Energy savings potential in the Hungarian public buildings for space heating

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Abstract

According to IPCC the largest amount of cost-effective mitigation potential is in the building sector. Most of the studies, however, focus on the residential sector, and only few on non-residential buildings. This paper describes the results of energy savings and mitigation potential analysis in the Hungarian public sector for space heating. The abatement options include improvement of energy efficiency of building envelope and heating system, heat controls and passive energy standard for new construction. The baseline energy use is based on the results of energy audits collected under UNDP/GEF project for municipal buildings. Energy savings potential is determined using two different approaches. According to the well-established component-based approach more than one third of the 2030 energy use can be reduced cost-effectively which is in line with other studies of this type. The rather new, performance-based analysis shows that 3 times higher total potential can be achieved by gradual phase-in of passive energy standard to both existing and new buildings. Based on this approach, several scenarios are constructed to analyze the impact of different rates of retrofit and performance levels on energy savings, mitigation potential and cost-effectiveness. The study shows that although the rate of retrofit is a significant factor for the total potential, it is even more important to what level of energy performance buildings are built or retrofitted. The study shows that if existing buildings are retrofitted at an accelerated rate only partially, the resulting potential will be only slightly higher than if buildings are retrofitted at natural rate of retrofit to passive energy standard.

Introduction

The impacts of the climate change can be already observed. In order to prevent further and irreversible changes in climate and environment, IPCC recommends to keep the global average surface temperature increase below 2ºC relative to pre-industrial levels, which translates into 50-85% by 2050 compared to current (2000) levels [Box 3.10, 1]. This means that in the short term CO_2 emissions should be reduced by 20-40% by 2020 relative to 1990 levels [Box 13.7, 2]. Therefore, several countries have committed to targets on reducing greenhouse gas emissions and targets on reducing energy consumption as one of the key emitters of CO_2 emissions. The EU has made a commitment to avoid the dangerous climate change and limit the warming of the average surface temperature below 2ºC compared to pre-industrial levels [3]. Within its climate-energy package the EU set a 20% reduction target for its energy consumption by 2020 compared to 1990 [4]. At the same time, energy resources are scarce and the energy prices are increasing due to instability in energy supply. Several countries invest into energy efficiency to improve the energy security for their economies. Moreover, energy efficiency not only decreases the energy costs for the end-users, but also provides several other non-financial co-benefits, such as improved indoor air quality and thermal comfort, increased productivity and other. Although the need for the required emission and energy reductions is large, there is a significant potential for reducing the energy in different sectors of the economy in cost-effective way. Buildings offer especially large potential at zero and negative costs [5].

The main aim of the presented research is to determine the energy savings potential in the public buildings in Hungary. Among the research objectives is to find the optimal pathway towards low-energy, low-carbon economy and to provide insights into the risk of the lock-in effect when buildings are retrofitted to suboptimal level.

The structure of the paper is following: first, the energy savings potential is shown from two different perspectives, and then the results of the scenario analysis, including the lock-in effect is discussed.

