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STUDY OF THE BRICK AND STONE BUILDINGS IN TARTU: EPV

Centre for Development Programs (EMI-ECO)
Tallinn
2013

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1. Foreword

This report has been prepared by Hevac Ltd for EMI ECO as a part of the INTERREG IVB program, project Nr.61 “Co2ol Bricks” to determine the energy performance value (EPV from here on) of the brick and stone buildings in Tartu which are located in milieu valuable areas or are part of the architectural heritage.

In accordance to the methodologies used in Estonia, EPV is conveyed in this study by weighted calculation of specific energy consumption of existing buildings and the calculations are based on the energy consumption of the last three years.

19 buildings are included in the analysis, 7 of which are schoolhouses, 8 are other types of buildings and 4 are apartment buildings.

In addition to the EPV the report also studies the heat and electricity consumption of the buildings and compares them to the average characteristics of another 64 buildings in Tartu.

The authors of the report extend their gratitude to the owners of the buildings included in the study, Tartu City Office and Tartu Regional Energy Agency who all helped in gathering the necessary initial data for the study.

2. The main criterion for the choice of buildings

The main criterion for selecting the buildings to be included in the Co$_2$ol Bricks Project was the year of construction (before 1945), and their historical value which does not allow external insulation. In all Cultural Heritage Buildings the external facade must not be altered other than due to renovation, to preserve the value of the building. According to this, 44 buildings were selected for the research.

Not all buildings are made of red bricks, but the restriction in external renovation makes them identical from the point of view of solutions for increasing energy efficiency.

On Figure 1 (below), the total number of buildings selected for research is shown. Unfortunately there were a number of problems in getting the needed data and therefore only 19 (42 %) of them were suitable for use in this study.

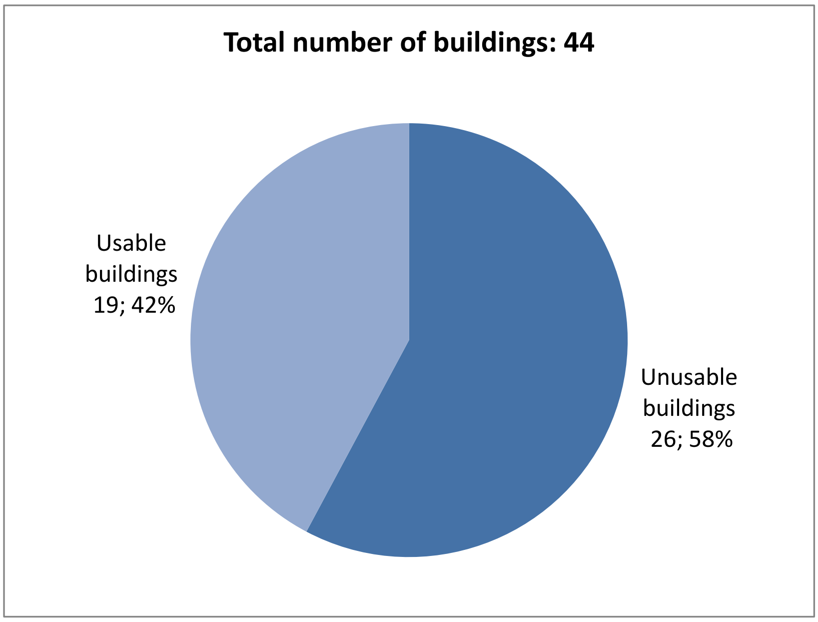

Figure 1: Proportion of usable buildings of the total selection

Some of the issues were the following:

- Not enough data of consumed energies (mostly because of stove heated buildings);
- The buildings were in use infrequently;
- Only part of the building was in use;
- The building was in use only during part of the year;
- The owners lived outside of Estonia and were unreachable.

Of the 19 building included in the analysis, 7 were schoolhouses, 8 were other types of buildings (bureaus, clubs and such) and 4 were apartment buildings.

