CHAPTER 7: PERFORMANCE-BASED MODEL AND ANALYSIS – TOWARDS AN INTEGRATED DESIGN

1. Introduction – why performance based, characteristics and earlier work?
2. Assumptions
3. Results – potential, cost-effectiveness
4. Comparison with the component-based model

Currently, the trend in the policy design in the building sector is to move towards the performance-based regulation and standards (such as the recast of the EPBD, Hungarian GIS). Although this trend in policy is not new, determination of the energy savings potential and the resulting CO_2 reduction has been relying mainly on the component-based approaches so far (see Table xx, Chapter xx for overview of the studies using component-based approach). However, need for a more radical transformation towards low-energy economy, as well as the need for integrated design makes it inevitable, that energy savings potentials are determined on the basis of performance. Several countries have already designed their building codes based on energy performance (Hui, 2002). The performance approach leaves a greater space for innovation and new techniques in energy efficiency design (Hui, 2009).

This chapter presents the assumptions behind the performance-based model, the resulting energy saving and CO_2 reduction potential and finally compares these results to the potential determined via the component-based approach.

7.1 Main assumptions in the performance-based approach

The basic assumptions behind the performance-based model are aligned to the component-based model, so that the results of the two scenarios can be compared. Similarly to the component-based model, the performance-based model consists of Business-as-usual (BAU) scenario and the mitigation scenario (called Passive accelerated scenario). The common basic assumptions include the following:

- Base year is 2005
- Projection period is 2005-2030
- Mitigation action starts in 2011
- In the period 2005-2010 the mitigation scenario is assumed to follow the same trajectory as the BAU scenario
- In the mitigation scenario: all existing buildings (built until 1990) are gradually retrofitted by 2030
- In the mitigation scenario: all new buildings are gradually built to the level of passive house standard by 2020

In addition, the building projections, floor area and other building characteristics, heating energy requirements are the same for the respective scenarios in both models.

- **Business-as-usual scenario (BAU_{perf}) scenario**

This scenario assumes that existing buildings built until 1990 are retrofitted at the natural rate of retrofit (1% p.a., based on Novikova, 2008) [1] to the level of the 2006 Building code (Ministerial order No.7/2006 published in Magyar közlöny, 2006, further 2006 Building code). All new buildings are assumed to be built also according to 2006 Building code. The Hungarian 2006 Building code represents approximately 50% energy savings compared to the existing buildings built until 1990 (Csoknyai, email communication, September, 2009). In this scenario no further energy efficiency improvements are assumed due to low level of compliance to building codes in the absence of additional policies.[2] At the same time, it is assumed that the partial retrofit is banned in the regulation starting in 2011. Energy consumption of the non-retrofitted buildings is based on the energy audits from the following sources: UNDP/Energy centre (2008), Csoknyai (2008), Display campaign (2008) (see Table 1 for overview).

Table 1 Assumptions behind BAU scenario

BAU_{perf} scenario	
Existing buildings	• Rate of retrofit: 1% p.a. of the existing buildings built until 1990 • All retrofitted buildings are renovated to the level of 2006 Building code • Non-retrofitted: average energy use based on survey of energy audits[3]
New buildings	• All new buildings are built to the level of 2006 Building code

While the costs in the BAU_{comp} scenario depend on the costs of individual components, the costs in BAU_{perf} are based on costs of achieving the level of 2006 Building code. The costs of new construction are based on ETK in years 2006-2009 (ETK, 2006-2009). The costs of retrofit are based on the costs of current Hungarian energy efficiency projects achieving 40-60% energy savings, which are around 100 Euro/m^2 (based on Dóbi-Rózsa, 2009).[4]

❖ Mitigation scenario

The mitigation scenario (also called Passive accelerated scenario) assumes that all existing buildings built until 1990 are retrofitted by 2030. This assumption implies accelerated rate of retrofit. The rate of retrofit is on average 4% p.a. of the existing building stock (built until 1990) depending on the building type. [can this actually vary based on the building type? In this way they should be actually equal, only that they vary in different years of mitigation action due to the different cessation rate of the existing buildings in different building types – however, then, this could also influence the different retrofit rates between building types??? Then, the retrofit rates should be the same for the building types which have the same rate of cessation of existing buildings! check!]

[1] This is also in a line with the assumptions in Schuering and Lechtenboehmer (2009), where the rate of retrofit is 1.2% for North-Western Europe, 0.9% for Southern Europe and 0.7% for Member States which joined EU in 2005 (including Hungary) in 2004. This is assumed to increase to just above 1% in 2010 for the Member States of 2005 accession (Schuering and Lechtenboehmer, 2009).

[2] According to Warren (2008) and Hjorn (2008) between 50-65% of new homes do not comply with basic energy standards (in Schuering and Lechtenboehmer, 2009).

[3] Survey includes energy audits of UNDP/Energy centre (2008), Csoknyai (2008), Display campaign (2008). Further referred to only as UNDP/GEF audits.

[4] Dóbi-Rózsa (2009) reports cost of retrofit of 6000 Euro/flat for retrofits which reach energy savings of 40-60%. The average size of a flat in Hungary is approximately 60m^2 (Csoknyai, email communication, 2008) and thus, average cost of retrofit is 100 Euro/m^2.

