Energy performance requirements for buildings in Europe

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The Building Performance Institute Europe (BPIE) is dedicated to improving the energy performance of buildings across Europe, and thereby helping to reduce CO_2 emissions from the energy used by buildings. BPIE acts both as an international centre of expertise on all aspects of energy efficiency and energy performance in European buildings, and as the European centre for a **Global Buildings Performance Network** (http://www.globalbuildings.org) created by ClimateWorks. Our main focus lays on policy analysis, implementation and dissemination of knowledge through studies, policy briefs and best practices.

Enforcing energy-related requirements during the design or retrofit phase of a building is a key driver for implementing energy efficiency measures in the building sector. Strong building energy codes cannot only bring substantial CO_2 savings and reduced energy bills, but also ensure more comfortable occupant conditions, more employment opportunities and increased energy security. Understanding the latest developments in building codes requires continuous monitoring and evaluation of what is adopted and enforced at country, regional and local level. Through its survey, the Buildings Performance Institute Europe has collected country information on the energy-related requirements in building codes adopted by the EU Member States. With the exception of a few countries, all countries have now embedded regulations for newly constructed, renovated residential and non-residential buildings.

Introduction

Energy codes for buildings comprise the energy efficiency requirements for newly constructed or renovated buildings. These requirements may apply to the building envelope and/or systems and can cover end uses such as heating, ventilation, air conditioning, lighting and water heating.

In Europe, energy codes for buildings are in a dynamic phase. The Energy Performance of Buildings Directive (EPBD, 2002/91/EC) was a major step forward through which Member States (MS) introduced requirements based on a "whole building" approach. In addition to overall building performance, a shift from an approach typically covering maximum permitted U-value only to a more extensive one including technical system requirements (e.g. on HVAC and lighting) has occurred. Moreover, major revisions in the building energy codes should be applied through the consideration of the cost optimality concept followed by the adoption of nearly zero energy standards (as introduced by the recast of the EPBD in 2010 (2010/31/EU)).

Given the environmental and climatic impacts of building codes, it is important to monitor all the key transformations happening at country level. The Building Performance Institute Europe investigated the status-quo of the building energy requirements through an extensive EU-wide survey on the building stock and building-related policies and regulations. This paper presents and discusses the findings of this survey.

Performance based requirements in building codes

In Europe, around 40% of the existing building stock was constructed before the 1960s when building energy codes were minimal (BPIE, 2011). It was only when the oil prices increased in the 1970s that several Member States introduced requirements for the thermal performance in their building codes with the exception of some Scandinavian countries which have had requirements in place since the mid-1940's. New residential buildings in Europe are estimated to consume about 60% less energy on average than those buildings constructed before the mid-1970s (World Bank, 2010). Enforcing energy-related requirements during renovations is, hence, of crucial importance.

Following the EPBD in 2002, requirements have gradually started shifting from prescriptive to a performance-based approach which is regarded as a major change in the building code trends. For many countries the

EPBD was the means of introducing new elements in their building codes prior to which there were no energy performance requirements concerning the building as a whole or specific elements. Nearly all countries have now adopted a national methodology which sets performance based requirements for new buildings. For countries in which prescriptive requirements existed before 2002 (e.g. Czech Republic, Belgium, Estonia, Bulgaria, Hungary, Ireland, Poland), there was a shift towards a holistic-based (i.e. whole building) approach whereby existing single element requirements in many cases were tightened. In some cases, the single element requirements are just supplementary demands to the energy performance requirements ensuring the efficiency of individual parts of a building is sufficient (e.g. Denmark). In others, they act as alternative methods where the two approaches exist in parallel (e.g. Norway, Spain, Poland, Switzerland); the first based on the performance of single elements and the second on the overall performance of a building. Typically in these cases, the single-element approach is preferred in major renovation projects while the performance-based in new constructions.

A detailed assessment of the energy performance requirements are provided in **Table 1**. It can be seen that many different approaches have been applied and no two countries have adopted the same approach. A variety of calculation methods are used and major differences exist in definitions (e.g. definitions of primary and final energy, heated floor area, carbon conversion factors, regulated energy and total energy requirement etc.). The setting of building code requirements with legally binding performance targets, is normally based on either an absolute (i.e. not to exceed) value, generally expressed in kWh/m^2a, or on a percentage improvement requirement based on a reference building of the same type, size, shape and orientation. Some countries (e.g. Belgium) express the performance requirement as having to meet a defined "E value" on a 0 to 100 scale, or on an A+ to G scale (e.g. Italy and Cyprus). Typically, these requirements cover heating consumption levels while in some cases more end-uses are included. It is also interesting to note that in many countries the requirements extend only to certain building types, usually just covering the residential sector.