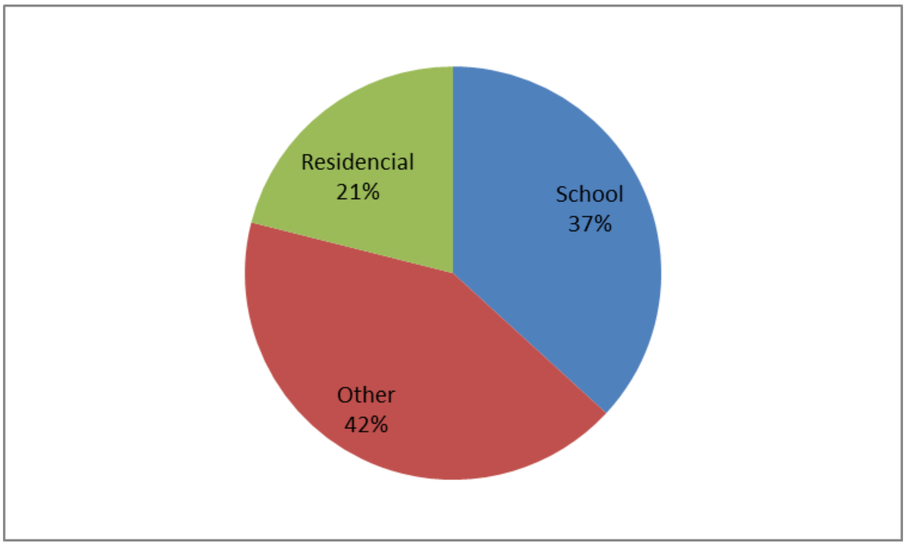

Figure 2: The distribution of the buildings included in the study based on their purpose

The gross heated area of the buildings analyzed is 33 134 m^2.

In Appendix 1 of this report there is an illustrative photograph and characteristic figures to describe the qualities of each building.

3. Attained information

After the preliminary estimation and selection of the 19 buildings, the Forms of Data of Consumed Energies (see Appendix 2) were sent to the users/owners of the buildings. 6 out of 19 Forms were sent back with correct (usable) data. 11 out of 19 Forms were only partly filled or the data was deemed not reliable.

To receive adequate data for all the selected buildings, queries were forwarded to energy distributors Eesti Gaas (natural gas), Tartu Vesi (water) and Fortum (district heating). Additionally, part of the data was received from the survey[1] of the Tartu Regional Energy Agency (TREA from here on). In order to receive data from energy distributors, an authorization of the owner of the building or their representative was required. The owners of some buildings or their representatives refused to grant their permission to supply the information. Some owners only granted the permission on the condition that their house is not directly identifiable in the comparative study.

[1] Monitoring and evaluation of the energy efficiency of municipal buildings of the City of Tartu. Draft report. 2012. Tartu Regional Energy Agency

Estonian EPV evaluation methodology stipulates that the heated area needs to be taken into account when calculating the EPV value. To determine the floor area of a building, information received from the owner, the National Register of Construction Works and the study of TREA was taken into consideration. In cases where there was no data in regards to the heated area of a building, closed net area figures were used in the study.

4. The Principles of Determining Energy Performance Value (EPV)

In Estonia, the energy efficiency of the existing buildings is characterized by specific weighted energy consumption (SWEC from here on).

The calculations to determine SWEC have been specified in the decree nr. 67, 17.12.2008 of the Estonian Ministry of Economic Affairs and Communications.

In this report, the aforementioned decree and the methodology and principles stated therein have been takes as basis when determining SWEC.

To determine the SWEC of existing buildings, the following Principles are used:

- In general the calculations are based on the measured consumption of the last 3 years;
- The heating consumption values are reduced to a normal year with the degree-day method, whereby the balancing temperature is fixed at 17 ^{o}C;
- All consumed types of energy in a building are taken into consideration (heating, ventilation, natural gas, lighting, electrical appliances etc.);
- The arithmetic average values of delivered energies of the observable period (generally 3 years) by energy carrier are calculated;
- The arithmetic average values of supplied energies are multiplied by the weighting factors of the energy carriers which are:
  - district heating 0,9
  - Natural gas 1
  - Electricity 1,5
- The energy consumptions multiplied by the weighting factors are summed up;
- The gross supplied energy consumptions multiplied by the weighting factors are divided by the heated area of the building and the resulting figure is SWEC kWh/(m^2·year). (In the English version of this report this indicator is called energy performance value and the acronym EPV stands for this term).

Thus SWEC incorporates gross supplied energy use, where the energy consumption of all the technical systems is taken into consideration and in addition to that the weighting factors of the energy carriers; essentially we are dealing with a parameter characterizing the primary energy use of a building – the yearly gross consumption of primary energy per heated area of the building.

In Estonia heated area is defined by law as follows: „Heated area is the floor area of rooms, in which the temperature of air during a heating period is not significantly responsive to the changes in the outdoor temperature “.

It is the net floor area of the rooms, meaning the area measured to the internal face of the external walls. The area occupied by walls and partitions is not included when measuring heated area.