The retrofit rate in this scenario is higher than usually assumed in similar studies on potential in the building sector. For instance, Lechtenböhmer et al. (2009) assumes an increased rate of retrofit of 2.5% of the existing buildings in their EU-wide scenario assessing mitigation potential by 2020. However, the assumption of Lechtenböhmer et al. (2009) applies both for the residential and tertiary buildings and to both Western and Eastern Europe Member States. The rate of retrofit assumed in the current study is much higher due to two reasons: first, we assume that since the public sector should play exemplary role in mitigation efforts (Article xxx, ESD - EC, 2006), it is justified to assume such high retrofit rate. Second, retrofit of the Eastern European existing buildings in the last decades has been lagging behind to the total EU-27 average (find citation xxx), and thus, it is expected that there will be taken measures to increase the retrofit rate in order to maintain the basic functioning of the public buildings. Some countries, such as France, have already started to plan accelerated retrofit in publically owned buildigns (Rockwool, 2009). [explore more, more examples with goals and budgets]

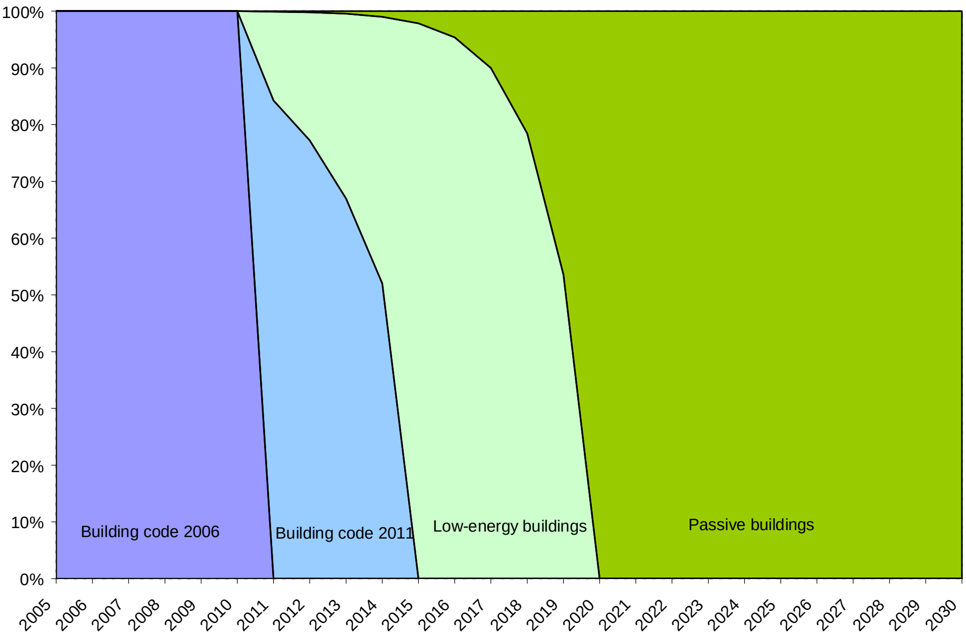
The Passive accelerated scenario assumes that majority of the existing buildings are gradually retrofitted to the level of passive house by 2020 (85%). According to Szekér (2009) passive retrofit entails more technical difficulties than new construction, nevertheless, it is possible with proper training of professionals during the transition period. This implies that in order to achieve 85% retrofit of existing buildings, architects, designers and engineers have to be trained intensively on integrated design and passive house techniques, as well as these subjects have to be included in the curricula at the technical universities. The transition towards the passive retrofit includes retrofit to the level of low-energy and 2011 Building code (see Table 4).

Table 2 Assumptions behind Passive accelerated scenario

Passive accelerated scenario	
Existing buildings	• All existing buildings (built until 1990) are retrofitted by 2030 • Accelerated rate of retrofit of 3-5% of the existing buildings built until 1990 depending on building type • Out of the retrofitted buildings these performance levels are achieved by 2020: • 5% 2011 Building code (60 kWh/m^2) • 10% Low energy (30 kWh/m^2) • 85% PH (15 kWh//m^2) • Phase-out of 2006 Building code: 2013 • Non-retrofitted: average energy use based on UNDP/GEF audits
New buildings	• All new buildings are PH by 2020 • The rest is assumed 2011 (phase-out in 2015) and low-energy (phase-out in 2020) • Phase-out of 2006 Building code: 2011

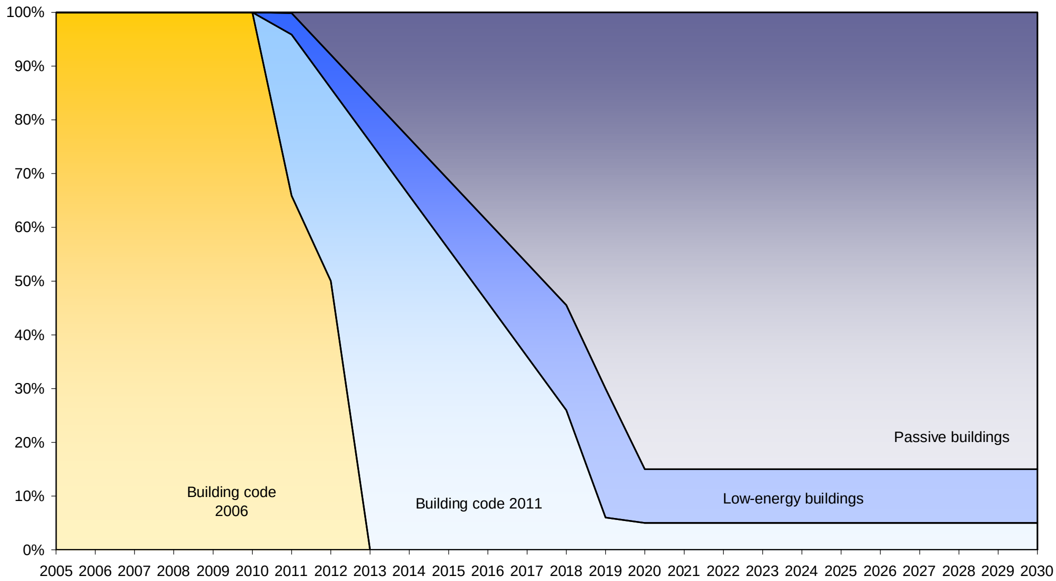
For the new construction it is assumed that the 2006 Building code phases-out in 2011. The 2011 Building code will phase-out in 2015 and the low-energy standard in 2020 and thus give way to the full implementation of passive house standard (Figure xx).

