.

6 This analysis is more focused on retrofits of the existing building stock rather than new construction, with more case studies related to residential sector.

Table 18. Case studies on legislative and regulatory framework

Country	Title/Scope	Period	Description	Key targets	Results
Albania	Law on Performance of Energy in Buildings	April 2018-ongoing	Regional Energy Efficiency Programme (REEP) for adoption and integration of EU EE- and BEP-related directives to increase quality of design/construction standards.	To support Albania towards implementation of the mentioned Law and EU directives.	Both directives transposed into laws, and technical working group (with support of European Bank for Construction and Development) is drafting sub-legislative acts to ensure the Law is fully compliant.
Armenia	Buildings EE	2010-2016	Increasing local capacity in building sector by introducing best international practices in the field of energy-efficient building construction (UNDP-administrated and GEF-funded project).	Improve national regulatory framework, test thermal insulation materials and provide technical assistance to certifying laboratories, raise awareness, deliver educational programmes in building EE design, and demonstrate its benefits.	Improved the relevant regulatory framework, created conditions for implementation of national EE standards on design, expertise and organization of public procurements in building sector.
Czech Republic	X-LOFT Project – Sustainable MFB	2003-2011	First residential project to receive SBToolCZ certificate (national standard to evaluate buildings with respect to sustainability, including considerations of human and social environments, construction quality, operational costs, etc.)	High quality of design and standards; Ecological and low running costs; Centrally located flat, priced 80,000 euro.	Following optimization of SBToolCZ certification (2009-2010), BE was improved (thermal insulation, triple glazed windows), and heat recovery ventilation, photothermic panels for DHW pre-heating and rain water retention tanks were installed in addition to added greenery on facades.
Russian Federation	Implementation of the urban energy management system	May 2015-April 2018	Establishment of urban energy management system (Pskov and Vologda regions) to ensure rational energy use on municipal level, determine key energy performance indicators and prioritize required actions.	Implementation of special administrative mechanism, which supports EE policy implementation nationally and municipally.	A system was established (based on data from 160 buildings), and regional energy managers were appointed. Technical measures (with feasibility studies) were prepared for retrofits, and these were incentivized for municipal buildings. Seminars for EE specialists were organized, and national energy managers were identified for dissemination of experience among other regions. A set of policies and regulations was prepared and implemented.

Country	Title/Scope	Period	Description	Key targets	Results
Serbia	Improvement of legislative and regulatory framework for buildings	2011-2017	Improvement of buildings EE regulation – to harmonize with relevant EU directives – was needed. Moreover, National Sustainable Development Strategy ordered reducing buildings' final energy consumption (amounted 60 percent) by 9 percent by 2018 compared to 2008.	Tightening norms and standards in construction sector in line with EU buildings EE-related directives.	In 2012-2016, 2,000 residential buildings were constructed/renovated in line with the new standard introduced September 2012, reducing primary energy consumption by around 150,000 MWh. Over 30,000 tons of CO_2 avoided each year. The project also supported National Data Management System for buildings EE and helped improve local capacity to implement new legislation.
Turkmenistan	EE building codes as main instrument to achieve scaled-up benefits in new buildings	November 2011-July 2017	Lack of legal framework impeded energy-efficient housing and curtailing greenhouse gas emissions.	To revise BEC for MFB; develop regulation on energy-efficient construction, accountable of regional climatic conditions; EE promotion.	BEC on Roofs and Roofing, Residential Buildings, Building Climatology, and Building Thermal Engineering were revised, adopted and made mandatory in 2015-2017. These have BEP and energy passport requirements and imply 15-25 percent heat consumption reduction in MFB.

3.2. Management of multi-family housing stock and public buildings

The case studies (Table 19) show advanced renovation and management practices, highlighting the role of smart data collection solutions and audits for proper building maintenance and operation.

While the primary focus in increasing buildings EE is on new constructions, immediately after commissioning the building falls into operation and maintenance process. Proper management of building stock requires effective administrative and professional technical solutions and entails engagement of qualified experts and special tools which streamline and automate the process. A pre-approved list of equipment manufacturers and suppliers can assist reduction of technical risks. As to EPC, it could also be used to encourage building owners in further EE investments.