Most methodology procedures are applied as software programmes. Software quality assurance accreditation is undertaken in only about half of the countries, a finding which has been drawn by the Concerted Action 2010 Report (CA-EPBD, 2010). About 50% of MS have already introduced changes to their methodology procedures to either; tighten requirements, achieve greater conformity with CEN standards, include additional technologies and/or to correct weaknesses/gaps in earlier EPBD methodology procedures.

Requirements on Heating, Ventilation and Air-conditioning systems

Different prescriptive requirements also exist in relation to maximum U values, minimum/maximum indoor temperatures, requirements for minimum ventilation rates and boiler and/or air-conditioning plant efficiency.

Most countries have introduced requirements to ensure minimum levels of ventilation within buildings. These are generally based upon metabolic rates and activity within the building. The requirements associated with ventilation relate principally to health, comfort and productivity; however they do have direct impact on energy requirements. Examples of different ventilation-related requirements in country building codes are presented in **Table 2**. These may apply as technical requirements on the ventilation systems (e.g. ventilation systems with heat recovery) or specified ventilation rates in designated areas of buildings. Given the increasing use of mechanical ventilation system, the fan power requirement in low energy buildings is becoming an increasingly important issue. A number of countries (e.g. Austria, Denmark, France, Estonia and Poland) have therefore introduced minimum requirements for specific fan power (generally expressed in W/l.s or $kW/m^3.s.$). Non-quantitative requirements also exist in some countries like Latvia and Hungary and this is an issue which needs to be addressed in several countries. As excessive or insufficient ventilation can lead to considerable energy wastage and uncomfortable conditions, many countries have introduced requirements to limit the air permeability/airtightness of buildings. Some of these requirements are listed in **Table 3**.

Most countries have requirements associated with the minimum performance of boilers and air-conditioning systems. Examples include minimum boiler efficiency levels and in some cases like Germany ban of old inefficient boilers (see **Table 4**). Additionally, many building codes require minimum levels of daylight to be achieved within buildings, whilst ensuring that solar gains do no result in significant overheating and/or the requirement for air conditioning. Building requirements associated with limiting solar gains vary from simple approaches (e.g. limiting window areas on building aspects exposed to solar gains) through to re-

Table 1. Performance-based requirements for new buildings.