Figure xx Annual shares of various standards on the new construction stock in Passive accelerated scenario



The existing buildings are assumed to be retrofitted to the level of 2006 Building code until 2013, when this standard will be banned. From then the buildings can be retrofitted to the level of 2011 Building code, low-energy and passive buildings. Passive house standard is gradually increasing its share on the stock of annually retrofitted buildings to 85% by 2020. It is assumed that in 2020 buildings which cannot be retrofitted to the level of passive house standard will be retrofitted to either 2011 Building code (5%) or low-energy standard (10% of retrofitted building stock).

Figure xx Annual shares of the building standards on the retrofitted building stock in Passive accelerated scenario



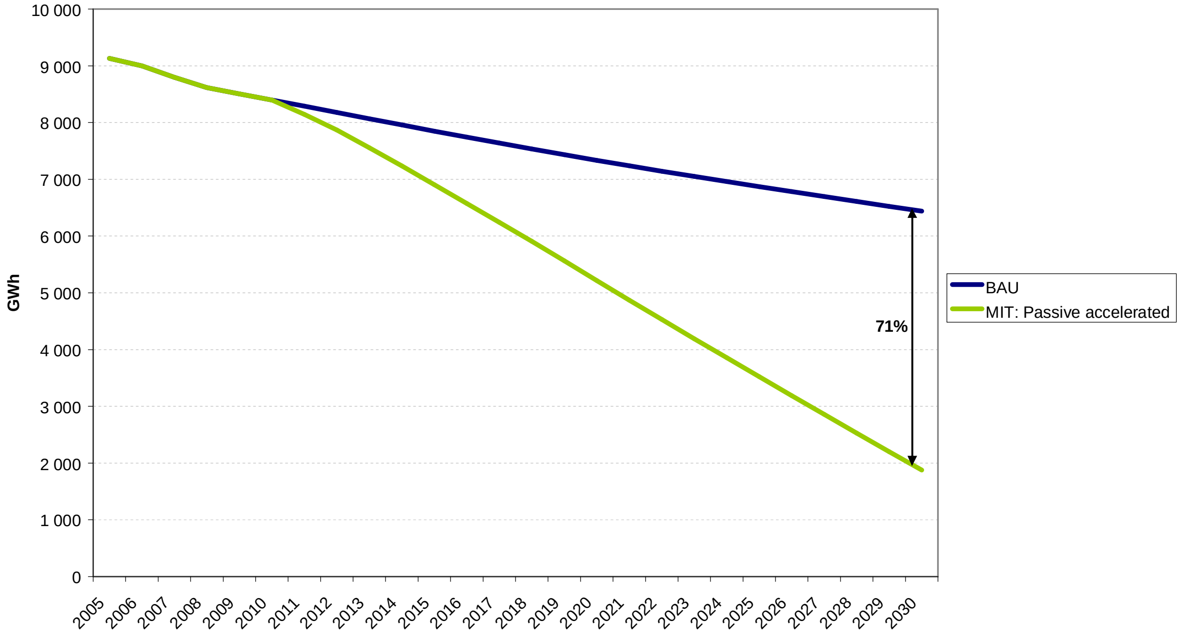
The heating energy requirement for the passive house standard is 15 kWh/(m^2.a) based on the PHPP (explain, cite). The 2011 Building code assumes energy consumption of 60 kWh/(m^2.a), which corresponds to the German Energieeinspaarverordnung (EnEV, 2009), and the low-energy standard an energy consumption of 30 kWh/(m^2.a) (Csoknyai, personal communication, July 2009).

The costs of the 2011 Building code are assumed 3% higher than the average costs of the standard building (i.e. 2006 Building code for both existing and new buildings) (Csoknyai, personal communication, July 2009). The costs of low-energy buildings are assumed 20% higher than the cost of 2006 Building code for existing and 10% higher for new buildings (based on Csoknyai, personal communication, July 2009). The current additional costs for the new passive house are assumed 20% higher and for passive retrofit 40% higher than the cost of a building under Business-as-usual scenario (Szekér, personal communication, July 2009). The latter is in line with the cost of the first passive retrofit of a residential building in Hungary with the additional costs of 41% (www.solanova.eu). The costs of the passive standard are decreasing gradually to the level of 7% for offices 8% for other buildings by 2020 (7% for offices is based on passive office in Tübingen cited in PHI Database (2009) and IZES (2003) and 8% for other buildings is based on Veronica, 2008; Matzig, personal communication, April, 2009 and Csoknyai, personal communication, July, 2009).

7.2 Determination of potential via performance-based model

The energy savings in the performance-based model (represented by Passive accelerated scenario) reach 4,562 GWh in 2030 and this leads to reduction of 908 kt CO_2 emissions. This decrease corresponds to energy savings of 71% compared to BAU scenario (Figure xx).