Table 19. Case studies on management of MFB and public buildings

Country	Title/Scope	Period	Description	Key targets	Results
Austria	Sinfonia Smart Cities	June 2014-May 2020	The city of Innsbruck selected its eastern district to demonstrate large scale implementation of energy-efficient measures, with the objective of achieving primary energy savings and to increase share of RES in demo sites. About 66,000 m² of 1930-1980s MFB and public buildings will be retrofitted to improve indoor quality and energy performance, and reduce final energy demand by 80 percent.	Achieve 40-50 percent primary energy savings and increase RES share in the district's energy mix by at least 30 percent, by improved BE (insulation, windows, thermal bridges, etc.), ventilation with heat recovery, on-site RES (PV, STS, HP); optimize district HSS (increase RES use by 95 percent and reduce fossil fuels use by 22 percent, by deploying low-temperature grid, heat/cold recovery from local industries, integration of solar energy and biomass gasification). Smart management systems to combine demand- and supply-side measures to reduce electricity demand by 3 percent; buildings to be transformed into Smart Urban Model houses with smart load control for refrigerators, boilers and HP.	Smart city tools developed, including DistrictPH (energy balance district tool) enabling users to investigate long-term consequences of planning decisions, referring to desired performance indicators. CROCUS tool (expert tool simulating a city energy consumption per end-use) that optimizes district HSS and provides cost-benefit analysis of refurbishment strategies) was elaborated to select refurbishment plan. Guidelines to build an energy baseline scenario, Good practices tool for stakeholders' involvement, and Smart City plans SWOT analysis were prepared. Database of best practices in energy-efficient refurbishment was created, and policymaker workshops were organized.
	Mineroom student dormitory in Leoben	October 2015-September 2016	The project consisted in the development of a student dormitory using Passive House concept and standards. The dormitory will accommodate about 200 international students.	Apply Passive House concept to dormitory by installing ventilation system with heat and moisture recovery, optimized BE, best possible PV system, and by optimizing energy consuming components. The project also aimed to disseminate the Passive House and EE concepts among students who could bring these ideas to their home countries.	The building was certified "Plus" by Passive House Institute Darmstadt.
Belgium	Belgium Renovates for Energy Efficient Living (BE REEL)	2018-2024	Development of retrofitting strategy in Belgium (regions of Flanders and Wallonia), in line with national targets and EU buildings EE-related directives.	To create conditions for full implementation of strategic housing renovation plans for the selected regions; help reaching Belgium's climate and energy targets in the EU2030 climate and energy framework.	Expected to lead to renovation of 8,000 dwellings, reduction of CO_2 emissions by 18,600 tons/year. In long run, renovation strategies (to be developed) are expected to help reducing CO_2 emissions by 75-80 percent by 2050.

Country	Title/Scope	Period	Description	Key targets	Results
Bulgaria	Renovation of a residential block (municipality of Pernik)	March 2015-September 2017	The project was developed under the national programme for Energy Efficiency in Multi-family Residential Buildings (supported by the Ministry of Regional Development and Public Works of Bulgaria).	The programme aims to secure better living conditions for residents in MFB, whereas the project objective was to retrofit the selected residential block (1993-built 15-floor MFB connected to district HSS, 70 apartments, 138 inhabitants) from energy class E to B.	Expected reductions of expenditures due to EE measures – 58,730 Bulgarian levs/year; rate of return – 8.23 years; reduction in energy consumption – 53.15 percent; calculated CO_2 emissions avoided – 23.27 tons/year.
Georgia	Energy Audit Report for “m2” Residential Building	July 2016-August 2016	Evaluation of measures aimed to improve the quality of internal comfort for inhabitants and decrease the specific energy consumption.	Identification of energy saving potential in residential building; identification of EE measures; calculation of energy savings; calculation of CO_2 emission reduction	Energy audit of the selected residential buildings revealed potential energy savings of 1,346,332 kWh/year and CO_2 emissions reduction of 255 tons/year.
North Macedonia	Improved Management to Energy Efficiency of MFB	2015-ongoing	The proper management of MFB is crucial for EE improvement, especially in post-Soviet countries. Abandoned mechanisms for maintenance and management that existed at the previous social system preconditioned establishment in 2015 of residential management company “Habidom” by the Habitat for Humanity Macedonia.	To improve management of MFB and thus increase access to financing for EE upgrades, facilitate homeowners’ joint decision-making process on retrofitting common spaces.	2,332 households in 100 MFB are managed, of which 2 already retrofitted (windows, doors, BE, roofing, common areas). Improved access to financing for repairs of elevators, stairs and common areas; reduced electricity consumption due to network upgrades and modern lightening of common areas. Also, common spaces were newly painted, bicycle parking and door phones were installed. Reduction of energy consumption is 319.628 kWh, of CO_2 emissions –121.5 tons.
Russian Federation	Individual residential “A+ house” in Ekaterinburg	2014-ongoing	A pilot project in the frame of “Establishment of economical and organizational incentives to implement innovative energy efficient technologies, eco materials in building sector” Road map, and the “Own home” state Duma Programme on low-rise buildings development.	To develop and implement energy-efficient solutions, affordable in every region, for low-rise residential buildings.	The first energy-efficient model of economy class SFB with optimal balance of energy consumption reduction, healthy microclimate and eco-friendly behavior, was delivered. The Project won the “National competition on ecological development and energy efficiency – Green Awards”.