Determination of energy savings potential by two approaches

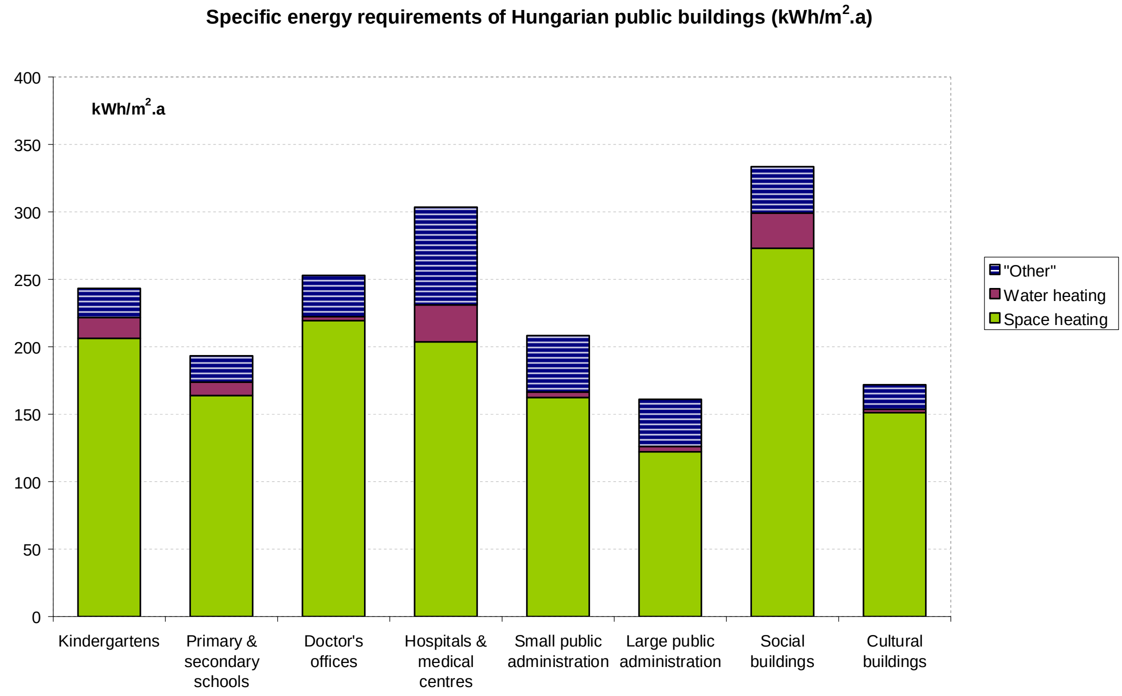
Most of the reviewed studies focusing on building sector use bottom-up modeling framework (for example [6, 7, 8, 9, 10,11]. These studies rely on the component-based approach which calculates the total energy savings potential based on the potentials of the improved individual building components. Although this approach is by now well-established in the area, it is often criticized for not considering energy savings potential from the holistic point of view. Holistic point of view means that all systems in the building are considered together, result of which is that the building as a whole is treated as a system itself. This can be done through integrated design - "a process in which all of the design variables that affect one another are considered together and resolved in an optimal fashion" (Lewis 2004 cited in 12).
A holistically-oriented alternative is performance-based approach, which has been already used in building codes in several countries and is increasingly popular – several countries have published their plans to implement some performance based building standards in the future. [13, 14] have calculated the energy savings that can be achieved by applying these performance standards in several countries by using a simple performance-based model for new buildings. The current study uses bottom-up modeling framework with both component-based and performance-based approach for both existing and new buildings.

While the component-based approach looks at the energy savings achieved by the individual building components, the performance-based approach considers the building as a whole. The component-based approach shows the cost-effectiveness of the individual measures. On the other hand, the performance-based model determines the potential on the basis of the energy performance of the building and compares cost-effectiveness in different building types.

Both approaches use the same building stock projections, building typology and specific heating energy requirements for the existing buildings (built until 1990). Hungarian public buildings are divided into eight main building types based on their function and size: small educational buildings (kindergartens and nurseries), large educational buildings (primary, secondary and tertiary educational buildings), small health care buildings (doctor's offices and ambulance stations), large health care buildings (hospitals, medical centers etc.), small and large public administration buildings, social buildings (homes for elderly, orphanages), cultural buildings (museums, community centers). The building stock for year 2005 is based on publications and online database of the Hungarian Central Statistical Office [15, 16]. The future building stock is projected based on relevant historical indicators which vary by subsector, and are usually linked to the population. Among the indicators are number of children in kindergarten per 1000 inhabitants, students in primary, secondary and tertiary education per 1000 inhabitants, number of beds in hospitals per 10,000 inhabitants etc. The building typology is based on the observation of the buildings listed in the energy audits (see below), and the average floor area per building type.

The specific heating energy requirements are based on a sample of energy audits collected from UNDP/GEF municipality project [17] and other sets of audits [18, 19]. The analysis of the energy audits shows that in general the large, multi-storey buildings use less energy than the small, one-storey buildings (Figure 1). This is in line with the premise that compact buildings (buildings with low A/V ratio) have a better energy performance. This premise, however does not hold for small and large health care buildings – high average daily temperatures and long working hours offset the low (suitable) A/V ratio in the large buildings (hospitals), and the large (unsuitable) A/V ratio in the small health care buildings (doctor's offices, ambulance stations) offsets the relatively low temperatures and shorter working hours.

Figure 1 Specific energy requirements of the Hungarian public buildings (kWh/m^2.a)



Source: UNDP/Energy centre (2008), Nagy (2008), Csoknyai (2008)
Note: 'Other' includes mainly lighting and appliances.

The most energy intensive are social care buildings (homes for elderly, orphanages) due to their high temperatures and day-long working hours. The most efficient in terms of space heating are public administration buildings followed by the large educational buildings, mainly because of the building compactness and shorter working hours.