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When comparing EPV in Estonia to some other country's EPV, one has to take into account the definition of heated area.

In some countries gross internal area value in those calculations is used including external walls and partitions.

In that case the heated area is considerably larger than in the EPV calculations in Estonia. **The larger the heated area, the smaller the EPV figure if the energy consumption remains the same**.

In this study the following initial data was taken as basis:

- Calculations were based upon the energy consumption of the years 2009, 2010 and 2011
- If natural gas was used as the heat source, then the calorific value used in calculations was 9,3 kWh/m^3 and the efficiency value of the boiler was 0,85
- Where there was no data about the consumption of domestic hot water (DHW), the total water consumption was takes as basis with the consideration that in residential buildings, domestic hot water accounts for 45% of the total water consumption, whereas in other types of buildings that percentage is 20 %. The heat energy of domestic hot water was determined with the presumption that water needs to be heated by 50 ^{o}C degrees
- The following degree days were used to reduce the heating costs to normal year[2]:
    - Normal year 4295;
    - 2011 3884;
    - 2010 4608;
    - 2009 4064.

5. Energy consumption analysis and determining EPV

Some building owners only agreed to take part in the study on the condition that their house is not directly identifiable in the report.

For this reason in the analysis the buildings are anonymous and denoted by a letter and number combination.

The designations are:

Schools	"ED" (Education);
Other buildings	„O" (Other);
Residential buildings	„Res" (Residential).

5.1. EPV analysis

The EPV and energy class of the buildings included in the study are listed in the following table (Table 1).

[2] http://www.kredex.ee/energiatohususest/kraadpaevad-4/

Table 1 EPV and energy class of buildings

Building	EPV, kWh/(m2.a)	Energy class
ED1	185	D
ED2	142	C
ED3	172	D
ED4	169	D
ED5	179	D
ED6	181	D
ED7	131	C
O1	220	E
O2	294	E
O3	247	E
O4	265	F
O5	153	C
O6	265	E
O7	240	C
O8	311	F
Res1	373	G
Res2	334	G
Res3	174	D
Res4	274	F

The buildings analyzed belonged to the following energy classes:

C class 4;
D class 6;
E class 4;
F class 3;
G class 2 buildings.

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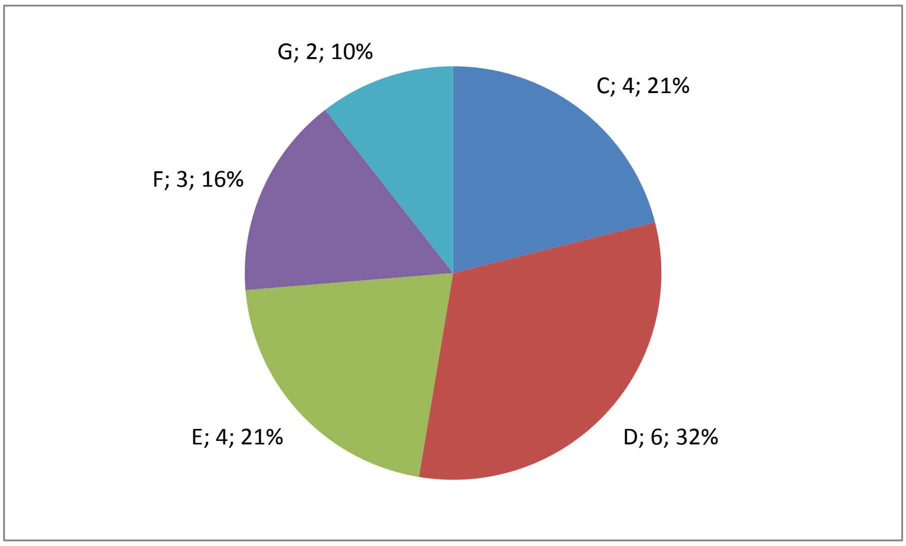

Figure 3: The division of buildings by energy classes.

The following graph (Figure 4) illustrates the EPV values of the buildings.

On the graph, the arithmetic average (277 kWh/(m^{2}·a)), weighted average by net area (193 kWh/(m^{2}·a)) and median (220 kWh/(m^{2}·a)) of EPV of the participating buildings are shown.