3.3. Awareness raising, capacity building and behavior change

The case studies (Table 20) demonstrate the important role of capacity building and awareness regarding EE in buildings.

Standard educational programmes and special training developed for target audience (construction professionals, maintenance specialists, inhabitants, public buildings users), as well as awareness raising campaigns and public entertainment activities (involving children and students) favor EE improvement. Focus should also be on building technical competence of banking specialists and lending officers that improves their understanding of the multiple benefits of EE investments.

Table 20. Case studies on awareness raising, capacity building and behavior change

Country	Title/Scope	Period	Description	Key targets	Results
Albania	Strengthening the country's capacities on buildings energy-efficient construction and design	July 2014-December 2015	Ministry of Urban Development and Tourism, National Housing Agency, International Financial Corporation, United Nations Development Programme and UNECE, conducted awareness-raising and series of trainings for specialists working in buildings construction and design sectors, to integrate energy-efficient practices of EE-advanced EU countries.	To increase awareness of challenges in the field of energy-efficient housing; to share information and knowledge in the field of legislation, regulations, norms and standards, financing and projects implementation, as well as on country's commitment to reduce energy consumption, especially in residential sector; to pave a roadmap for future activities in this field; to highlight the importance of housing management in retrofitting the existing housing stock.	Raised awareness regarding the benefits of EE in housing for businesses, families, economy and environment. A network of 'ad hoc' experts in the field of EE was created to support the programme and further construction. Experts enabled partners to assess energy consumption of buildings used before the project was implemented, which served as a benchmark for new investments.
Albania	Joint Actions for Energy Efficiency (ENERJ)	November 2016-April 2019	Joint Actions for Energy Efficiency (ENERJ) is an Interreg Mediterranean project that aims to support cities in attaining EE targets in municipal building stock, and to improve coordination of Sustainable Energy Action Plans and other relevant EE plans, to reach energy savings and national targets on EE of public buildings.	To develop and test technologically oriented methodology that focuses on increasing cooperation among public authorities; to create ENERJ web-platform to host geo-database on Sustainable Energy Action Plans, other local energy plans, and EE measures, and serve as forum for stakeholders. Also, integrated large-scale Joint Actions for EE, able to achieve economies of scale and impacts on energy consumptions and emissions, and catalyse a range of investments and leverage funds; enhancement of public and private stakeholders' skills to assess, define, adopt, implement and monitor EE actions and plans.	Report "Public buildings energy audits", which aims to collect data on selected public buildings and integrate it with new studies to complete the status quo situation; "Guidelines for Joint Actions for Energy Efficiency", which provide indications on technical and administrative steps needed to plan, design, implement, manage and monitor joint actions for EE; report "Plans and Measures Analysis", which investigates EE plans and measures for partner countries' public buildings, assesses EE-related EU directives and their implementation; "Funding Tool Report" listing funding opportunities to improve EE in public buildings in partner countries.