Based on this common basic framework the business-as-usual (BAU) and mitigation scenarios are constructed under each approach.

Component-based approach

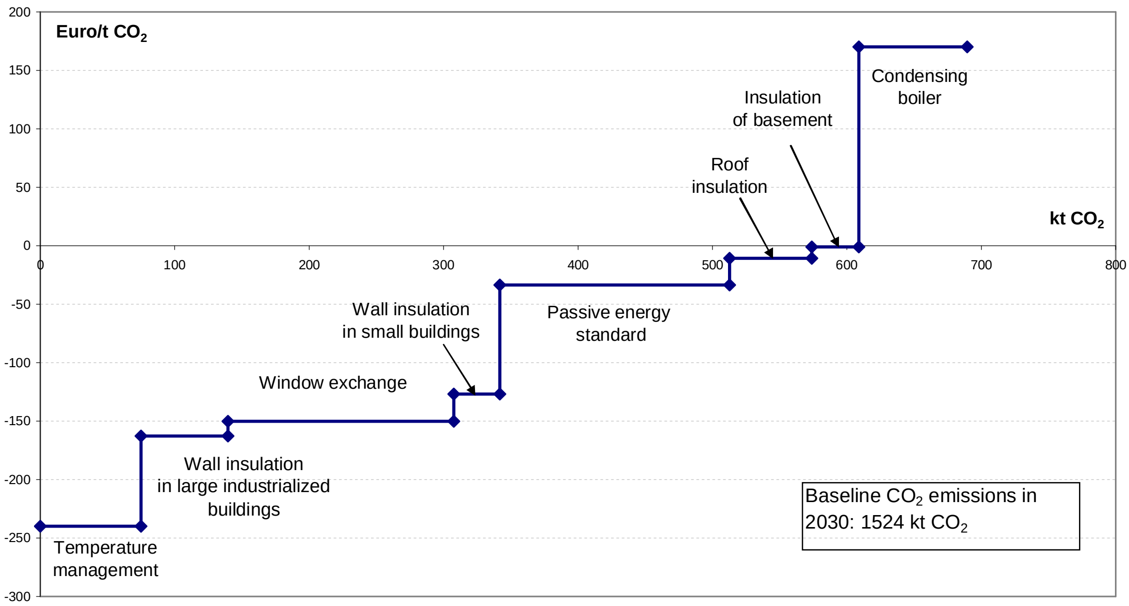
The BAU scenario in the component-based approach is based on the assumption that the considered energy savings measures are applied at natural rate of retrofit [1% p.a., based on 20, 21][1]. These include improving building envelope and replacement of the old boiler by a standard boiler (based on [10], [22] and product catalogues [23]). In the mitigation scenario all existing public buildings are assumed to be retrofitted by 2030. In addition to the BAU measures, temperature management is included and the old boiler is replaced by a more efficient, condensing boiler. New buildings are assumed to become passive by 2020[2] and this part of the model is the same as in the performance-based model.

The component-based approach works on the basis of cost curve method. The advantage of this method is that when adding up the energy saving potentials of the individual measures together, the overlap of the potential of the interrelated measures is avoided. The costs of the different technology

[1] This is also in a line with the assumptions in [20], 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 [21].
[2] This assumption is based on the proposal for the recast of the EPBD directive in time of conducting the research, which requires countries to set targets for share of buildings which become low-carbon or low-energy by 2020 [24].

options are based on [20], [10], product catalogues and consultations [22]. Cost learning is assumed for high-performance windows and passive new construction. The results of the analysis show that about 34% of the baseline 2030 energy use can be reduced cost-effectively. This means that for those measures the energy cost savings offset the initial investment costs over the lifetime of the measure. The most cost-effective measures are temperature management, insulation of the external wall and exchange of windows (Figure 2). According to experts, over 80% of all public buildings are overheated and can lower their average temperature by 2ºC [25]. Installation of a condensing boiler is the least cost-effective option. The results of this method may be understood in such a way that only the most cost-effective measures should be applied. However, only a holistic approach to retrofit including simultaneous insulation of walls, exchange of windows and renovation of heating systems provides better thermal performance and lower risk of fabric damage [26]. Thus, less cost-effective options should be implemented during the retrofit as well, together with the most cost-effective measures, so that full potential of the applied measures can be achieved.