	Single Family Houses	Apartment Blocks	Offices	Educational Buildings	Hospitals	Hotels & Restaurants	Sports facilities	Wholesale & retail trade
AT	H: 66 kWh/m²a	H: 66 kWh/m²a	H: 22.75 kWh/m³a C: 1 kWh/m³a	H: 22.75 kWh/m³a C: 1 kWh/m³a	H: 22.75 kWh/m³a C: 1 kWh/m³a	H: 22.75 kWh/m³a C: 1 kWh/m³a	H: 22.75 kWh/m³a C: 1 kWh/m³a	H: 22.75 kWh/m³a C: 1 kWh/m³a
BE - Br	E70		E75	E75				E75 (services)
BE - Wl	E<100, E_{spec}<170 kWh/m²a, Overheating<17500 Kh/an	E<100, E_{spec}<170 kWh/m²a, Overheating<17500 Kh/an	E<100	E<100				
BE - Fl	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60	From 2012, E70 From 2014, E60				
BG	F:122-146 H&C: 82.5-102.5 kWh/m²a	F: 90-146 H&C: 50.0-102.5 kWh/m²a	F: 80-132 H&C: 40.0-82 kWh/m²a	F: 56-98 H&C: 40-82.0 kWh/m²a	F: 180-242 H&C: 50-102.5 kWh/m²a	F: 176-230 H&C: 50-102.5 kWh/m²a	F: 90-134 H&C: 40-82 kWh/m²a	F: 90-134 H&C: 40-82 kWh/m²a
CH	Space heating demand (effective energy): 5 litre heating oil equivalent per m² (based on MuKEn 2008)							
	H: 54 kWh/m²a	H: 42 kWh/m²a	H: 46 kWh/m²a	H: 43 kWh/m²a	H: 44 kWh/m²a	H: 58 kWh/m²a	H: 40 kWh/m²a	H: 36 kWh/m²a
CY	A or B category on the EPC scale							
CZ	F: 142 kWh/m²a	F: 120 kWh/m²a	F: 179 kWh/m²a	F: 130 kWh/m²a	F: 310 kWh/m²a	F: 294 kWh/m²a	F: 145 kWh/m²a	F: 183 kWh/m²a
DE	New buildings must not exceed a defined primary energy demand for heating, hot water, ventilation, cooling and lighting installations (lighting installations only for commercial) based on of a reference building of the same geometry, net floor space, alignment and utilisation.							
DK	P: 52.5+1650/A kWh/m²a	P: 52.5+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a	P: 71.3+1650/A kWh/m²a
EE	P: 180 kWh/m²a	P: 150 kWh/m²a	P: 220 kWh/m²a	P: 300 kWh/m²a	P: 400 kWh/m²a	P: 300 kWh/m²a	P: 300 kWh/m²a	P: 300 kWh/m²a
EL	The Primary energy requirement for new and renovated building in Greece is = 0.33 – 2.73 x Reference Building energy performance							
ES	The energy performance requirements is not expressed in units of kWh/m²a							
FI	This is based on thermal transmittance (heat loss) measured in units of W/K. For a single family house, a typical value is 134 W/K							
FR-H1	P_{FF}: 130 kWh/m²a P_{ESH}: 250 kWh/m²a	P_{FF}: 130 kWh/m²a P_{ESH}: 250 kWh/m²a	n/a	n/a	n/a	n/a	n/a	n/a
FR -H2	P_{FF}: 110 kWh/m²a P_{ESH}: 190 kWh/m²a	P_{FF}: 110 kWh/m²a P_{ESH}: 190 kWh/m²a	n/a	n/a	n/a	n/a	n/a	n/a
FR -H3	P_{FF}: 80 kWh/m²a P_{ESH}: 130 kWh/m²a	P_{FF}: 80 kWh/m²a P_{ESH}: 130 kWh/m²a	n/a	n/a	n/a	n/a	n/a	n/a
HU	P: 110-230 kWh/m²a	P: 110-230 kWh/m²a	P: 132-260 kWh/m²a	P: 90-254 kWh/m²a				
IE	MPEPC = 0.6 & MPCPC = 0.69	MPEPC = 0.6 & MPCPC = 0.69	MPEPC & MPCPC should not exceed 1	MPEPC & MPCPC should not exceed 1				
IT	Regulations for new buildings are based on a set limit for heating, DHW, cooling and lighting. Only Class A+ to C buildings comply with requirements for new buildings							
LT	Min Class C buildings: 80 kWh/m²a for buildings over 3000 m², 100 kWh/m²a for buildings between 501 and 3000 m², 115 kWh/m²a for buildings up to 500 m².							
LV	No performance requirements are set							
MT	No performance requirements are set							
NL	P: 68388-68552 MJ/a	P: 35595-36855 MJ/a						
NO	N: 120-173 kWh/m²a	N: 115 kWh/m²a	N: 150 kWh/m²a	N: 120-160 kWh/m²a	N: 300-335 kWh/m²a	N: 220 kWh/m²a	N: 170 kWh/m²a	N: 210 kWh/m²a
PL	F: 142 kWh/m²a H&C: 108 kWh/m²a	F: 123 kWh/m²a H&C: 99 kWh/m²a	F: 174 kWh/m²a H&C: 183 kWh/m²a	Requirements for other non-residential buildings apply				
PT	P: 203 kWh/m²a F: 80 kWh/m²a	P: 203 kWh/m²a F: 80 kWh/m²a	P: 407 kWh/m²a F:122 kWh/m²a	P: 174 kWh/m²a F: 52 F kWh/m²a	P: 465 kWh/m²a F:140 kWh/m²a	P: 523/1395 kWh/m²a F: 157/419 kWh/m²a	P: 233 F:70 kWh/m²a	P: 1279 F: 384 kWh/m²a
RO	No performance-based requirements are set							
SE	F_E: 55-95 F_{NE} 110-150 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a	F_E: 55-95 F_{NE} 100-140 kWh/m²a
SI	P: 170-200 H&C: 50 kWh/m²a	P: 170-200 H&C: 50 kWh/m²a	P: 163-180 kWh/m²a for social housing, for non-residential H&C: 30-50 kWh/m²a, for non-residential (public investment) H&C: 20-40 kWh/m²a					
SK	P: 80-160 H&C 42-86 kWh/m²a	P: 63-126 H&C: 27-53 kWh/m²a	P: 120-240 H&C: 16-56 kWh/m²a	T: 42-84 H&C: 28-56 kWh/m²a	T: 101-201 H&C: 27-70 kWh/m²a	T: 94-187 H&C: 14-71 kWh/m²a	T: 48-95 H&C: 28-56 kWh/m²a	T: 81-161 H&C: 27-70 kWh/m²a
UK	17-20 $kgCO_2$	16-18 $kgCO_2$	Other TER (Target carbon dioxide Emission Rate) values apply for non-domestic buildings					