Country	Title/Scope	Period	Description	Key targets	Results
Armenia	Residential Energy Efficiency for Low Income Households (REELIH) Project (by Habitat for Humanity Armenia)	May 2013-March 2019	Involved local authorities, financial institutions, homeowners, tenants; included capacity-building, awareness-raising, advocating for MFB management and maintenance reforms, stimulating EE financing, implementing upgrades.	To develop and test viable and replicable financial models for implementation of EE measures in residential buildings; mitigate the impact of energy rising prices for low-income households; improve legislative framework for residential EE in Armenia; increase capacity and awareness of homeowner associations.	Financial model developed and tested for partial thermal retrofitting of MFB; homeowner associations and tenants gained knowledge on residential EE; EE of 13 MFB upgraded.
Georgia	Training and Certification of Private Sector Energy Auditors and Awareness Campaign for Energy Efficiency in Buildings	April 2017-November 2018	Training of 40 energy auditors on EE principles and energy auditing in buildings, to conduct 50 energy audits in public buildings.	To increase motivation and awareness of managers of municipal departments/public buildings; staff responsible for daily energy management, maintenance and operation of public buildings; municipality staff in charge of developing and controlling budget of public buildings.	Of 77 training participants (experienced individuals, officials, students), 61 completed theoretical part, 39 started audits, and 20 finished audit reports. Of 122 buildings selected for pilot phase, 51 were involved in audit, of which 27 audit reports are finished.
Portugal	CLASSE+ Voluntary Energy Labelling Scheme	January 2018-ongoing	Creation of national voluntary energy labelling scheme for building construction products (not covered by EU energy label). The scheme is endorsed by the industry associations, thus assuring market acceptance.	To make the scheme independent business model for suppliers who join voluntarily to label their products' energy performance and to gain market recognition through CLASSE+ brand; to make label's rating (from F to A+) a reference in financing and public incentive schemes; training of installers.	Labelling of windows was adopted by the market (100 companies that cover 50 percent of local production joined in the first year), which made CLASSE+ almost a market standard. Labelling insulation, paints and window films starts in 2019 and beyond. Substitution of existing materials with those of A/A+ labels allows up to 50 percent reduction in energy consumption/losses.
Russian Federation	Establishment of continuous educational system in the field of EE	June 2011-February 2017	In the frames of UNDP-GEF Project "Buildings energy efficiency in the North-West of Russia", a holistic educational system in the field of EE was developed.	To provide continuity in basic educational programmes to establish models for personal behavior and develop rational energy resources consumption skills/patterns, regardless of age, level of education and location.	Implemented in 11 regions: 5,000 pupils (47 schools) and 3,700 college students were trained. New programmes (master's degree in energy management) established in 5 universities. Inter-regional center of online education established: international educational programmes organised for young specialists from 35 countries.

3.4. Technical measures

The case studies (Table 21) show examples of energy-efficient technologies deployment.

They confirm that modern BEP components should include insulation and glazing, space heating, AC, water heating and cooling, lighting, energy management system and other EE solutions and innovative approaches, including individual smart technologies (sensors, Internet of Things, metering devices, etc.), which also improve buildings' functionality.

Table 21. Case studies on technical measures

Country	Title/Scope	Period	Description	Key targets	Achieved energy conservation
Albania	Energy Efficient Rehabilitation of a Student Campus in Tirana	September 2015-ongoing	Implementation of energy-efficient solutions for student campus no.2 in Tirana: 4 buildings with total gross floor area 15,624 m² were involved.	The proposed package of EE measures aims to improve thermal comfort conditions; reduce energy costs; reduce environmental impact (by using RES); implement energy saving measures with least disruption to building; monitor savings and ensure further maintenance.	Reduction of buildings' energy consumption by 82 percent, to 654,593 kWh/year; conversion of buildings to "B" EU energy class; reduction of energy cost to 80,278 euro/year; CO_2 reduction to 732,748 kg/year.
Belarus	Energy efficient residential house	January 2015-June 2017	Building energy-efficient MFB in municipality of Hrodna using cutting-edge engineering solutions to reduce fuel consumption for heating and hot water supply.	To decrease heat power consumption up to 15 kWh/m²/year, and up to 30 percent for hot water supply.	Ventilation with heat recuperation; wastewater heat recovery; 2 HP as key heat power source; PV (400 m²) installation led to A+ class rating, heat power for heating of 340,000 kWh/year and for hot water supply of 300,000 kWh, and actual electricity production in 2017-2018 of 50,000 kWh/year.
Bosnia and Herzegovina	Residential Energy Efficiency for Low Income Households (by Habitat for Humanity, with contribution from USAID)	July 2015-September 2017	The project seeks to address market, capacity and knowledge gaps, and improve living conditions, reduce energy costs and carbon emissions of selected low-income MFB in 5 municipalities.	Improve regional investment conditions through knowledge sharing (including technical), awareness-raising and advocacy; promote entrepreneurial solutions; help job creation; develop and test replicable financing models; development and improvement of management and maintenance of MFB homeowner associations and/or other stakeholders in public/private sectors.	Reduction of energy cost to 24,465.45 US dollars/year; reduction of buildings' energy consumption – 527,403.45 kWh/year; CO_2 emissions reduction – 151.16 tons/year.
Croatia	The first passive house based on ECO-SANDWICH® concept	2015	The case considered is 1 of 11 planned, in the city of Koprivnica. It is the world's first implementation of ECO-SANDWICH® material.	Construction of residential buildings of A+ energy class, with affordable price for low- and middle-income households, using innovative energy-efficient material ECO-SANDWICH® – ventilated prefabricated wall panel which utilizes recycled construction and demolition waste and sustainably produced mineral wool.	ECO-SANDWICH® was presented at 12 conferences and had a good publicity. A report on the projects' objectivities and results was published. ECO-SANDWICH® system is also a good example of cooperation of scientific institutions and industry.