Figure 2 Average supply cost curve for the Hungarian public buildings for space heating



Performance-based approach

The BAU scenario in the performance-based approach assumes that the existing buildings (built until 1990) are retrofitted at the natural rate of retrofit (1% p.a.) either to level of partial retrofit (23% energy savings compared to existing buildings built before 1990; based on [27]) or to the level of the 2006 Building code [28] (50% energy savings relative to the existing buildings, [29]). These assumptions are based on the observation that in Hungary an increasing number of buildings is retrofitted to a low level of retrofit and only part of the renovated buildings are retrofitted to the level of 2006 Building code. However, it is assumed that the share of the 2006 Building code on the total number of retrofitted buildings is increasing over time. All new buildings are assumed to be built according to 2006 Building code.

In the mitigation scenario (referred to as Passive accelerated scenario), three levels of energy building performance are considered – 60kWh/(m^2.a) level referred to as 2011 standard, 30 kWh/(m^2.a) level referred to as low energy standard and 15 kWh/(m^2.a) referred to as the passive energy standard. It is assumed that all existing buildings are retrofitted by 2030. The majority of the retrofitted buildings gradually implement passive energy standard by 2020, while the rest (those which cannot be retrofitted to such high level, such as historical buildings, buildings with unsuitable orientation) constitutes of the 2011 standard and low-energy standard. For the new construction it is assumed that all buildings are built to the level of passive energy standard by 2020, assuming a similar transition through the low energy and 2011 standard as in the retrofit. Technical and cost assumptions are based primarily on [27, 28, 29, 30, 31, 32, 33] and other sources. Technology learning is assumed for all mitigation measures (i.e. 60kWh/m^2, low-energy and passive standard).

The performance-based approach shows that the most cost-effective potential occurs in retrofitting of the social and health care buildings, which belong among the most energy intensive buildings. These are followed by new construction in social and health care sectors (Figure 3 and Figure 4).

Figure 3 CO_2 mitigation potential in terms of the cost of CO_2 reductions for retrofit of existing buildings

