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ENERGY EFFICIENCY POTENTIAL OF PUBLIC EDUCATIONAL AND OFFICE BUILDINGS

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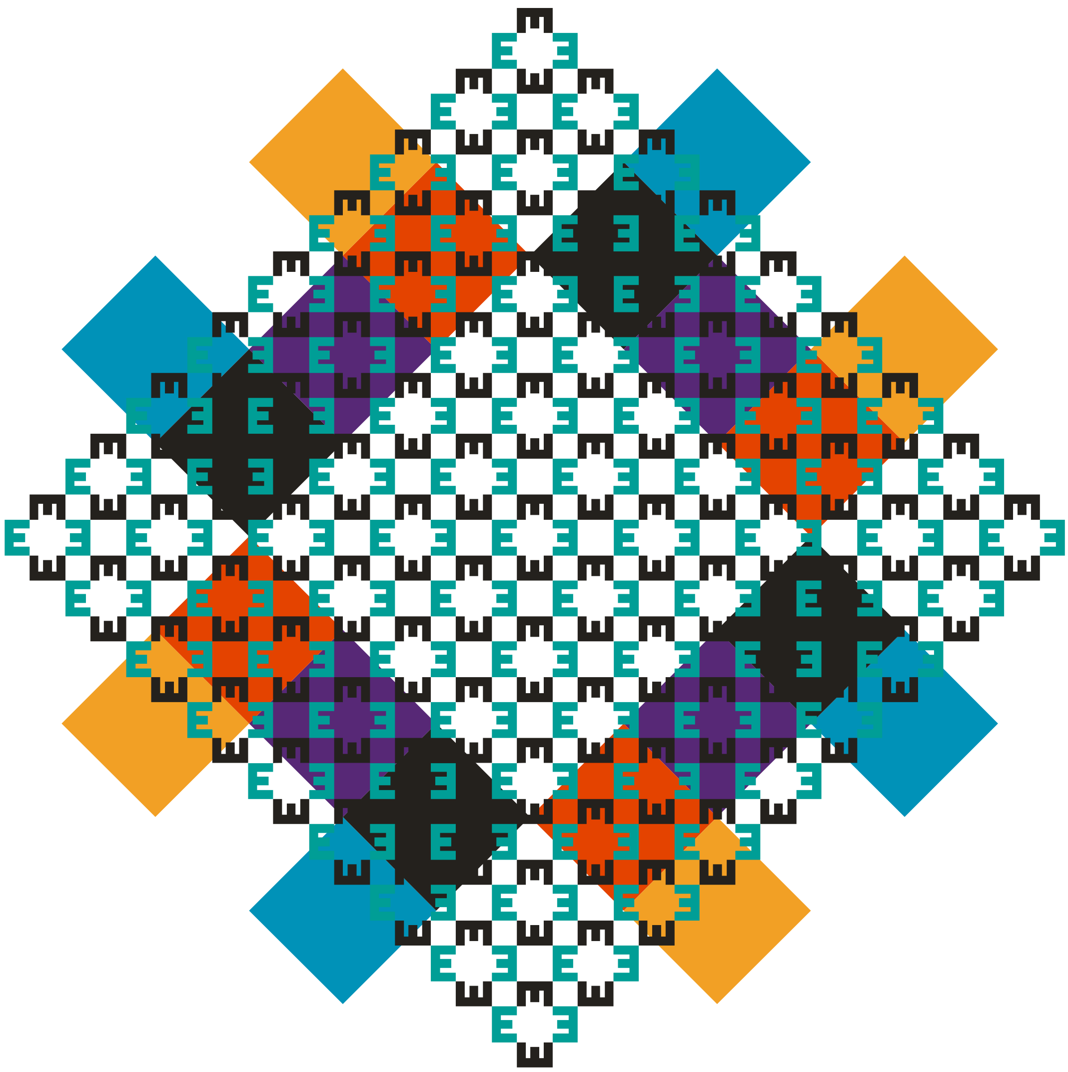

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The research and its background can be found and downloaded from the website of Energiaklub Climate Policy Institute and Applied Communications: www.energiaklub.hu.

The analysis is greatly based on the results of Negajoule2020 research (Energiaklub 2011). The related data can be found on the website www.negajoule.hu .

EXECUTIVE SUMMARY

The European Union has been placing more and more emphasis on improving the energy efficiency of public bodies' buildings. The Directive 2012/27/EU on energy efficiency does not only recommend to the Member States' governments to lead by example and renovate public buildings, but the makes it mandatory for Member States to each year renovate 3%[1] of their buildings owned and occupied by central governmental institutions.

The goal of our analysis and calculations is to provide an overview to energy efficiency stakeholders – professionals, decision makers, and laypersons interested in the subject – on the energy efficiency potential of public bodies' buildings.

For the purpose of this research study, public bodies' buildings are defined as buildings that are part of state-owned assets. According to Act CVI of 2007 on state-owned assets, the Hungarian National Asset Management Inc. (HNAM) distributes and keeps inventory of all building stock used by central budgetary organizations. In this study, we have analyzed data received from HNAM's database on approximately 12,000 buildings. In addition, a worksheet containing records on ministerial buildings provided by the Public Procurement and Supply Directorate General was also used for our calculations.