Country	Title/Scope	Period	Description	Key targets	Achieved energy conservation
Georgia	Warm Elderly – Energy Efficiency Measures for Tbilisi Elders Boarding House	September 2015-June 2016	The city of Tbilisi joined Covenant of Mayors and committed to several common targets by 2020. One of these is renovation of municipal buildings following the standards for improved EE and use of RES. This project falls under this objective.	To assess social, technical, economic and environmental aspects of introduction of RES and energy saving solutions in community, regional, municipal and local self-government; promote benefits of energy-saving technologies and practices in state, municipal, community buildings among energy managers/decision-makers; demonstrate potential clean energy solutions to secure increased comfort and reducing energy costs and CO_2 emissions; raise awareness on actions to reduce energy use at workplace; build capacity in development of EE policies and action plans.	9,000 US dollars (compared to baseline); 185,028 kWh (compared to baseline); Average payback period – 9.3 years; 31.4 tons of CO_2 emission reduction (compared to baseline).
Georgia	Retrofitting 3 kindergartens in the city of Rustavi	2015-2017	EE-oriented retrofitting, aimed at creating an example that could be replicated in other cities.	To create a business case of a public buildings retrofitting; use RES and more energy-efficient technologies.	Space heating system; outside boiler room; DHW supply, combined with solar collectors; ventilation with heat recovery; electrical system with efficient bulbs and ground loop; windows with low-emissive glazing and diffusion-tight/-open sealing tapes.
Germany	EuroPHit buildings retrofits project	April 2013-March 2016	To reach the EU buildings-related energy goals, the project aimed to deepen, and significantly increase quality of retrofits. This was achieved through developing building cases that form a step-by-step retrofit concept.	With EnerPHit standard (PassiveHouse) as goal, share knowledge on applying energy retrofits to often overlooked yet critical areas.	Criteria, tools and guidelines; training on energy retrofits (including RES); step-by-step refurbishment plans for 11 pilot sites (40,000m²) in 8 countries, implementation of first step (26 million euro); documentation of findings (reports, recommendations, videos, product lists); 15 workshops to promote retrofitting; guidelines for 18 PassiveHouse-suitable components. Average calculated specific heating demand reduced by 103 kWh/(m²a) to 79 kWh/(m²a); saving potential at further steps may reach 60kWh/(m²a) – to 18 kWh/(m²K); CO_2 emissions reduction 1,005 tons/year.

Country	Title/Scope	Period	Description	Key targets	Achieved energy conservation
Russian Federation	EE in new construction in municipality of Parfino, Novgorod region	May 2015-July 2016	Construction of energy-efficient MFB in Novgorod Region, as part of governmental programme on resettlement from outdated houses – free for low-income families. The project proved possibility (for municipalities) to implement EE solutions and use modern technologies within budget limitations.	To implement a complex of EE measures considering regional climate, construction materials and equipment affordability; demonstrate benefits of energy-efficient MFB as compared to typical resettlement programme's buildings.	Most affordable, applicable and efficient technologies were implemented. Comparative energy saving potential is 57 percent (due to special windows) and 86 percent (due to insulation). Replicable in regions with similar climate conditions. Achieved energy conservation: electricity saving – 13,600 kWt/year; heat saving – 115.11 Gkal/year; estimated payback period – 27 years (including insulation); CO_2 emissions reduction – 28.12 tons/year. Inhabitants received keys from new apartments in 2016.
Turkmenistan	New EE enhancements to typical designs for SFB (GEF-funded)	2016-2017	This project seeks to develop new EE design and construction types of SFB, approved for typical conditions of Turkmenistan (no approved EE design in residential sector before 2016)	To achieve transformation of SFB design and construction Turkmenistan, saving energy and curtailing greenhouse gas emissions through compliance with new mandatory code.	Changes to 11 commonly-used existing designs developed to increase thermal efficiency and ensure code compliance. With average cost increase 20 percent, energy savings were: for heat and ventilation – 57 percent; for cooling and ventilation – 50 percent; for DHW – 27 percent. Annual natural gas savings – 17.4 m^3/m^2 of residential area; CO_{2e} emission reduction – 0.033 tons/year (per m^2 of residential area).