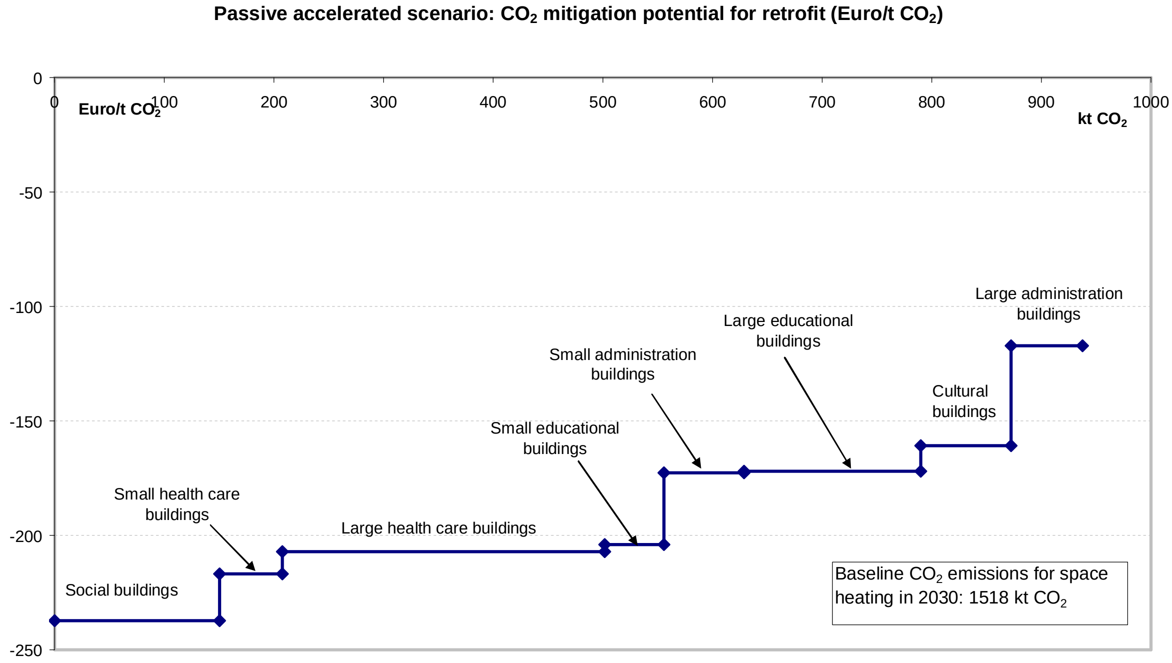
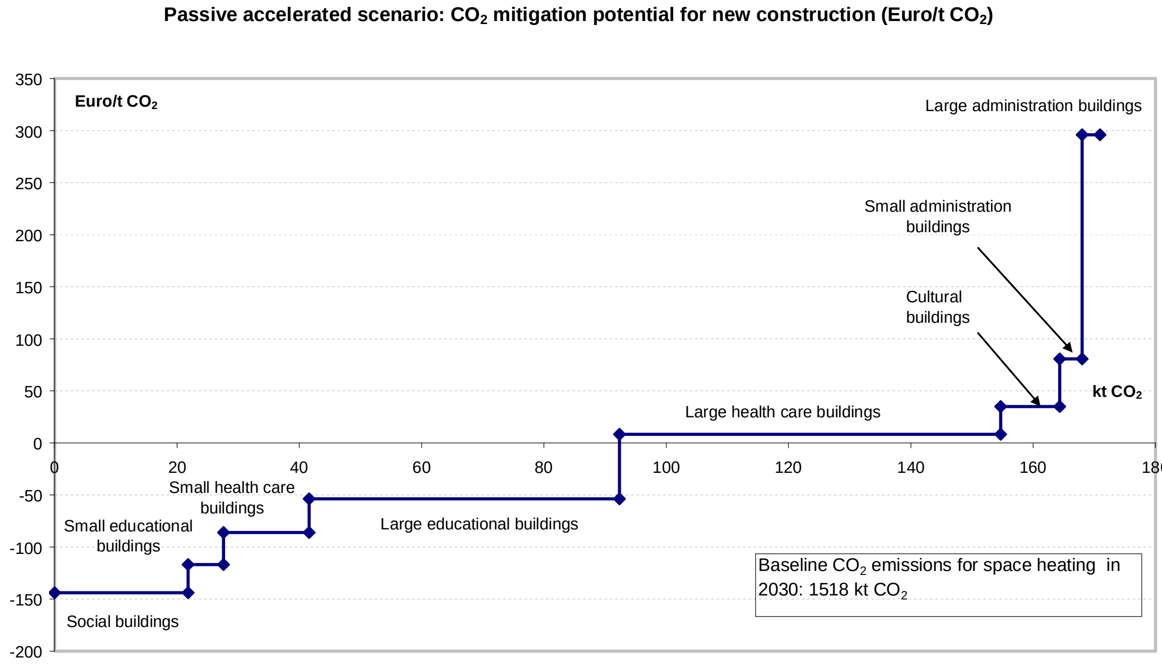


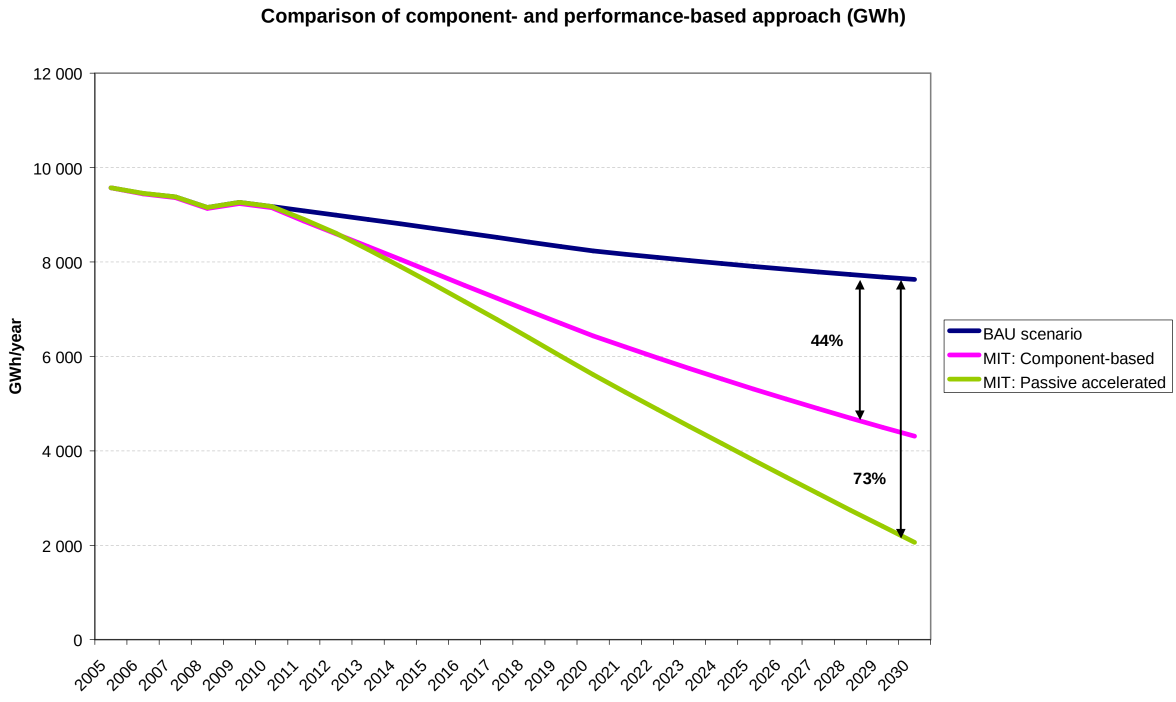
Figure 4 CO_2 mitigation potential in terms of the cost of CO_2 reductions for new construction