Legend of Table 1:

P:	Primary Energy
F:	Final
N:	Overall Net energy demand limit (includes all electricity for lighting and appliances)
T:	Total delivered energy
H:	Heating
C:	Cooling
H&C:	Heating and cooling
MPEPC:	Irish Maximum Permitted Energy Performance Coefficient
MPCPC:	Irish Maximum Permitted Carbon Performance Coefficient
ESH (subscript)**:**	Space heating provided by electricity (incl. heat pumps)
FF (subscript)**:**	Space heating provided by Fossil Fuels
E (subscript)**:**	Electrically heated building
NE (subscript)**:**	Non-electrically heated building

Notes for Table 1:

AT:	Based on gross floor area and gross building volume
BG:	Based on assumption of DD=2100, A/V=0.2 for SFH, A/V=0.8 other, 32% share of glazing for upper limit and DD=330, A/V=1.2, 32% glazing for lower limit
CH:	Effective space heating demand for a typical building shape calculated on the basis of the SIA-norm 380/1:2009
DK:	A denotes the gross heated floor area in the Danish formulate, example 73.1 P @80 m^2 58 P @300 m^2
EE:	Heated floor area
FI:	For a single family house with building volume 522 m^3, gross floor area 163 m^2, and height between floors 3m.
FR:	H1, H2 and H3 represent the three main climatic regions in France
IE:	MPEPC and MPCPC denote the Maximum Permitted Energy Performance and Maximum Permitted Carbon Performance Coefficients used in the Ireland scheme
NO:	In Small houses, calculated overall net energy demand is limited to 120+1600/m^2 heated floor area.
PL:	Based on formula EPH+W=73+ΔEP for A/Ve<0.2; EPH+W=55+90 A/Ve+ ΔEP for 0.2< A/Ve<1.05; EPH+W=149.5++ΔEP for A/Ve>1.05 for residential buildings
PT:	Electricity production efficiency is approx. 0.30. For a 120 m^2 building, max energy needs (in kWh/m^2a) are 52-117 for heating, 198 for cooling, 38.9 for DHW
SI:	Requirements by 31.12.2014
SK:	Based on assumptions for shape factor, internal air temperature, floor to floor height, air change rate, degree days, etc.
UK:	The UK requirements are based on achieving a % reduction in CO2 emissions over a notional building of the same size/shape.
SE:	Electric heated buildings divided in three climatic zones: 95, 75, 55 kWh/m^2a

Table 2. Examples of different (non-exhaustive) ventilation-related requirements in country building codes.

AT	Mechanical ventilation systems must be equipped with a heat recovery system when installed in new buildings or when renewed in the course of a renovation procedure. In major renovated or newly constructed non-residential buildings, the maximum heating energy consumption is reduced by 2 kWh/m^3a or 1 kWh/m^3a, if not more than half of the useful area is supplied by a mechanical ventilation system with heat recovery. In major renovated residential buildings, the maximum permitted calculated heating energy consumption is reduced by 8 kWh/m^2a.
DK	Mechanical ventilation systems must meet the following requirements for specific electricity consumption for air transportation: • 1800 J/m^3 in constant air volume (CAV) systems • 2100 J/m^3 a max air volume for variable air volume (VAV) systems • 800 J/m^3 for exhaust ventilation systems • 1000 J/m^3 for ventilation systems for one dwelling
LV	Ventilation systems shall be designed and installed: • to protect human health using the space as intended; • to ensure adequate air quality, sanitary requirements and standards of comfort level; • in order to ventilation system does not encourage a flame or smoke spread and to prevent explosive gas and vapour mixture formation.
PL	Ventilation (in-blow) fan: • Complex AC installation 1.60 • Simple ventilation installation 1.25 Draught fan: • Complex AC installation 1.00 • Simple ventilation installation 1.00 • Air out-blow installation 0.80
ES	Minimum ventilation by person: • IDA 1: hospitals, clinic, laboratories and day-care centres ⟶ 20 dm^3/s • IDA 2: office, reading rooms, museums, rooms of courts, classrooms of education and swimming pools ⟶ 12,5 dm^3/s • IDA 3: commercial buildings, cinemas, theatres, assembly halls, rooms of hotels, restaurants, bars and similar, gymnasiums and rooms of computers ⟶ 8 dm^3/s • IDA 4: air of low quality ⟶ 5 dm^3/s

Table 3. Examples of different airtightness requirements in country building codes.