Since conducting an analysis on all types of public bodies' buildings was not feasible due to the lack of capacity, we have decided to narrow our focus on two types of institutions, namely those performing some type of administrative activity (hereinafter referred to as offices) and educational institutions. This way, the study is also aligned with the content of Energiaklub's analysis on cost-optimal levels of minimum energy performance requirements of buildings in 2012. The Decree No. 7/2006 TNM has identified requirements for energy characteristics of new residential buildings, as well as of the two types of buildings mentioned above – these requirements are also the focus of the cost-optimality calculations. Finally, we have worked with data from a worksheet consisting of approximately 3,500 lines.

In general, the building stock analyzed was old or has been slightly renovated. The buildings' energy consumption and the energy-saving opportunities were expert-based estimates. The technical calculations were based on the methodology and data issued in the TNM Decree and the State Decree No. 176/2008. The energy consumption calculations and potential energy saving calculations cover the following areas: space heating, DHW generation, ventilation, space cooling, and lighting.

According to our findings, the currently unrenovated, state-owned office buildings' total primary energy consumption is approximately 1.5 PJ annually. Improvements to the building envelope (upgrading doors and windows and installing external insulation) could help save approximately 26% on total energy consumption on a national level, which approximately equals to 0.39 PJ primary energy. If a building system upgrade was implemented, in addition to a structural renovation, an additional 0.41 PJ primary energy saving could be achieved, meaning that the primary energy consumption in public bodies' buildings could be reduced to 0.7 PJ, which is more a than 50% reduction.

The ministerial buildings' annual energy use is approximately 0.2 PJ. The refurbishment of the doors and windows and installation of external insulation could reduce this amount by 0.05 PJ. Furthermore, an upgrade to the technical building system would lead to an additional 0.06 PJ reduction in the energy use of ministerial buildings.

The primary energy consumption of school buildings adds up to approximately 2.75 PJ annually. According to our findings, an improvement of the building structure could help reduce the total energy consumption in school buildings by 1.16 PJ, which equals to a more than 40% reduction. An upgrade to the technical building could help save an additional 0.57 PJ in the educational institutions' buildings.

Overall, the energy efficiency potential of the state-owned educational and office buildings analyzed in this study exceeds 3.0 PJ in total. However, we want to note again that only 3500 building with a total heated floor space of ca. 4,3 million square meters were examined out of the 12000 buildings with nearly 8,4 million m^2 included in HNAM's database. Thus, the 3 PJ savings could be further increased by savings in other public buildings, and investments in renewable energy technologies. More research is needed in order to calculate this.

[1] The target rate shall be calculated for buildings with a total useful heated and/or cooled floor area over 500 m (from 2015 the threshold shall be lowered to 250 m).

CONTENTS

1. RESEARCH METHODOLOGY

1.1. Research framework

We have focused our research on existing public bodies' buildings in Hungary. For the purpose of this study, public bodies' buildings are defined as buildings that are part of the state-owned assets[2]. Since conducting an analysis on all types of public bodies' buildings was not feasible due to the lack of our capacity, we have decided to narrow our focus on two types of institutions, namely office buildings and educational institutions. This way, the study is also aligned with the content of Energiaklub's analysis on cost-optimal levels of minimum energy performance requirements of buildings in 2012. The Decree No. 7/2006 (V.24) TNM[3] (hereinafter referred to as TNM Decree) has identified national requirements for energy characteristics of new residential buildings, as well as of the two types of buildings mentioned above— these requirements are also the focus of the cost-optimality calculations. It is our future goal to conduct further research on other types of public buildings, as well.

In order to reduce energy consumption and achieve sustainability, the first step is energy efficiency, since there is no value to using renewable energy sources, if we do so in wasteful manner. Therefore, in this research study, we focus primarily and exclusively on increasing energy efficiency and the energy saving potential of energy-efficient technologies and investments. We do not cover the use of renewable energy sources.

We have conducted calculations of energy consumption and potential energy saving in the following areas: space heating, DHW generation, ventilation, cooling, and lighting.

1.2. Data

According to Act CVI of 2007 on state-owned assets, the owner rights and obligations held over state-owned assets are exercised by the minister responsible for supervising state assets. The minister carries out his duties largely via the Hungarian National Asset Management Inc. (HNAM), the Hungarian Development Bank, and other organizations that were assigned to exercise owner rights according to the Act. HNAM distributes and keeps inventory of all buildings stock used by central budgetary organizations. According to the Act, HNAM shall also keep records of state-owned assets over which it exercises owner rights, and shall provide data on these assets. In this study, we have analyzed data received from HNAM's database on approximately 12,000, educational, office, cultural, social, police buildings, hospitals and health care institutions etc. from all over the country. After screening the data for office buildings and educational institutions we have obtained a worksheet consisting of approximately 3,500 lines.

Within the central budgetary organizations, for the ministries and institutions that are managed under the ministries' jurisdiction (hereinafter referred to as ministries) the Public Procurement and Supply Directorate General (Közbeszerzési és Ellátási Főigazgatóság, hereinafter referred to as KEF) has a significant role. KEF was created based on State Decree No. 272/2003 and among other things, it manages and operates the building stock used by the ministries. As stated in its asset management agreement with HNAM, KEF also performs asset management activities. According KEF's deed of foundation, it assumes the following responsibilities in relation to buildings assigned for ministerial use: asset management, record keeping, operations, maintenance, renovation, as well as public works planning, contracting and maintenance.

KEF has provided data for our research on 21 institutions, in addition to the data received from HNAM. Although, the HNMV database also contains the records stored in KEF's database, during our analysis we have performed separate calculations for the buildings managed by KEF. Our goal was to place a special emphasis on the ministerial buildings in order to underline the importance of the state's role to lead by example.