Large health care (hospitals and medical centers), large educational (primary, secondary and tertiary education) and social buildings provide the largest potential.

Comparison of the component-based and performance-based approach revealed a large gap between these two approaches. While the component-based approach provides approximately 44% energy savings compared to 2030 baseline, the performance-based approach results in 73% energy savings relative to the baseline in 2030 (Figure 5).

Figure 5 Comparison of the energy saving potential between the component-based and performance-based modeling approach



The difference in the results of the two approaches is mainly due to difference in the build-up of the two modeling approaches. While in the component-based model only one abatement option is applied at one point in time, in the performance-based model several performance levels may be in place in parallel. The difference can also be explained by the differences in setting the BAU scenario for the existing buildings in the two approaches. In the component-based model the BAU is constructed by applying selected individual measures to the frozen efficiency scenario, while the share and technical parameters of these measures are the same over the projection period. In addition, the technical features of the measures in BAU scenario are the same as in the mitigation scenario except for the condensing boilers and temperature management, and only the rate of retrofit is different from the mitigation scenario. However, the BAU scenario of the performance-based approach is constructed based on the assumption of combination of two performance levels (the prevailing partial retrofit and a retrofit with 50% energy savings – the 2006 Building code) - and thus assumes two different technologies. The two approaches are compared on basis of the performance-based BAU scenario (Figure 5).

The analysis showed that the performance-based modeling tools can provide a flexible support tool for the energy and climate policy makers. Its flexibility lies in the possibility to set different performance levels to be implemented with consideration to timing of phase-out of the existing performance levels and gradual phase-in of the new levels. Several performance levels can be set to be implemented to the same building stock in parallel. Although this may be possible in component-based approach as well, it is very labour intensive (especially in Excel-based model) and lacks flexibility which is often needed in decision making in order to see alternative outcomes given varying assumptions. Thanks to this flexibility, the performance-based approach is used further for the scenario analysis.

Scenario analysis – different pathways to low-energy future

The aim of the scenario analysis is to show the risks of mass application of the suboptimal retrofit in the public building sector. Once the buildings are retrofitted to suboptimal level, they will not be renovated again for several next decades until major renovation is needed again (the renovation cycle in Hungary is about 30-50 years, [29]). This way the energy consumption remains on relatively high level until the next renovation and thus, the emissions are locked-in in the current infrastructure for several next decades. The effect of the lock-in effect can be determined as the difference between the most energy efficient scenario and the suboptimal scenario.