3.5. Financial mechanisms

The case studies (Table 22) contain examples of financial instruments of 2 main types: non-refundable grants and refundable loans of different variations, introduced in cooperation with national or international banks.

Specific financial assistance (subsidies, loans), or imposition of certain legal obligations (fiscal solutions for EE activities), is instrumental for improving buildings EE. Mechanisms involving local or international banks, private business investors (ESCOs, EE equipment manufacturers and suppliers), exist and should be supported locally, with a view to reducing financial risks.

Table 22. Case studies on financial mechanisms

Country	Title/Scope	Period	Description	Key targets	Results
Bulgaria	Bulgarian Energy Efficiency and Renewable Sources Fund (BgEEF)	June 2005-ongoing	Establishment of Fund, to operate on revolving principle based on independent management, operations' sustainability, transparency in financial resources administration, and equal opportunities for applicants.	To establish fund with capital of 15 million US dollars – as valid instrument to facilitate EE investments and promote development of EE market. Ensure energy consumption and greenhouse gas emission reductions.	EE loans to 200 projects (51.4 million US dollars), partial credit/portfolio guarantees to 33 projects (14.3 million US dollars). Fund became self-sustainable after 5 years. As of Q3 2018, savings of 124,161 MWh/year and reduction of CO_2e of 90,339 tons/year.
Croatia	Energy renovation with ESCO financing	April 2015-September 2015	Renovation of a hospital co-financed by public entity and private ESCO (public-private partnership).	Complete renovation of a hospital, including improvement of EE and reduction of energy costs. The main issue was time limitation for carrying out the works – to ensure continuous service of the hospital.	37,000 m^2 renovated; 18,000 m^2 facade, 7,700 m^2 flat roof; 8,300 m^2 exterior joinery. Reduction of 58 percent of CO_2 emissions; 7,901,840.03 kWh/year of energy consumed (56 percent reduction compared to past performance).
Estonia	Reconstruction grant for apartment associations	2015-2019	Fund KredEx established a grant, aimed at full-scale renovation of MFB, which may cover 15, 25 or 40 percent of total project cost.	Achievement of better EE and indoor climate for existing MFB; reduction of CO_2 emissions.	By end-2019, 400 MFB to be renovated. Planned heat energy reduction – 60 percent; evaluated reduction of CO_2 emissions – 11,000 tons/year, energy consumption – 70 GWh/year
Finland	Energy Efficiency Agreements	2017-2025	Agreements are voluntary commitments to fulfil EU EE obligations (without new legislation or other coercive measures). These unite participants from various sectors that enjoy governmental support in form of grants/incentives for deployment of EE technologies, investments and audits.	To cover more than half of binding energy-saving targets set for Finland in the EU EE directives; to improve efficiency of energy use in industry, energy, service, real estate and building sectors, as well as municipalities and oil-heated buildings.	In first 'period' (2008-2016), hundreds of companies/municipalities joined the Agreements, and by 2016 implementation of EE measures factored in reduction of energy consumption by 15.9 TWh/year, CO_2 emissions – by 4.7 million tons/year; energy costs by 560 million euro. Evaluated reductions of CO_2 emissions – 141,000 tons/year, of energy consumption – 454 GWh/year; energy cost savings amount 33.9 million euro/year.