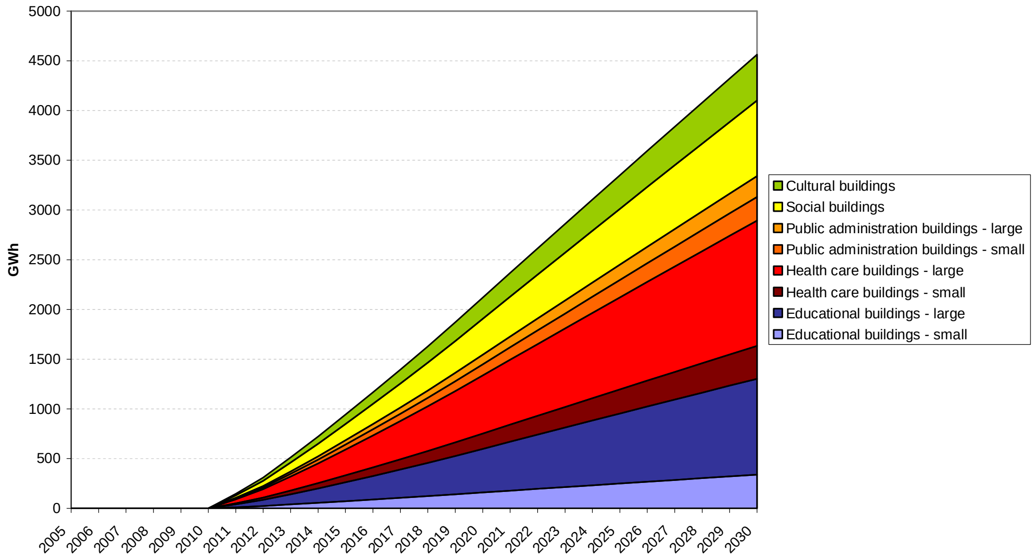
Figure xx Comparison of mitigation and BAU_{perf} scenario in the performance-based model



Potential by building types

The largest potential is represented by large educational (primary, secondary and tertiary education), large health care (hospitals and medical centers) and social buildings (Figure xx).

Figure xx Energy savings potential in Passive accelerated scenario by building type (GWh)



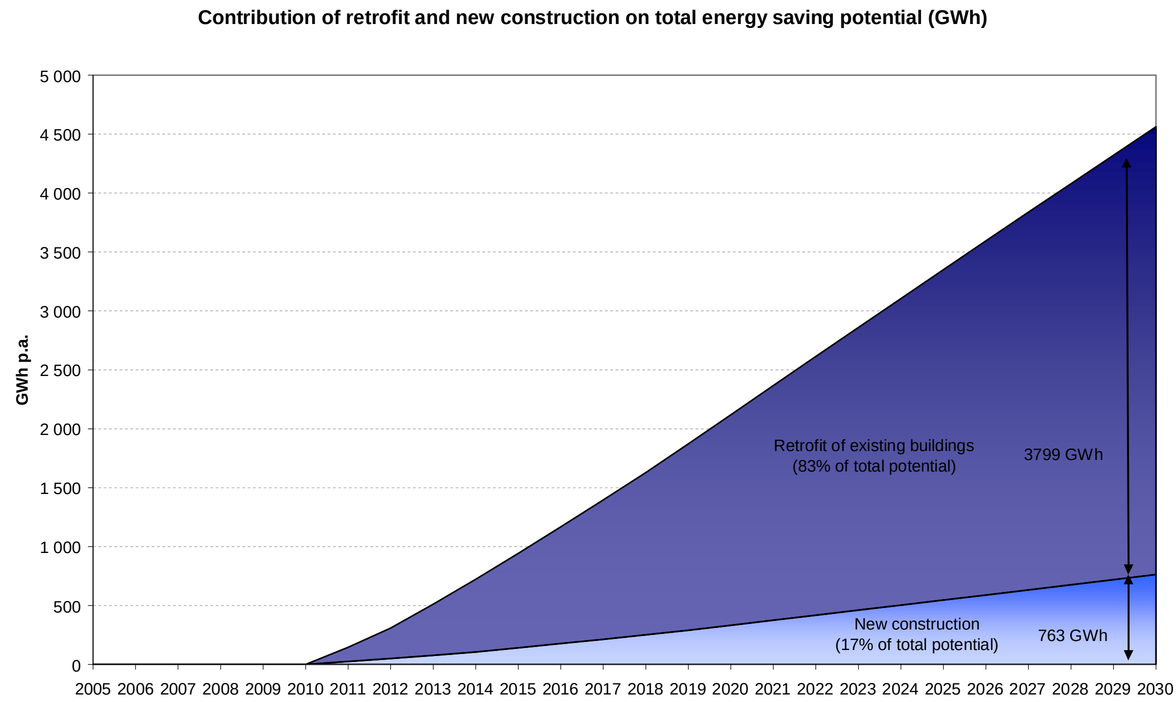
The share of different sectors on the potential in the three scenarios is similar in all three mitigation scenarios and thus, the split of the potential by building types is shown only for the Passive accelerated scenario. The extent to which a particular building code contributes to the overall potential depends on the specific heating requirement, number and size of the building. Although hospitals and social buildings are relatively low in number, and social buildings are not particularly large, their contribution to the total potential can be attributed to the high heating energy requirement. On the other hand, it is the number and the size in the case of large education buildings rather than their heating requirement that play an important role in their large share on the overall potential.

Potential – contribution of new construction and existing buildings

The existing buildings can achieve in the performance-based model (Passive accelerated scenario) savings of 3,799 GWh in 2030, which is savings of 81% compared to the BAU energy use in the existing buildings. The resulting CO_2 emission reductions account for 765 kt CO_2 emissions.