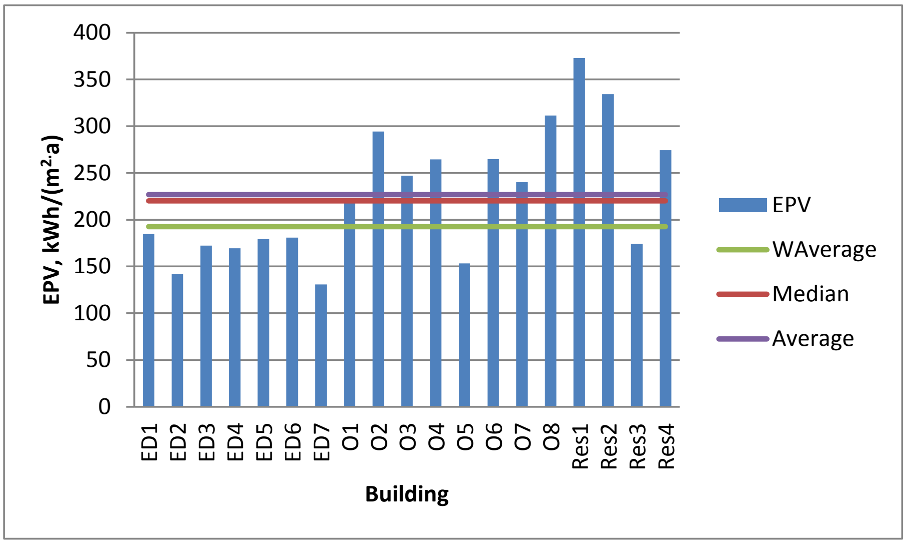

Figure 4: EPV of buildings

The EPV of schools (ED) is lower than average and ranges from 131 to 185 kWh/(m^{2}·a). The EPV of the other types of buildings (O) is a bit higher than average and falls within the range of 153…311 kWh/(m^{2}·a). The EPV of residential buildings (excepting Res3) is higher than average and ranges from 174 to 373 kWh/(m^{2}·a).

TREA has compiled an analysis on 64 municipality buildings in Tartu. That particular analysis also includes some of the brick buildings participating in this study.

The following table (Table 2) brings out the differences in the EPV of the buildings analyzed in the course of the Coolbrick program and the buildings analyzed by TREA.

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Table 2: Comparison of the EPV of brick buildings (CoolBrick) and 64 Tartu buildings (TREA)

Difference indicator	**CoolBrick**	**TREA Study**	**CoolBrick/TREA**	**CoolBrick-TREA**
Average	227	196	1,16	31
Weighted average	193	166	1,16	27
Median	220	179	1,23	41

According the comparison of the EPV averages of the brick buildings (CoolBrick) and the rest of the buildings (TREA), the average EPV of the brick buildings was 16 % higher than the average of Tartu buildings. The average EPV of brick buildings was higher by 27…31 kWh/(m^{2}·a).

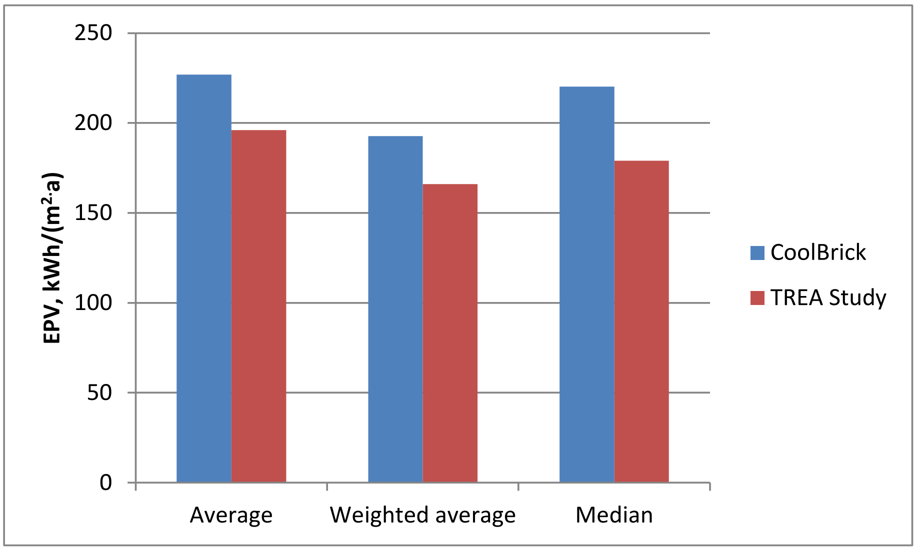

Figure 5: Comparison of the average EPV of brick buildings (CoolBrick) and 64 Tartu buildings (TREA)

EPV is affected by the method of heating. On the following graph (Figure 6), buildings using natural gas as heat source are marked in red. One of the buildings used both gas and district heating as heat source. The EPV of that building is marked in yellow.