Country	Title/Scope	Period	Description	Key targets	Results
Italy	Implementation of "Climate Energy Plan - South Tyrol 2050" in the Autonomous Province of Bolzano	November 2015-ongoing	As of 2015, the provincial public buildings' energy expenditures amounted 11.1 million euro/year. The project concerns renovation of 263 public buildings (total volume 3.1 million m^3, floor area 810,000 m^2).	To reduce energy costs of public buildings; generate innovative partnerships with private sector (especially professional investors); develop ESCO financing mechanism and analyse alternative instruments.	Expected final energy savings (gas and district heating energy use avoided) – 13,400 MWh/year (84 percent of heat energy); primary energy use for heating reduced by 16,650 MWh/year (from 19,800); avoided CO_2 – 2.45 tons/year (0.25 kg/kWh gas consumption, 0.10 kg/kWh district heating); energy costs (gas and district heating) decreased by 1.2 million euro/year (at gas-fired generation and district heating price 72 and 113 euro/MWh respectively).
Montenegro	ENERGY WOOD II - Biomass Heating System Program for Residential Sector in Montenegro (financed by Norway, 240,000 euro)	October 2015-December 2018	Households to receive individual interest-free soft loans up to 3,500 euro with 5 years repayment period (through partner banks) to purchase and install modern biomass HSS (pellet, briquette).	To offer households a financial mechanism for installing biomass HSS; develop national HSS market and ensure de-risked financial institutions' participation; economic and energy savings by introducing EE technologies; reduce CO_2 emissions.	Partner banks granted 532 loans amounting 1,193,557.06 euro, which had a significant influence on HSS market. These also factored in annual reduction of CO_2 emissions by 853 tons.
North Macedonia	Energy Efficiency Homes for Low-Income Households (by Habitat for Humanity Macedonia)	2009-ongoing	In the frames of USAID-financed project on EE in MFB (2011-2015), a unique loan product was developed and offered to homeowner associations to improve EE in low-income MFB. Elaboration of 6 financial models to support households.	To develop financial models and a set of activities to help low-income MFB households reduce vulnerability to energy price; reduce buildings' environmental impact while ensuring their comfort.	Over 1900 apartments in 60 MFB have been retrofitted, resulting in energy savings 7,910 MWh/year and CO_2 emissions reductions 3,670 tons/year. Local governments introduced supporting subsidy schemes. Microfinance organizations were motivated to develop loans for EE in housing, reaching out to homeowners from vulnerable groups, especially those in rural areas.
Portugal	"IFRRU 2020 via SCE" - Buildings renovation - Support access to financial instruments using EPC	November 2017-December 2023	IFRRU 2020 is a financial instrument, which combines funding from European funds (PORTUGAL 2020), European Investment Bank, Council of Europe Development Bank, and commercial banks.	To support urban rehabilitation projects, including improvement of BEP.	In 2017-2018, there were 51 contracted projects of total investments 199 million euro. These resulted in 122 rehabilitated households, 260 new residents, 1,031 new jobs, renovation of 85,523 public and commercial buildings. Also, 2,335 tons/year of CO_{2e} avoided, reduction of energy consumption by 5.108 tons/year of oil equivalent.

CONCLUSIONS AND RECOMMENDATIONS

The general recommendations arising from the analysis are presented below:

1. Continue harmonization of BEC by ensuring comprehensive coverage of all types of buildings.
2. Define national EE target, which is to be based on primary (or final) energy consumption, primary (or final) energy savings, or on energy intensity.
3. Continue strengthening requirements for insulation, ventilation and technical installations, *i.e.*:
    - Give more attention to air-tightness of BE;
    - Ensure building codes include requirements for AC, lighting, RES and natural lighting;
    - Make mandatory requirement for inspection of boilers and AC systems to improve quality and precision of EPC in MFB;
    - Follow holistic approach in BEC based on BEP requirements (HVAC, lighting, etc.);
4. Introduce/strengthen quality assurance measures, especially during the early stage of EPC, *i.e.*:
    - Requirements for certifying experts should be harmonised;
    - Certifier needs to be physically present on-site;
    - Quality check procedure of EPC should be harmonized;
    - Development of centralised EPC databases and digitalisation of certification process.
5. Challenges of BEP gap and data collection on energy use should be priority areas for research.
6. Establish/strengthen proper electronic monitoring system of compliance, enforcement and quality control processes to ensure compliance with international BEC and standards.
7. Define measures to establish in BEC regular inspection of boilers and AC systems.
8. Include measures in BEC allowing to continuously monitor, analyze and adjust energy usage.
9. Consider creating incentives for improving EE through appropriate policies, tax incentives and low-interest loans for EE projects (particularly countries with economies in transition).
10. Define measures in BEC to facilitate harmonization of energy-efficient materials and products testing and certification using international best practices. Lower-middle income economies, while taking affordability in consideration, should ensure that BEC promote local materials manufacturing, support research and development for local traditional techniques, and do not create dependency on imported materials that may stifle local innovation.
11. Define measures to ensure that materials and products used in construction are subject to rigorous quality control to meet EE requirements, to maintain resistance of buildings to local environmental loads, and to ensure they do not threaten safety of people and property.
12. Fund collaborative international research to assist establishment of new harmonized building materials' testing mechanisms, and to ensure that independent organizations (beyond manufacturing community) play a key role in developing market-neutral procedures.
13. Particularly for countries with economies in transition, and especially those which already have BEC in place, and are at the stage of their practical implementation with real positive effects:
    - Improve access to information by making full-featured versions of BEC accessible and available online with applicable calculation methods, free of charge;
    - Provide assistance, methodological or other, to countries that need it;
    - Consider developing common approaches to BEC, reflecting specifics relevant to energy exporting and energy importing countries.
14. Define policies based on well-founded identification of EE technology options that best facilitate achievement of national energy-related goals, and carry out in-depth review of economic and non-economic barriers to progress as a baseline for future policies.
15. Particularly for countries with economies in transition, define policies to increase awareness within national and local governments, developers, local funders, and international financial community on feasibility of investments in energy-efficient technologies.
16. Particularly for countries with economies in transition, define necessary policies to educate government officials in ministries and municipal offices on business environment necessary to attract investments in EE in buildings, and how to translate private sector requirements into effective policy measures and/or government initiatives.
17. Define policies to facilitate deployment of EE technologies in the market by improving coherence with relevant programmes and other policies to meet public policy goals.