The new construction can potentially realize 763 GWh of energy savings in 2030, which is equal to 62% of energy savings compared to BAU energy use in new construction. This savings corresponds to reduction of 151 kt CO_2 emissions.

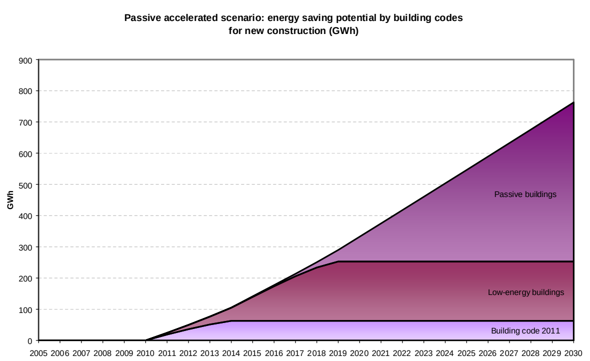
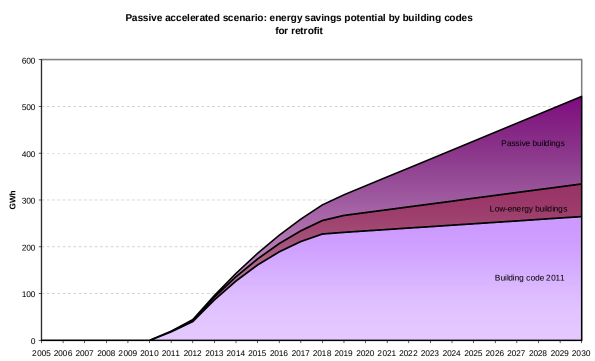
The existing buildings contribute with majority (83%) of the energy savings and CO_2 reduction potential in the public building sector (Figure xx). This can be assigned to the assumed accelerated rate of retrofit, as well as to the relatively low new construction rate in this sector.



Potential by building standards

Although the most promising in terms of specific energy savings (per unit of floor area) is the passive house standard, it is the Building code 2011 which can bring the largest total potential in the existing buildings (built until 1990) (Figure 9). This is due to the fact that the retrofit is accelerated and the phase-in of the high-performance standards (passive and low-energy) is gradual, and thus, majority of the buildings are retrofitted to the level of 2011 Building code in the first years of the mitigation action. This large number of buildings remains in the building stock over the projection period and thus contributes to the total potential by largest share.

Figure 1 Contribution of building codes to energy savings for new construction (9.a) and retrofit (9.b), Passive accelerated

Figure 9.a New construction	**Figure 9.b Retrofit**
	

Cost effectiveness

The results of the cost-effectiveness analysis under the Passive accelerated scenario in the performance-based model show that the social buildings are the most cost-effective building types for both new construction and retrofit of existing buildings. This is due to their extremely high heating energy requirement. The social buildings are followed by health care and educational buildings, the order of which is different in new construction and retrofit. [why? Because of the different number of buildings – in new and retrofit?]

The least cost-efficient are large administration buildings in both cases (new construction and retrofit). This is due to relatively low heating energy requirement and small number of buildings representing this building type (Figure xx and xx).

Figure xx: CO_2 mitigation potential in terms of the cost of CO_2 reductions for new construction

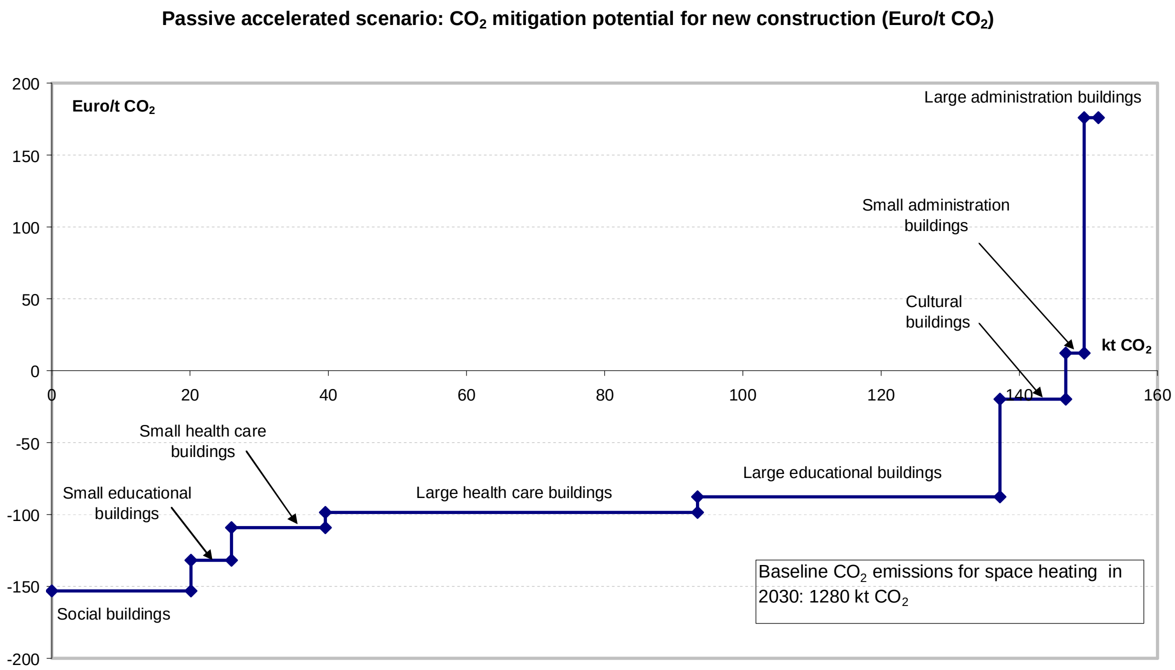


Figure xx: CO_2 mitigation potential in terms of the cost of CO_2 reductions for retrofit of existing buildings