1.3. Technical calculations

For the calculations, we used the methodology and data outlined in the TNM Decree and State Decree No. 176/ 2008[4]. We should emphasize, that this methodology is theoretical, hence the calculated values and the actual energy consumption may differ (e.g. the average temperature in public bodies' buildings is typically not 20 °C). Nevertheless, the methodology outlined in TNM Decree can be successfully applied towards modeling calculations.

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[2] Act CVI of 2007 on state-owned assets

[3] Decree No 7/2006 (V. 24.) TNM on the energy characteristics of buildings

[4] State Decree No. 176/2008 (VI. 30.) on the certification of energetic characteristics of buildings

2. PUBLIC BODIES' BUILDING STOCK

2.1. Office buildings

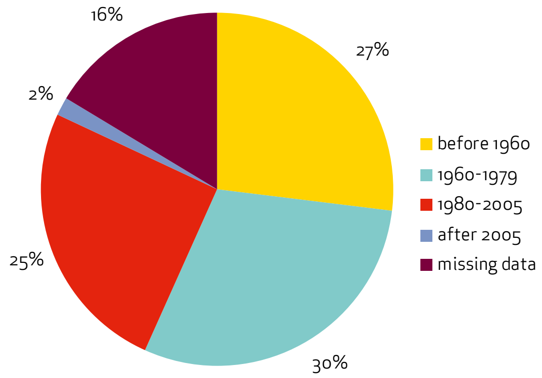
2.1.1. Number and size of buildings

The data provided by HNAM lists 2,300 offices (after subtracting the number of buildings managed by KEF). The average size of an office building is 988 m^2, and the total heated floor space is close to 2 million square meters.

The heated net floor space of the 21 institutions maintained by KEF (mainly ministerial buildings) is 13,500 m^2 on average. The total area of all ministerial buildings is nearly 285,000 m^2, hence the size of these institutions is quite large.

2.1.2. Age and material of buildings

The state-owned buildings stock, similarly to the housing stock, is rather old. Only 2% of them were built during the past 5-7 years, therefore meet the current energy performance requirements, and 57% were built before 1980.

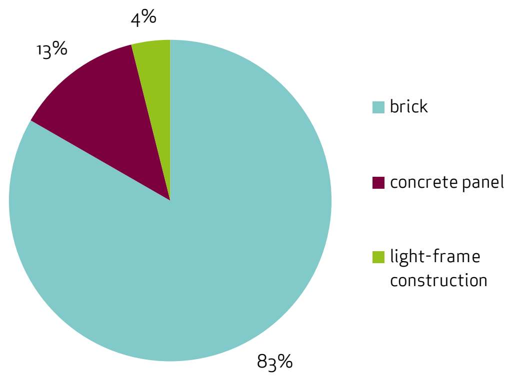


Source: HNAM

Figure 1. Breakdown of state-owned office buildings by construction year

After conducting a separate analysis on ministerial buildings, the outcome was similar. More than half of the buildings were built before 1960, one-fourth were built between 1960 and 1980, and none were built after 2005.

The majority of state buildings were built of brick, and the number of concrete panel constructions is also significant.



Source: HNAM

Figure 2. Breakdown of state-owned office buildings by material

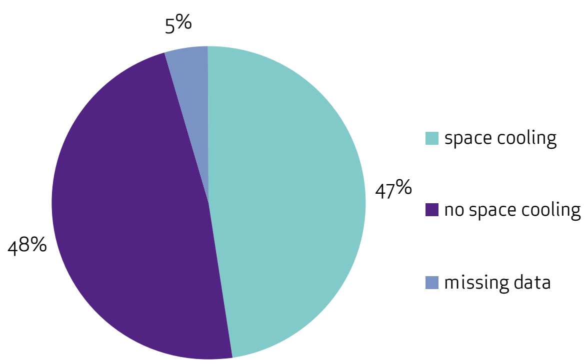
The results were alike for the ministerial buildings, where 14% of them were made of concrete panel constructions and the rest were built from brick.

2.1.3. Technical building system

Unfortunately, the information in the HNAM database on the current heating and hot water generation systems used in the institutions is ambiguous. Although, the spreadsheet lists the annual energy consumption data broken down by energy sources, which would allow us to make assumptions on the heating system used, however the information is missing for about half of the buildings. Therefore, we are unable to draw appropriate conclusions.

The buildings maintained by KEF, however, contain sufficient data according to which 86% of the ministerial buildings use a gas boiler to generate heat and the rest is supplied by district heating.

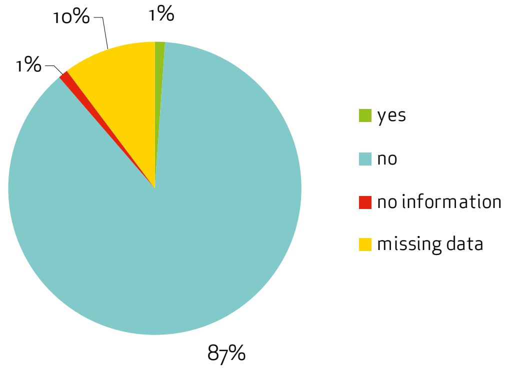
It is worth mentioning, that nearly one-half of the state office buildings use space cooling.



Source: HNAM

Figure 3. Breakdown of state-owned office buildings by use of air conditioning

According to the data, renewable energy sources are used only in a very small fraction of the buildings.