Countries can also take priority actions to deploy technologies to enhance buildings EE, following the below recommendations that cover multiple perspectives (Table 23).

Table 23. Priority actions for governments to enhance buildings EE

Policy and legislation
1. Provide good policy, strong institutions and efficient public services to ensure private sector can thrive, and commit to developing institutions that implement, oversee and regulate policies. Being critical to economic growth, private sector cannot (and does not) act alone: public sector should support a balanced strategy. 2. Governmental research and development programmes should advance venturous technologies which are too risky for private sector. To convert innovations into marketable products, increased collaboration between government, industry, and energy programme administrations is required. 3. Specific requirements to better define cooling degree-days should be included in building standards, which will help evaluating BEP during warm seasons more accurately.
Role of public and private sector; new market opportunities
4. Governments should undertake initiatives to raise the bar for developing building EE technologies to meet specific local needs, which can create new international markets.
Connecting building EE with targets of Nationally Determined Contribution; reducing fossil fuel use in heating
5. Explicitly reference building EE measures in targets of Nationally Determined Contributions. 6. Governments of countries in which coal is used for residential heating, and coal is the lowest-cost fuel, should promote cleaner technologies for its use and adoption of other fuels.
Information awareness for multiple social benefits of EPC
7. To encourage building EE investments, local governments can publish city-level data, which demonstrates decreased energy costs and higher income associated with EPC levels.
Technological adaptation through effective promotion and awareness campaigns
8. Governments should scale up effective promotion and awareness campaigns which are essential to encourage consumers to purchase appliances labelled with high EE ratings. 9. More stringent regulations are needed to promote exterior and interior lighting in non-residential buildings and develop social pricing structures for homeowners to install smart meters. Governments should create awareness programmes reflecting upon the variety of benefits from adopting these technologies.
Key focus on building retrofits
10. Governments should promote collection of data which guide analysis and demonstrate financial benefits of increasing EE through retrofitting buildings. This should also include use of simulation software tools for BEP during design phase of new building construction and major retrofits. 11. Governments should develop and promote programmes to encourage complete retrofitting of decrepit and condemned residences, involving private real estate investors or developers.
National and local authorities' coordination to reassess building codes' development and implementation
12. Closer coordination is needed between national and local governments on building codes and EE policy design. Performance-based codes should be preferred to prescriptive to increase flexibility.
Investment and finance
13. Governments should develop and promote financial mechanisms to increase adoption of EE projects in buildings. To help overcome the complexity of investments and lack of capacity at individual and suppliers' level, ESCO should be promoted.
Capacity building to promote building retrofits
14. Standard civil engineering, educational, and training curricula should include building lifecycle management discipline, which should emphasize courses and programmes on EE and building renovations. 15. Financial institutions should be empowered to understand profitability of EE investments, which require promotion and dissemination of best practices, appropriate de-risking, and financing solutions for bankers. Clear technical and financial criteria should be defined by financial institutions to grant loans. Additionally, a pre-approved list of eligible equipment manufacturers and suppliers can assist in measuring and avoiding risks.
Expanded use of EPC
16. Governments could create tiered energy tariffs linked to EPC rating. Such pricing could drive EPC and encourage implementation of EE technologies. 17. Incentives for implementing EE technologies could be linked to EPC rating: *e.g.*, A-class building retrofitted from C, should receive higher land use tax compensation or lower interest rate, as compared to C-B upgrade.

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