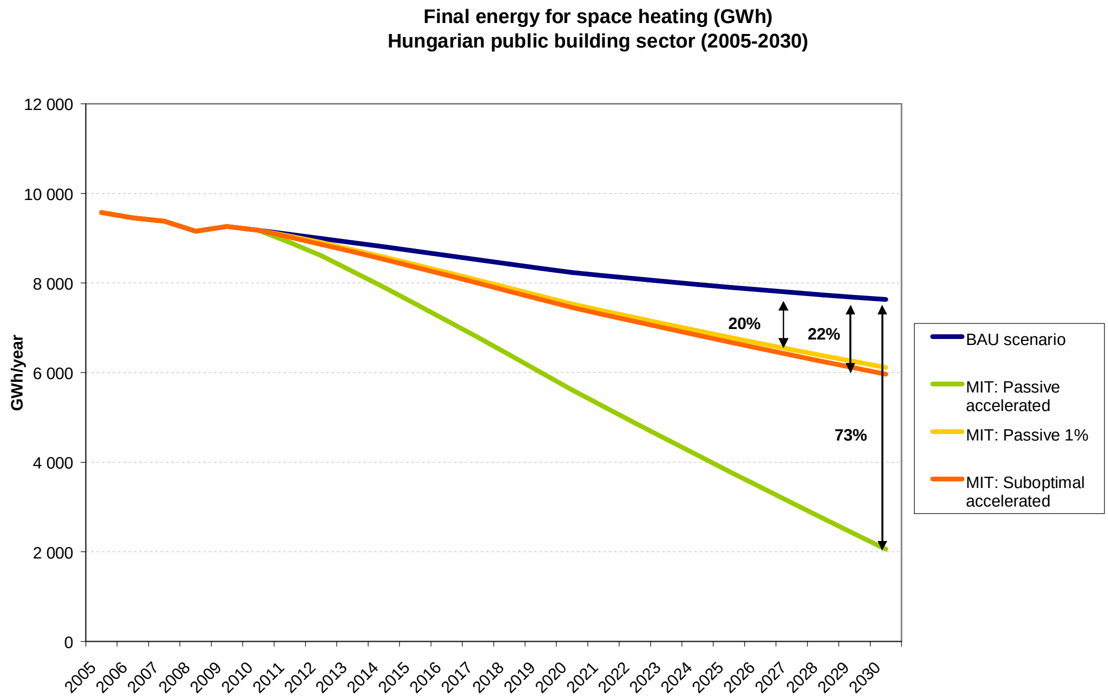
In addition to these two scenarios, another scenario is constructed, which aims to show the effect of the gradual phase-in of the passive energy standard applied to only 1% of the existing building stock per year (natural rate of retrofit). Table 1 shows the main assumptions of the considered scenarios.

Table 1 Basic assumptions for the scenario analysis

	Existing buildings	**New buildings**
BAU scenario	• Natural rate of retrofit (1% p.a.) • Partial retrofit and 2006 Building code	2006 Building code
Passive accelerated	• All existing buildings retrofitted by 2030 • Gradual phase-in of passive energy standard to majority (85%) of the existing building stock by 2020	Gradual phase-in of passive energy standard to the whole building stock by 2020
Passive 1%	• Natural rate of retrofit (1% p.a.) • Gradual phase-in of passive energy standard to majority (85%) of the retrofitted building stock by 2020	Gradual phase-in of passive energy standard to the whole building stock by 2020
Suboptimal accelerated	• All existing buildings retrofitted by 2030 • Partial retrofit only (23% energy savings compared to existing buildings)	Gradual phase-in of passive energy standard to the whole building stock by 2020

The results show that the Passive 1% scenario provides the lowest potential, which is, however, only slightly lower than the Suboptimal accelerated scenario. Passive accelerated scenario provides three times higher potential than either of the two previously mentioned scenarios (Figure 6).

Figure 6 Comparison of BAU and three mitigation scenarios (GWh)



The most important message from the scenario analysis is that the energy savings from the suboptimal scenario are only slightly higher than those of the Passive 1% scenario. This is important taking into consideration the effort which is put into retrofitting of the whole building stock (scaffolding, involvement of the work force), i.e. the fixed costs of the retrofit. On the other hand, in the Passive 1% scenario only 1% of the whole existing building stock is retrofitted annually and it has a similar effect as a large-scale partial retrofit. This means that not only the rate of retrofit is deterministic for the total achievable and cost-effective potential but even more important is the level to which the buildings are retrofitted. When buildings are retrofitted to the suboptimal level and even the whole stock is retrofitted the total effect will be similar as if only the part of the stock is gradually retrofitted to passive energy level.

However, once the optimal level for retrofit is determined and a feasible timing and transition period is decided, this level of retrofit should be applied to the whole existing building stock. In this case the rate of retrofit can make a large difference – by increasing retrofit rate from 1% p.a. to about 4% p.a. more than 3 times higher energy saving potential can be achieved.

The difference between the energy savings potential of the Passive accelerated scenario and the Suboptimal accelerated scenario is about 50%. This means that applying the more ambitious scenario can bring additional 50% energy savings relative to 2030 baseline. Other way round, by applying partial retrofit to the whole building stock by 2030 energy saving potential of 50% (relative to 2030 baseline) can be lost. This difference represents the lock-in effect of the suboptimal scenario – the emissions that are locked in the infrastructure until the next renovation cycle.