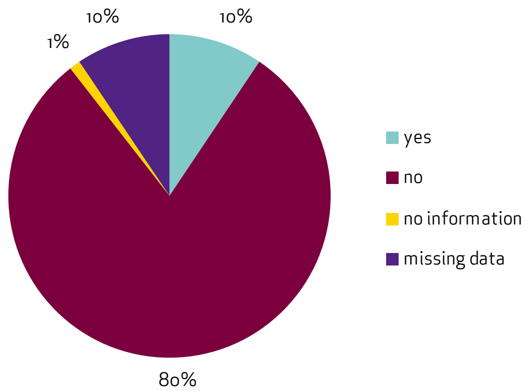


Source: HNAM

Figure 4. Use of renewable energy sources in state-owned office buildings

2.1.4. Buildings' condition and previous refurbishment

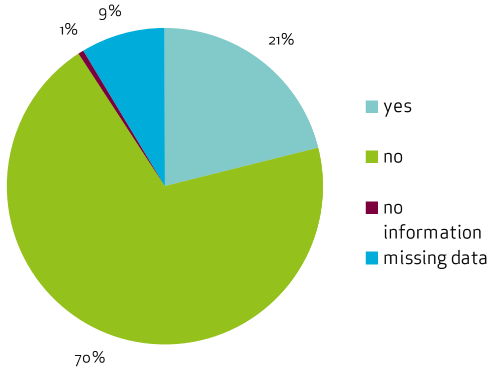
According to the analysis, the facades were retrofitted using insulation only in 10% of the state buildings. The roof and the attic slab were insulated in 9% of the buildings and the perimeter slab was insulated in 2%.



Source: HNAM

Figure 5. External facade insulation in state-owned office buildings

A larger percentage, one-fifth of the institutions, upgraded their doors and windows.

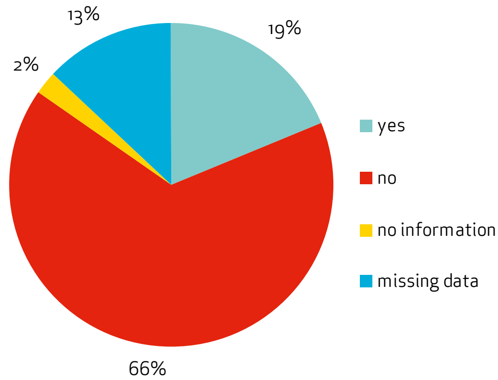


Source: HNAM

Figure 6. Doors and windows upgraded in state-owned office buildings

According to the data provided by KEF, external insulation was not installed on any of the ministerial buildings and only two of them upgraded their doors and windows.

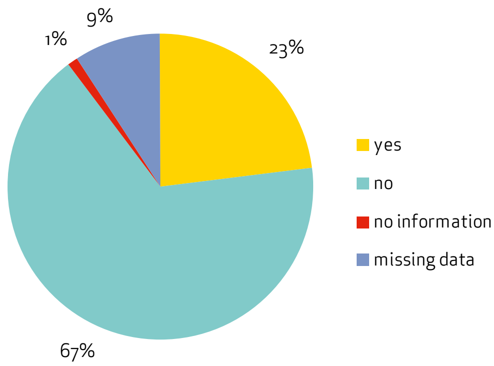
The HNAM data shows, that the boilers were upgraded in one-fifth of the state buildings and somewhat less than that (17%) made an upgrade to their heat rejection system (e.g. radiators) and implemented thermostatic valves.



Source: HNAM

Figure 7. Boiler upgrade in state-owned office buildings

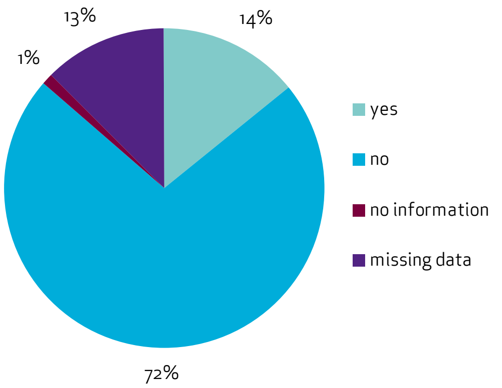
Improvements to the lighting system were made in almost one-fourth of the office buildings, so far.



Source: HNAM

Figure 8. Improvements made to the lighting system in state-owned office buildings

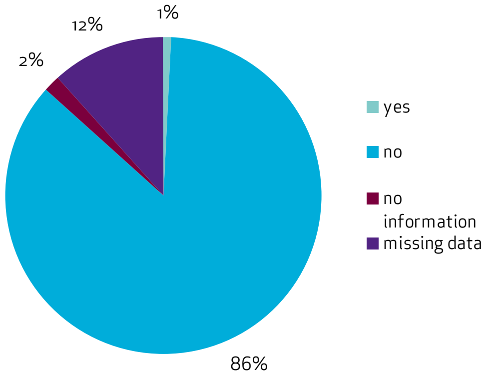
According to the data provided by HNAM, the air-conditioning system was reconstructed in 14% of the buildings until now.



Source: HNAM

Figure 9. Reconstruction of the air condition system in state-owned office buildings

The implementation of heat recovery ventilation is not a commonly used method in state buildings. During the past year, heat recovery ventilation was implemented only in 1% of the institutions.