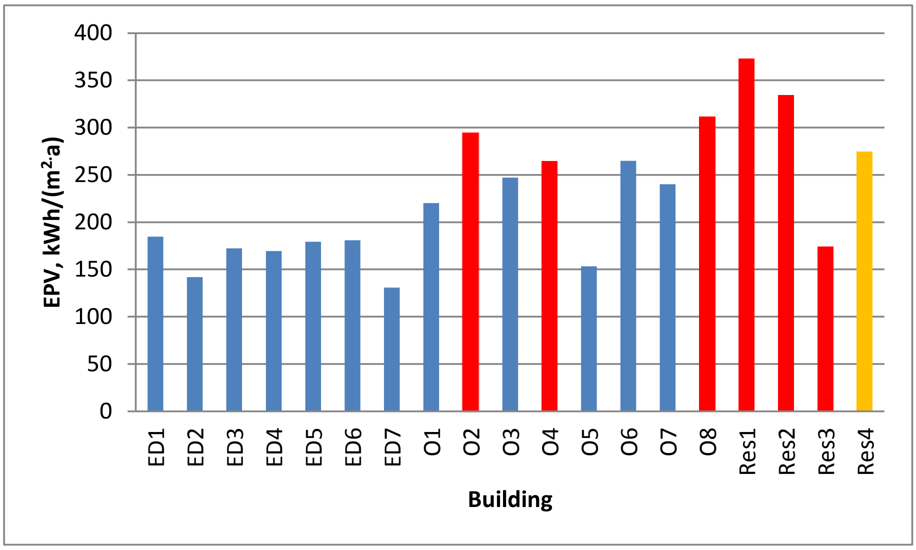

Figure 6: EPV and heat energy source (blue: district heating, red: natural gas, yellow: gas and district heating)

In general the EPV of the buildings heated by natural gas is higher. The following graph (Figure 7) illustrates the division of EPV between heating, domestic hot water and electricity.

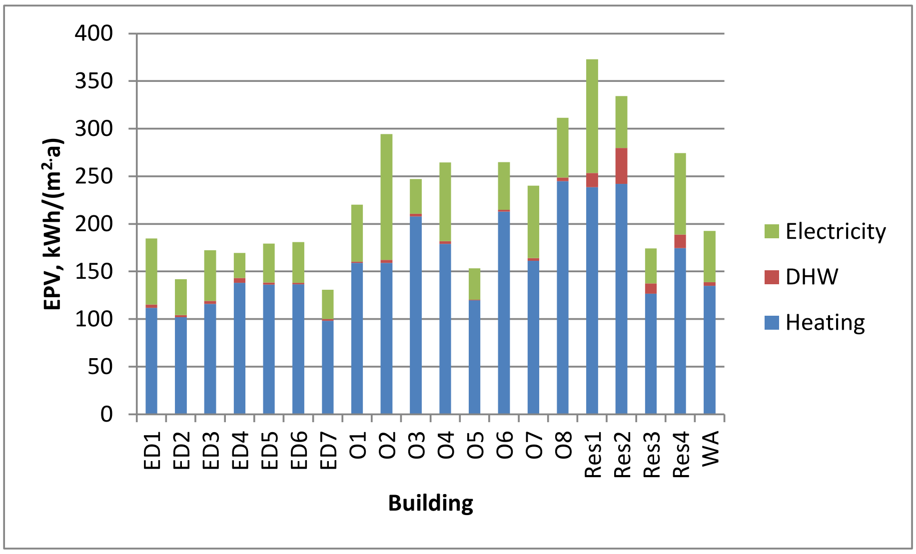

Figure 7: Division of EPV between heating, domestic hot water (DHW) and electricity

Heating makes up an essential part of the EPV of the buildings.