Moreover, the cost analysis shows that the Suboptimal accelerated scenario is not even cost-effective, meaning that the energy cost savings do not offset the initial investment for implementation of the applied measures (Table 2). This only supports the argument that partial retrofit should not be applied to the whole building stock, neither that there should be any financial support given for partial retrofit, which would otherwise increase the demand for this kind of retrofit.

Both Passive 1% and Passive accelerated scenarios are cost-effective. Due to higher energy savings achieved in the Passive accelerated scenario the financial savings are much higher than the initial investment as compared to Passive 1% scenario.

Table 2 Energy savings and CO_2 reduction potential in the three mitigation scenarios

	Energy savings			CO_2 emissions			Investment vs. savings	
	Business-as-usual in year 2030	Energy saving potential in year 2030	Energy saving potential in year 2030 (% of BAU)	Business-as-usual 2030	CO_2 mitigation potential 2030	CO_2 mitigation potential 2030 (% of BAU)	Total cumulative investment (2011-2030)	Cumulative energy cost savings (2011-2030)
Scenario/Unit	GWh	GWh	GWh	kt CO_2	kt CO_2	kt CO_2	Billion Euro	Billion Euro
Suboptimal accelerated	7 633	1 667	22%	1 518	331	22%	1.82	0.97
Passive 1%	7 633	1 518	20%	1 518	302	20%	0.84	0.88
Passive accelerated	7 633	5 572	73%	1 518	1 108	73%	2.62	3.24

Conclusions

Buildings provide large cost-effective potential for deep reductions provided proper measures are taken already today. The aim of the paper is to investigate the extent of cost-effective potential in the public buildigns in Hungary and to quantify the so-called „lock-in effect“.

Two modeling approaches are used for calculating of the energy savings potential – a well-established component-based and a new performance-based approach. The results show significant difference between the two which can be mainly explained by the method of implementation of the mitigation measures. The performance-based approach shows significantly higher energy savings potential than the component-based. The performance-based model is suitable for modeling several performance levels (i.e. several types of the same measure) at the same point in time. This feature provides a greater flexibility to set assumptions, such as phase-in and phase-out dates, length of the transition period. On the other hand, the designers and planners have to use more sophisticated tools to decide on the right mix of components so that in total the building as a whole does not exceed the required performance level.

The performance-based model is used to construct several scenarios. The aim of the scenarios is to quantify the lock-in effect of the suboptimal accelerated retrofit of the existing building stock. The results show that the lock-in effect, the difference between the application of passive energy standard and suboptimal level to the whole existing building stock, is up to 50% of the 2030 baseline energy consumption (or almost 2/3 of the total potential). The energy savings potential of the suboptimal retrofit is only slightly higher than if the passive energy standard is gradually phased-in at only 1% annual retrofit rate by 2030. In addition, unlike both of the passive scenarios, Suboptimal accelerated scenario is not cost-effective. The energy costs savings under the Passive accelerated scenario can bring energy savings costs that are several times higher than the investment costs of its implementation, which means greater benefit for the end-user.

The results imply that the retrofit rate is not the most deciding factor for the total and cost-effective potential. More important is the level of performance to which the building is retrofitted. Once the performance is set to the optimal level then the retrofit can be applied to the whole building stock. Subsidies should be applied only to the most ambitious levels, so that the currently applied suboptimal level does not lock-in the high energy use in the existing buildings for several next decades.

Implementation of the Passive accelerated scenario requires a strong commitment in form of a long-term strategy, and the plan to phase-in the passive energy standard for both new and existing buildings has to be announced well in advance so that the construction industry can adjust to these new targets. Although there are already plans to phase-in the near-to-zero energy buildings in the recast of the EPBD directive, this is only valid for the new construction [24]. However, most of the potential occurs in the existing buildings. Moreover, large number of existing buildings in Central Europe needs renovation. This offers opportunity to avoid the lock-in effect if passive retrofit is strongly promoted.
This scenario can be only realized in an environment with a strong enforcement and incentives for the early uptake of low-carbon technology. As the energy efficiency in municipalities is usually hindered by lack of capital for the initial investment, relevant legislation should be passed to overcome these barriers and suitable financial schemes should be offered to the municipalities. Last but not least, in the transition period, architects, planners and designers should be educated in areas such as integrated design, principles of sustainable energy design, use of optimization programs for selecting the right components fitting the required performance levels, as well as life cycle energy and material use and the related emissions.

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