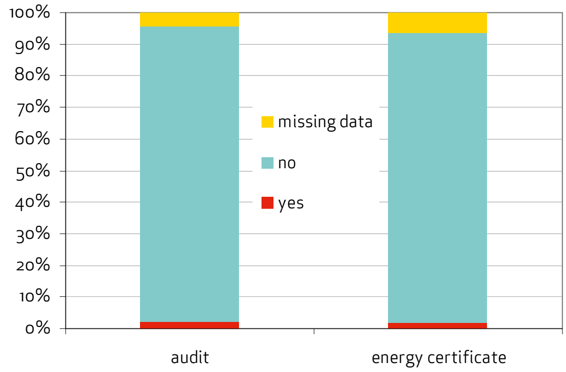


Source: HNAM

Figure 10. Implementation of heat recovery ventilation in state-owned office buildings

2.1.5. Audits, tenders

The information obtained from HNAM's database shows, that only 2% of the institutions had an energy audit and received energy certification.



Source: HNAM

Figure 11. Existence of energy audit and energy certificate in state-owned office buildings

Only 3% of the institutions submitted a tender application of some sort to increase energy efficiency.

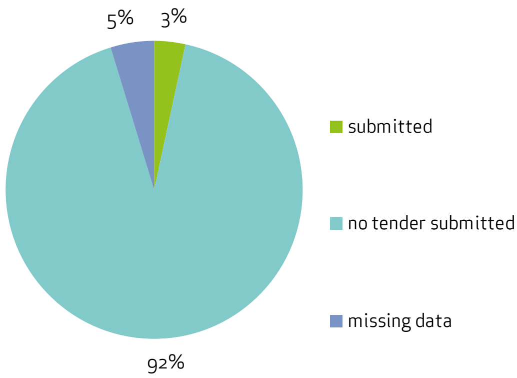


Figure 12. Tenders submitted for energy rationalization in state-owned office buildings

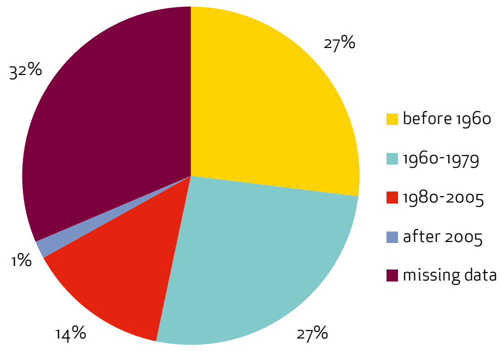
2.2. Educational institutions

2.2.1. Number and size of buildings

The HNAM database contains records on 1,243 educational institutions (including kindergartens and nurseries). The average size of an institution is 2040 square meters, however there is a difference in the average size of brick and concrete panel buildings, for example. While the total heated net floor space is 1,800 m^2 on average in brick buildings, it is 5,300 m^2 in concrete panel buildings.

2.2.2. Age and material of buildings

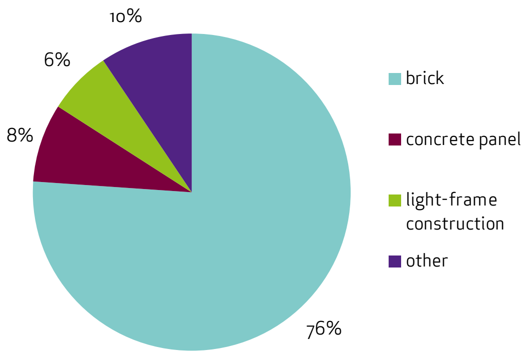
Similarly to the office buildings, the building stock of educational institutions is also relatively old, however it should be noted, that there was no data available on the construction date in the database for about one-third of the buildings.



Source: HNAM

Figure 13. Breakdown of state-owned educational buildings by construction year

Two-thirds of the educational institutions were built of brick and a significantly smaller percentage was built using concrete panels and light-frame structures.

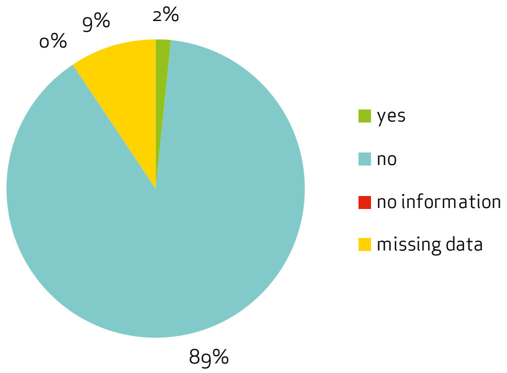


Source: HNAM

Figure 14. Breakdown of state-owned educational institutions by building material

2.2.3. Technical building system

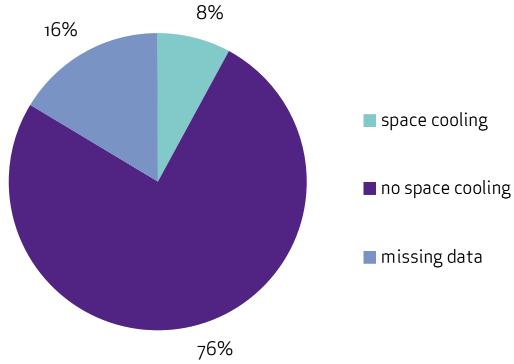
Unfortunately, there was no data available on the heating systems used in school buildings. The data on energy consumption was also missing for about three-fourth of the buildings. We found more information about the use of renewable energy sources, where 2% of the educational institutions have some type of technology using renewable energy source.



Source: HNAM

Figure 15. Use of renewable energy sources in state-owned educational institutions

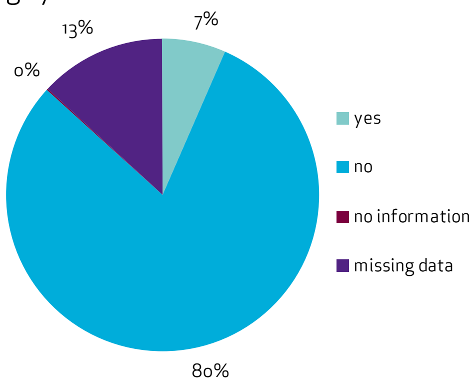
According to the data, a low percentage (only 8%) of the educational institutions uses space cooling.