Passive accelerated scenario: CO_2 mitigation potential for retrofit (Euro/t CO_2)

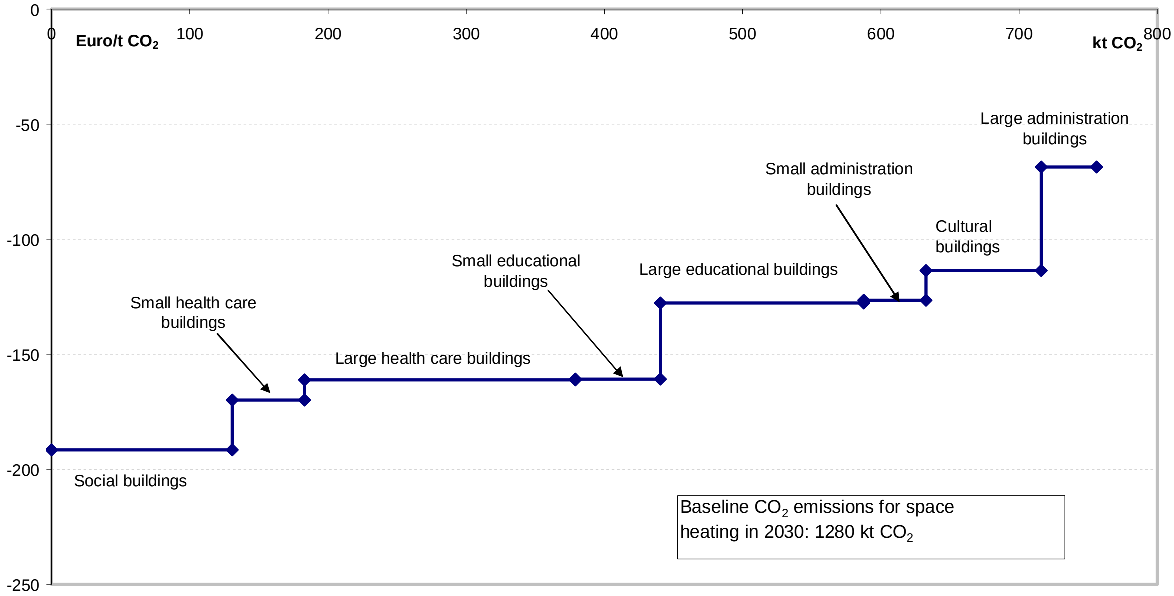


Table xx: CO_2 mitigation and energy saving potential in the Passive active scenario

Building type	CO2 savings in 2030	Cost of mitigated CO2 in 2030	Cost of mitigated CO2 in 2030	Energy savings in 2030	CCE in 2030	CCE in 2030	Total annual Investments in 2030	Total energy cost savings in 2030
	kt CO2/yr.	EUR/tCO2	1000 HUF/tCO2	GWh/yr.	EUR/ kWh	HUF/ kWh	Thousand Euro	Thousan d Euro
Public buildings built until 1990	151			763			24468	27924
Retrofit - Social buildings	131	-192	-57	658	0.02	5	11,092	9,872
Retrofit - Health care small buildings	52	-170	-51	264	0.02	6	119	5,038
Retrofit - health care large buildings	196	-161	-48	987	0.02	7	22,703	20,856
Retrofit - Educational small buildings	61	-161	-48	309	0.02	7	146	5,451
Retrofit - Educational large buildings	147	-128	-38	743	0.03	9	567	20,730
Retrofit - Public administration small buildings	45	-127	-38	225	0.03	9	6,545	5,768
Retrofit - cultural buildings	83	-114	-34	414	0.03	9	12,959	11,298
Retrofit - Public administration large buildings	40	-69	-21	200	0.04	12	8,149	7,182
Public buildings built after 2005	756			3799			62280	86195
New construction - Social buildings	20	-153	-46	101	0	7	2,495	2,544
New construction - Educational small buildings	6	-132	-40	29	0	8	565	777
New construction - Health care small buildings	14	-109	-33	67	0	10	1,561	2,239
New construction - Health care large buildings	54	-99	-30	273	0	11	9,783	9,888
New construction - Educational large buildings	44	-88	-26	221	0	11	6,006	8,257
New construction - Cultural buildings	10	-20	-6	47	0	15	2,381	2,549
New construction - Public administration small buildings	3	12	4	13	0	17	737	733
New construction - public administration large buildings	2	176	53	10	0	27	941	937
Total potential	908			4562			86748	114119

Table xx shows that the retrofit in the social buildings has the lowest cost of CO_2 reductions. Moreover, most of the measures are negative, only the New construction in (both small and large) administration buildings show positive values for the cost of CO2 reduction.

Table xx: CO_2 mitigation and energy saving potential in the Passive active scenario by cost-effectiveness

Measure/Building type	CO2 savings in 2030	Cost of mitigated CO2 in 2030	Cost of mitigated CO2 in 2030	Energy savings in 2030	CCE in 2030	CCE in 2030	Total annual Investments in 2030	Total energy cost savings in 2030
	kt CO2/yr.	EUR/tCO2	1000 HUF/tCO2	GWh/yr.	EUR/kWh	HUF/kWh	Thousand Euro	Thousand Euro
Retrofit - Social buildings	131	-192	-57	658	0.02	5	11,092	9,872
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Total potential	908			4562			86748	114119

The following Table xx shows the mitigation and energy savings potential according to the cost categories.