AT	In naturally ventilated buildings, maximum n_{50} is 3.0. In mechanically ventilated buildings, maximum n_{50} is 1.5.
BE	Default value of 12 $m^3/h\ m^2$ is used in methodology if no pressure test is available. Actual test result is used in the calculation if available
BG	In apartments with high airtightness, n_{50} <2.0 h^{-1}, with medium airtightness n_{50}=2.0-5.0 h^{-1} and with low n_{50}>5h^{-1}. In SFH with high airtightness, n_{50}<4.0h^{-1}, with medium airtightness n_{50}=4.0–10.0 h^{-1} and low airtightness n_{50}>10.0 h^{-1}
CY	Not regulated in building codes
CZ	Recommended maximum for common buildings is 4.5 h^{-1}, low energy buildings 1.5 h^{-1} and passive houses 0.6 h^{-1}. For mechanically ventilated buildings w/o heat recovery 1.5 h^{-1}, with heat recovery 1.0 h^{-1}
DE	For naturally ventilated buildings, n_{50} is 3.0h^{-1} and for mechanically ventilated buildings, n50 is 1.5h^{-1}
DK	Airtightness must be better than 1.5 l/s m^2, tested @ 50 Pa
ES	Air permeability of windows and doors depend on the climatic zone. For zones A and B (Class 1, 2, 3 and 4), maximum air permeability is 50 $m^3/h\ m^2$. For zones C, D and E (class 2, 3 and 4), maximum air permeability is 27 $m^3/h\ m^2$.
EL	Air penetration for the reference building, is taken equal to 5.5 $m^3/h\ m^2$ frame.
EE	For small buildings, maximum airtightness is 6 $m^3/h\ m^2$ (for new buildings) and 9 $m^3/h\ m^2$ (for existing buildings). For large buildings, maximum airtightness is 3 $m^3/h\ m^2$ (for new buildings) and 6 $m^3/h\ m^2$ (for existing buildings).
FI	n_{50} equal to 2.0 is used for reference building heat loss in Finnish Building Code. For EPC, n_{50} of 4 is considered unless the measured value is different. Air change rate in new apartments should be at least 0.5 h^{-1}.
FR	Airtightness under 4 Pa of building envelope is limited to 0.8 $m^3/h\ m^2$ for SFH, 1.2 $m^3/h\ m^2$ for other residential buildings, offices, hotels educational and health care buildings and 2.5 $m^3/h\ m^2$ for other buildings.
HU	Not regulated in building codes
LT	For naturally ventilated building, maximum n50=3 1/h, for mechanically ventilated buildings, maximum n50=1.5 1/h
LV	Maximum n50 in dwellings is 3 $m^3/h\ m^2$, 4 $m^3/h\ m^2$ in public buildings, 6 $m^3/h\ m^2$ for industrial buildings. For ventilated buildings, maximum n_{50} is 3 $m^3/h\ m^2$.
MT	Not regulated in building codes
NL	For residential buildings, 200 d m^3/s @10 Pa and for non-residential buildings 200 d m^3/s per 500 m^3 @10 Pa
NO	Maximum n_{50} is 3
PT	For residential buildings, the requirement is 0.6h^{-1}. Requirements for non residential buildings with mechanical ventilation exist depending on type of use
SI	For naturally ventilated buildings, maximum n_{50} is 3.0, for mechanically ventilated buildings, maximum n_{50} is 2.0
SK	For SFH with high quality windows, maximum n_{50} is 4 h^{-1} and for all other buildings is 2 h^{-1}. Other values apply for buildings with double glazed windows with seals or single glazed windows without seals.
UK	Maximum n_{50}=10 $m^3/h\ m^2$

quirements for complex modelling and simulation to demonstrate that effective measures have been adopted to provide solar protection. The Concerted Action report recommended that much greater attention should be given to the issue of estimating the impact of summertime overheating in the methodology in order to reduce the rapid increase in demand for air-conditioning (CA-EPBD, 2010).