Source: HNAM

Figure 16. State-owned educational institutions by use of air conditioning

The air conditioning system has been reconstructed in 7% of the buildings, which means in almost all air-conditioned institutions. It should be noted, that it was not clear from the data what the respondents meant by reconstruction – either the implementation of a new system or an upgrade to an existing system.

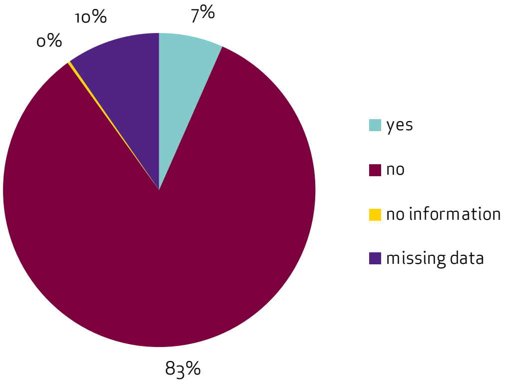


Source: HNAM

Figure 17. Reconstruction of the air condition system in state-owned educational buildings

2.2.4. Buildings' condition and previous refurbishment

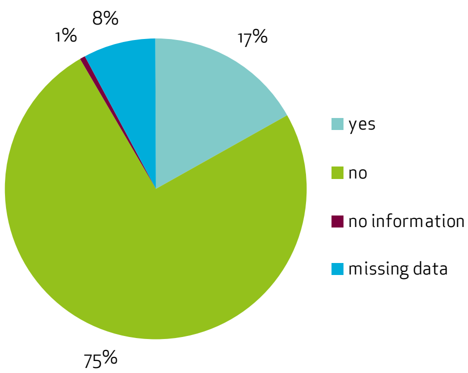
In the last decade, 7% of the educational institutions listed in the HNAM database had their facades retrofitted using insulation. The proportion of buildings that carried out attic slab and roof insulation was similar (8%) and only 2% insulated the perimeter slab.



Source: HNAM

Figure 18. Use of external facade insulation in state-owned educational institutions

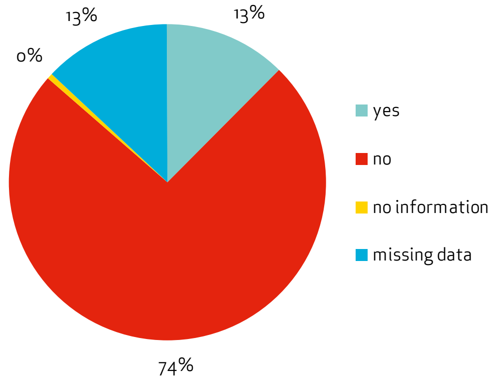
In the educational institutions the percentage of door and window refurbishment was greater, than that of the insulation installed, yet still, in three-fourths of the buildings the doors and windows are old, and probably inefficient.



Source: HNAM

Figure 19. Replacement of doors and windows in state-owned educational institutions

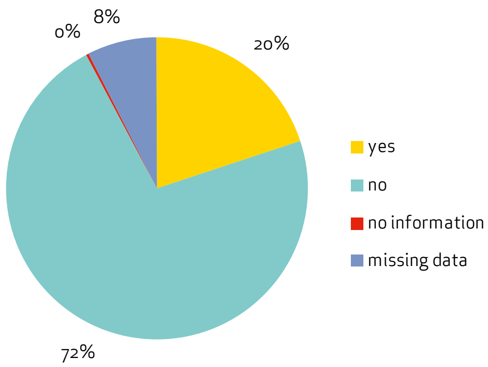
The boiler was replaced in 13% of the educational institutions. The heat rejection system was modernized and regulation was created in 15-16% of the buildings.



Source: HNAM

Figure 20. Boiler upgrade in state-owned educational institutions

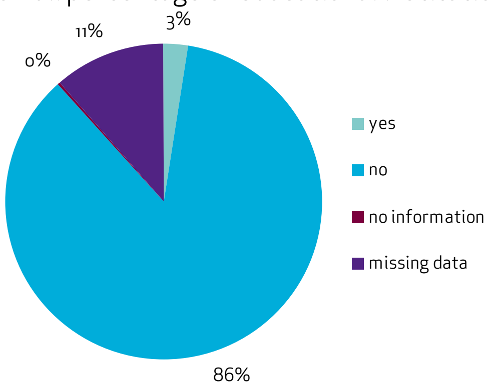
During the past 10 years, one-fifth of the institutions made improvements to their lighting system.



Source: HNAM

Figure 21. Improvements made to the lighting system in state-owned educational institutions

Heat recovery ventilation was implemented in a very small percentage of educational institutions.