Table xx: CO_2 mitigation and energy saving potential in the Passive active scenario by cost groups

	CO2 savings		Energy savings		Investment vs. energy cost savings	
	Cumulative CO_2 savings in 2025	% of the baseline CO_2 emissions in 2030	Cumulative energy savings in 2030	% of the baseline final energy in 2030	Cumulative investments 2011-2030	Cumulative energy cost savings 2011-2030
Cost group	kt CO_2/yr.	%	GWh/yr.	%	mil. EURO	mil. EURO
<0	903	70,5%	4538	70,5%		
0-20	3	0,2%	13	0,2%		
20-100	2	0,2%	10	0,2%		

Table xx: Average cost of CO_2 reduction for retrofit and new construction

Investment and energy cost savings

The total investment required under the Passive accelerated scenario is 115 million Euro, while the savings on energy costs reach 250.4 million Euro.

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The assumptions behind the costs for the different building standards and building types are the same as in the Passive 1% scenario (see above). The shares of the building standards on the new construction and retrofitted building stock are also the same for both Passive 1% and Passive accelerated scenarios. The investments are taking into consideration both additional and full costs when compared to the BAU scenario.

The performance-based model is based on the model for the existing buildings and model for the new construction (for buildings built after 2005). The basic assumptions are the following:

New construction (buildings built after 2005):

- BAU: all new construction built under the BAU scenario is assumed to be built according to the Building code of 2006 during the whole projection period. No further improvement is assumed in the building code as due to low enforcement of the current Building code of 2006 in practice (Csoknyai, personal communication, July 2009).
- MIT: In the mitigation scenario it is assumed that by 2020 all new buildings will be built at the passive house standard. New buildings which are not built as passive (until 2020), are assumed to be built according to the Building code 2006. (Thus no low-energy buildings are assumed). This scenario shows the ambitious path requiring a strong regulatory support and enforcement for passive new construction. In the period 2005-2011 all new buildings are built according to the Building code 2006.

Existing buildings (built until 1990):

- BAU: In the BAU scenario, the retrofit rate is 1% of all existing buildings built until 1990. These buildings are retrofitted to the level of Building code 2006.
- MIT: In the mitigation scenario, an accelerated rate of retrofit is assumed. This is done in such a way that it is assumed that all existing buildings are retrofitted by 2030. It is assumed that the buildings are retrofitted to the level of either low-energy or passive house. It is assumed that while in 2011 the share of low-energy and passive standard on the retrofitted stock is equal, by 2030 all retrofitted buildings are reconstructed to the level of passive house.
- In period 2005-2011 all retrofits are performed to the level of Building code 2006.

Table xx: Rate of retrofit required [ale musi byt konzistentne s component based!]

	2005	2010	2015	2020	2025
All existing buildings built before 1990	28920	26591	25140	23709	22349
Retrofit of buildings to achieve goal (cum)	1%	6%	27%	49%	80%
Buildings to be retrofitted (cum)	289	1659	7066	12473	17879
Buildings to be retrofitted (annually)	289	266	1081	1081	1081
Rate of retrofit needed (Total)	**1%**	**1%**	**4%**	**5%**	**5%**
Rate of retrofit 2005-2009 (MIT)	1%	1%	0%	0%	0%
Rate of retrofit 2010 - 2025 (LE and PH)	0%	0%	4%	5%	5%

Table xx: Assumption of gradual phase-in of low-energy and passive standard in the retrofit

	2005	2010	2015	2020	2025
Low-energy buildings	80%	50%	40%	20%	0%
Passive buildings	20%	50%	60%	80%	100%

Graphs:

- Shares of the 2006, low-energy and passive standard on the total building stock

- The same 3 on the total CO2 emissions (MIT)

7.2 Best practices of energy performance levels for space and water heating

To be added (when finished)

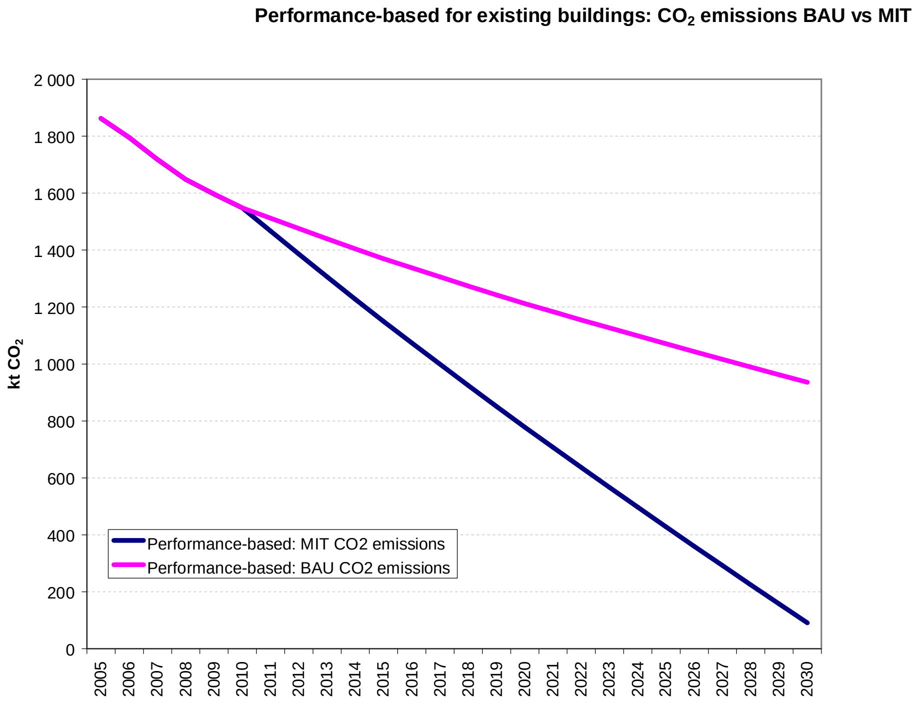
7.3 Economic evaluation of the cost-effectiveness of the performance levels