Although most of the countries have now inspection schemes for boilers and/or air conditioning systems, data collection on the number of inspections done by each Member State is still at a very low level. Insufficient data makes it difficult to formulate an appropriate evaluation on the effectiveness of these schemes. Moreover, Finland, France, Ireland, the Netherlands, Slovenia, Sweden and the UK have opted for option b (advice to the users) of article 8 regarding the EPBD requirement for inspection of boilers. This shows that not all Member States have inspection schemes in place. With the implementation of the EPBD recast (Article 18, Directive 2010/31/EU), independent control systems for energy performance certificates and inspection reports should be established. However, the design of effective systems is pre-requi-

Table 4. Examples of different (non-exhaustive) heating system requirements in country building codes.

BG	Minimal efficiency requirements for boilers are in % and function of the boiler nominal capacity(Pn) in kW: 1. standard boilers - 87 + 2 log Pn; 2. low temperature boilers - 90 + 2 log Pn; 3. condensing boilers - 93 + 2 log Pn
DE	Prohibited use of boilers filled with liquid or gaseous fuels which were installed or set up before October 1, 1978. Prohibited use of electrical thermal storage systems according to the provisions if the heating in the buildings is produced exclusively by electrical thermal storage systems.
DK	Oil boilers must have efficiency, according to CE-labelling scheme not less than 93% at full load and 98% at part load. Gas boilers must be condensing with efficiency, according to CE-labelling scheme not less than 96% at full load and 105% at part load.
UK	Gas boilers (the primary heating systems used in UK homes) must meet a minimum efficiency of 86% using the SEDBUK methodology.

site for the success of these schemes so information exchange of past experiences and best practices between the Member States is very important.

Conclusion

Energy codes are in general a very cost-efficient regulatory measure whose benefits can go well beyond energy savings. The implementation of the EPBD has resulted in a step-change in the energy requirements in building regulations across Europe. The survey undertaken by BPIE shows large variations in the approaches adopted by different countries. Whilst there are a small number of countries which are still to implement requirements on heating, cooling or ventilation, many Member States have now requirements in place as a result of the EPBD.

Adopting, implementing, and enforcing codes requires rigorous procedures by the authorities. It is generally accepted that compliance and enforcement of building energy codes is undertaken with less rigour compared to other building regulations such as structural integrity and fire safety. Whilst data on compliance levels are scarce, studies suggest that non-compliance in Europe can reach up to 50% levels in certain regions (Fraunhofer ISI et al, 2009). However, as the energy performance requirements become stricter (e.g. in line with EPBD recast provision on nearly zero-energy buildings), the gap between the theoretical performance during design phase and the actual energy performance in-use may increase substantially. While energy codes offer a very attractive opportunity to reduce CO_2 emissions of buildings in a cost-effective way, low compliance levels will bring significant lock-in effects in CO_2 savings. If the EU Member States are to deliver the climate and environmental targets related to buildings in the coming years, it is critical that they focus and invest more on control and enforcement procedures.

References:

The World Bank, Mainstreaming Building Energy Efficiency Codes in Developing Countries Global Experiences and Lessons from Early Adopters, Energy Sector Management Assistance Program, 2009. http://www.esmap.org/esmap/sites/esmap.org/files/WP_204_GBL_Mainstreaming%20Building%20Energy%20Efficiency%20Codes%20in%20Developing%20Countries.pdf

European Commission, DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings (EPBD). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:001:0065:0065:EN:PDF

European Commission, DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (EPBD recast) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

CA-EPBD, Implementing the Energy Performance of Buildings Directive – Featuring country reports 2010. http://www.epbd-ca.org/Medias/Downloads/CA_Book_Implementing_the_EPBD_Featuring_Country_Reports_2010.pdf

Buildings Performance Institute Europe, Europe's Buildings under the Microscope – a country by country review of the energy performance of buildings, 2011. http://dl.dropbox.com/u/4399528/BPIE/HR_%20CbC_study.pdf

Fraunhofer ISI, ENERDATA, ISIS, Technical University Vienna, Wuppertal Institute for Climate, Environment and Energy WI, Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries, Final Report for the European Commission Directorate-General Energy and Transport, EC Service Contract Number TREN/D1/239-2006/S07.66640, March 2009, revised. http://ec.europa.eu/energy/efficiency/studies/doc/2009_03_15_esd_efficiency_potentials_final_report.pdf