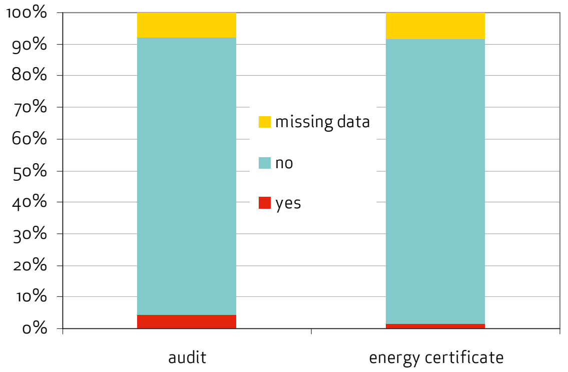


Source: HNAM

Figure 22. Implementation of heat recovery ventilation in state-owned educational buildings

2.2.5. Audits, tenders

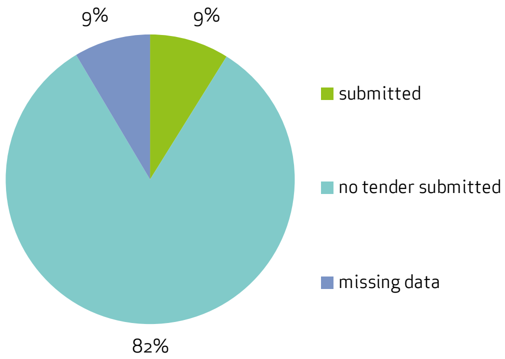
According to the data, an energy audit was conducted in 5% of the educational buildings, however only 1% of them received energy certification.



Source: HNAM

Figure 23. Energy audit and energy certification in state-owned educational institutions

Nine % of the institutions have previously submitted some type of an energy rationalization tender application.



Source: HNAM

Figure 24. Tenders submitted for energy rationalization in state-owned educational institutions

3. ENERGY CONSUMPTION

3.1. Office buildings

As we have noted earlier, the HNAM database does not contain sufficient data on energy consumption, therefore the current building stock's energy consumption can be defined only as an expert-based estimate.

As we have shown in the previous section, the state-owned office buildings were typically built of brick, several decades ago. For our calculations, we considered the following main heat transfer coefficients to determine the initial energy consumption of the buildings:

Heat transfer coefficient – initial state	W/m²K
Facade wall	1.27
Attic slab	0.36
Wooden doors and windows	3.2
Metal doors and windows	4.2

We made the calculations using a constant temperature gas boiler without space cooling or ventilation technology.

According to the calculations[5], similar office buildings without improvements to their building envelope, in theory, typically use 200-210 kWh/m energy annually. This amount of primary energy consumption is necessary in order to heat 1 square meter of office space up to 20 °C under the given weather conditions, generate hot water, and operate the various technical building systems (lighting, ventilation, etc.). Unfortunately, the buildings' geometry (floor plan, number of stories etc.) can not be defined based on the data provided, so we determined an approximate, average value.

The institutions, which had some type of refurbishment, have a lower theoretical energy consumption, than the value stated above. This was taken into consideration when performing the calculations for the actual buildings and the theoretical consumption value was adjusted as described in section 5.1 of this study.

After that, the consumption data was multiplied by the floor area of the building (where this information was missing we used data for the average size office for our estimates), and the

[5] Cost-optimal levels of minimum energy performance requirements of buildings, Energiaklub, 2012

numbers calculated were added up for all office buildings. According to the results, the annual primary energy consumption of office buildings contained in the HNAM database was approximately 1.5 PJ. It must be emphasized again, that this is a theoretical value. The actual consumption data depends on the actual building use (temperature inside the building, opening hours etc.) and it is much likely to differ from the theoretical value.

The actual consumption data of buildings managed by KEF (mainly ministerial buildings) was available for the year 2011. According to the numbers, the 21 institutions' final energy consumption was over 61 million kWh (0.22 PJ) energy per year. The main energy carrier consumed was gas (more than 4 million m^3, which approximately equals to 38.5 million kWh).

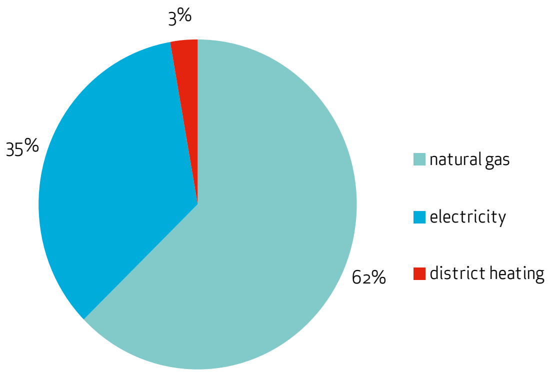


Figure 25. The final energy consumption data of buildings managed by KEF by energy carriers

The electricity and district heating consumption values were multiplied by the conversion factor set in the TNM Decree. As a result, the primary energy consumption of the buildings managed by KEF was 0.34 PJ. After performing the same calculation method as for the rest of the office buildings the theoretical primary energy consumption value calculated was 0.2 PJ. This clearly shows the difference between the theoretical and actual consumption.

3.2. Educational institutions

According to the HNAM database, the buildings of educational institutions managed by the state were also built of brick, several decades ago. Since even more energy consumption data were missing from the HNAM database on educational institutions, than on office buildings, in order to estimate current energy, we used the theoretical annual consumption as a basis.

According to the modeling calculations[6] of Energiaklub, the theoretical energy consumption of similar educational buildings without improvements to their buildings shell is typically 330-340 kWh/m^2 per year. This value was determined based on the following parameters:

Heat transfer coefficient – initial state	W/m^2K
Facade wall	1.42
Attic slab	0.96
Perimeter slab	1.5
Wooden doors and windows	3.2

The heating system assumed for schools was also a constant temperature gas boiler without space cooling or ventilation technology.

After using the above mentioned parameters and the same methodology as for the office buildings, the theoretical primary energy consumption calculated for state-owned educational buildings before renovation was 2.75 PJ.