Graphs of the cost curves – for new construction and for existing buildings

7.4 Analysis and conclusions

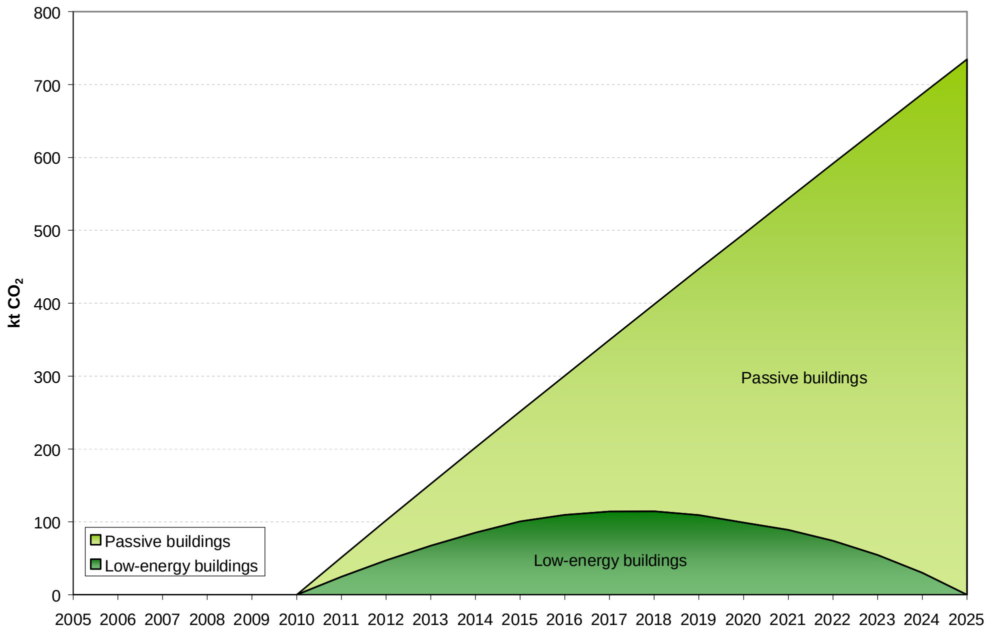
In this section the resulting potential is shown in total and the results are analyzed for both existing and new buildings.

Existing buildings
The total potential in the existing buildings by retrofit to the level of low-energy and passive house standard can reach 735 kt CO_2 emissions (Figure xx).



Most of this potential (Figure xx) is achieved by progressively increasing share of the passive house standard on the stock of annually retrofitted buildings (Table xx).

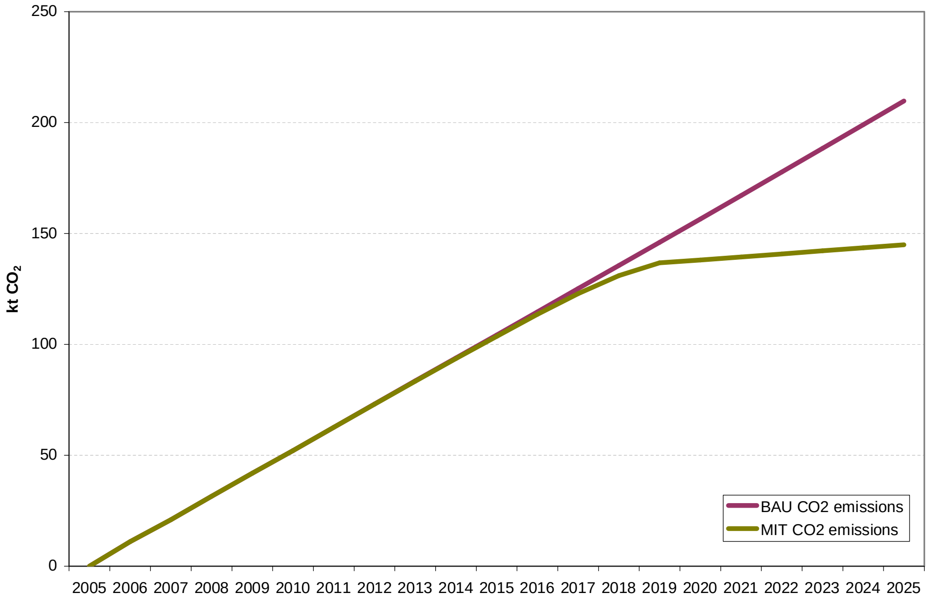
Figure xx: Share of the low-energy and passive standard on the total mitigation potential of retrofit in existing buildings



New construction

The total mitigation potential that can be achieved in 2011-2025 through gradual phase-in of passive house standard in new construction is 226 kt CO_2.

Figure xx: The CO_2 emissions of the new construction in BAU scenario and in mitigation scenario



Xxx

From the start of the mitigation action (2011) until 2020, both passive house and low-energy buildings are assumed to be built. It is assumed that while in 2011

- It is assumed that while in 2011 (start of mitigation action) most of the reconstructions will be conducted to the level of low-energy standard (80% of the annually retrofitted stock), and the rest to the level of passive house standard, by 2025 all retrofits will be performed to the level of passive house standard.

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