[6] Cost-optimal levels of minimum energy performance requirements of buildings, Energiaklub, 2012

4. ENERGY SAVINGS

4.1. Input assumptions

During our calculations, the facade and slab insulations, the door and window upgrades, and the replacement of technical building systems with more up-to-date technologies were all considered as investments that would improve energy efficiency.

For the facade insulation the minimum criteria for the heat transfer coefficient was determined at 0.35 W/m²K or better. For the slab insulations the criteria was that the heat transfer coefficient could not be greater than the current standard requirement for new buildings (0.3 W/m²K). As for the doors and windows, the U value had to be U=1.2 W/m²K to be considered up-to-date, and the data for upgrading doors and window were calculated using this value.

Form the energy efficiency standpoint, installing insulation and upgrading doors and windows simultaneously is considered to be most effective, therefore we have put an emphasis on it. In cases where an investment was made for either one of these upgrades, the energy saving potential of either investment was calculated.

Upgrading the entire technical building system is defined as follows: upgrading the boiler to a condensing boiler and implementing heating control; upgrading the heat rejection system; upgrading the hot water system; upgrading the lighting and implementing a control system; upgrading lamps; and implementing a complete HVAC system with heat recovery ventilation.

4.2. Research findings

4.2.1. Office buildings

According to the modeling calculations performed, a building can move to category 'A' by implementing a complex structural and technical building upgrade. As a result, the theoretical primary energy consumption of these buildings could be reduced to approximately 85 kWh/m per year. The reduction can be achieved as follows:

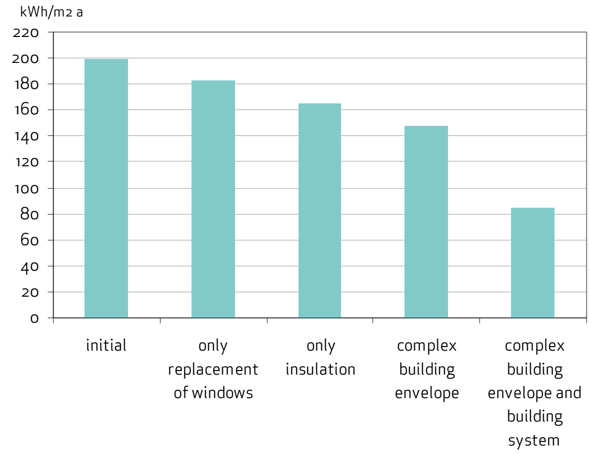


Figure 26. Primary energy consumption of office buildings by the level of the refurbishment

Building shell improvements (door and window upgrade and external insulation) of the buildings listed in HNAM's database could help save 26% of the total current energy consumption on a national level, which approximately equals to 0.39 PJ primary energy. If the above mentioned technical building upgrades were implemented in addition to the structural renovations, a further 0.41 PJ primary energy saving could be achieved. This means that the primary energy consumption in public bodies' buildings could be reduced to 0.7 PJ which is more a than 50% reduction.

After performing separate calculations for the ministerial buildings we can state that an upgrade to the doors and windows and implementation of external insulation could reduce the energy consumption by 0.05 PJ, in other words by one-fourth of the original primary energy use. An upgrade to the technical building system of the ministerial buildings could lead to an additional 0.06 PJ reduction.

4.2.2. Buildings of educational institutions

As a result of a complex upgrade to the buildings of educational institutions the theoretical primary energy consumption could be reduced to 110 kWh/m²a .

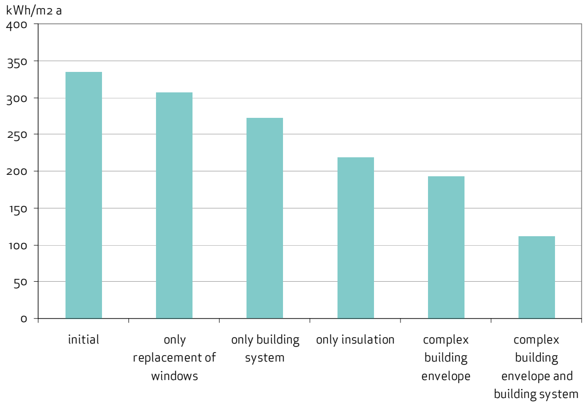


Figure 27. Primary energy consumption of school buildings by the level of upgrade

According to our findings, an improvement to the building structure could help reduce the total energy consumption by approximately 1.16 PJ, which equals to a more than 40% reduction. An upgrade to the technical building in school buildings could help save another 0.57 PJ.

5. CLOSING REMARKS

Summing it up, the energy efficiency potential of the state-owned educational and office buildings analyzed in our study exceeds 3.0 PJ (855 GWh) in total. This could be further increased by savings in other public buildings not examined in this research, and investments in renewable energy technologies. To include all types of public buildings in the calculations, further research is needed, primarily on the average, typical energy consumption of the different types of public institutions.

We make a reference to the study[7] of Non-Profit Limited Liability Company For Quality Control and Innovation in Building which quantifies the 3% target set in the Directive at 11.4 GWh savings per year. Clearly, this number is only a fraction of the actual energy saving potential of state-owned buildings. Since increasing energy efficiency has proven to be the most cost-effective strategy to reduce energy dependence, we recommend that the state should implement a faster paced and a more comprehensive renovation strategy of public bodies' buildings.

[7] Energy efficient refurbishment of central governmental buildings – Preparatory study, Non-Profit Limited Liability Company For Quality Control and Innovation in Building, 19.04.2012

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