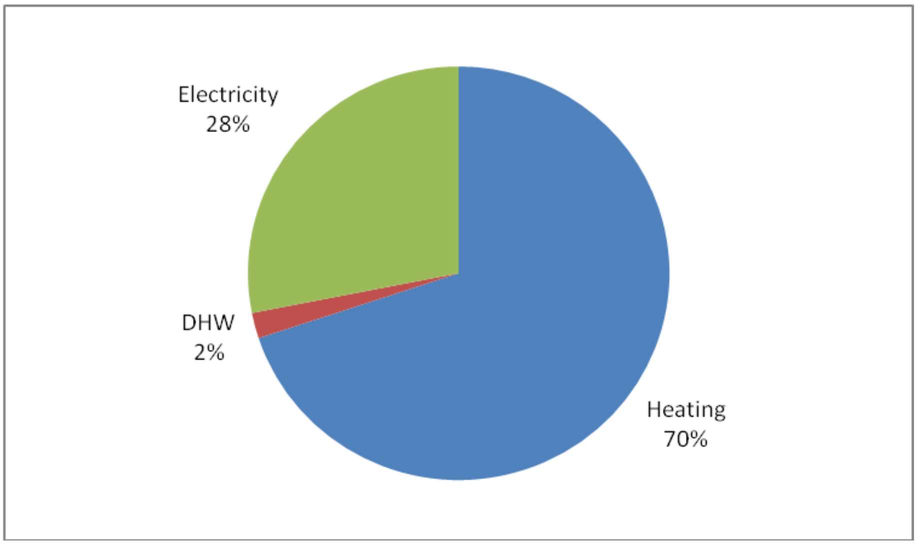

Figure 8: The division of weighted average EPV between heating, domestic hot water and electricity.

70 % of the weighted average EPV of the analyzed buildings was made up by heating and 28 % by electricity. The proportion of domestic hot water was relatively small.

5.2. The analysis of heat consumption

The heat loss of buildings is not directly dependent on the heat source. For this reason the buildings' net consumption of heat which does not depend on the heat source and does not contain the use of domestic hot water is separately analyzed below.

In table 3 below the net energy consumption of heat of the buildings is listed.

Co$_2$olBricks

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Table 3: Net energy of heating

Building	Net heating, kWh/(m^2·a)
ED1	124
ED2	113
ED3	129
ED4	153
ED5	151
ED6	152
ED7	109
O1	177
O2	135
O3	231
O4	152
O5	133
O6	237
O7	179
O8	208
Res1	203
Res2	206
Res3	108
Res4	167
Weighted average	141
Average	161
Median	152

The data presented in table 3 is illustrated by the following graph (Figure 9).

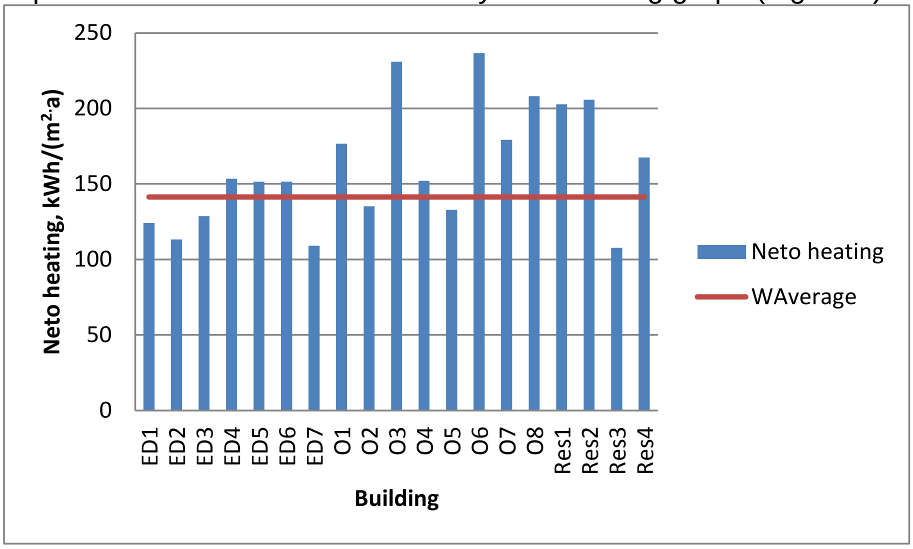

Figure 9: Net energy of heating of the buildings.

Net energy for heating the buildings falls into the range of 108…237 kWh/(m^2·a) which means that consumption varies hugely (the differences are more than twice in size) and do not depend directly on the intended use for the building.

The weighted average net energy consumption of the brick/stone buildings of Tartu was 141 kWh/(m^2·a). The yearly energy consumption is considerably dependent on the outdoor air temperature in winter in the particular area. The warmer the climate the building is situated in, the smaller the yearly energy consumption.

To measure the heat energy consumption of Tartu buildings against the buildings in other areas, we need to take into consideration the climatic peculiarities of the region. The following graph (Figure 10) illustrates the potential average heat energy consumption in Tartu, were we dealing with some other city. Balance point temperature of 17°C is taken as basis for degree days in recalculations of the heat energy consumption.

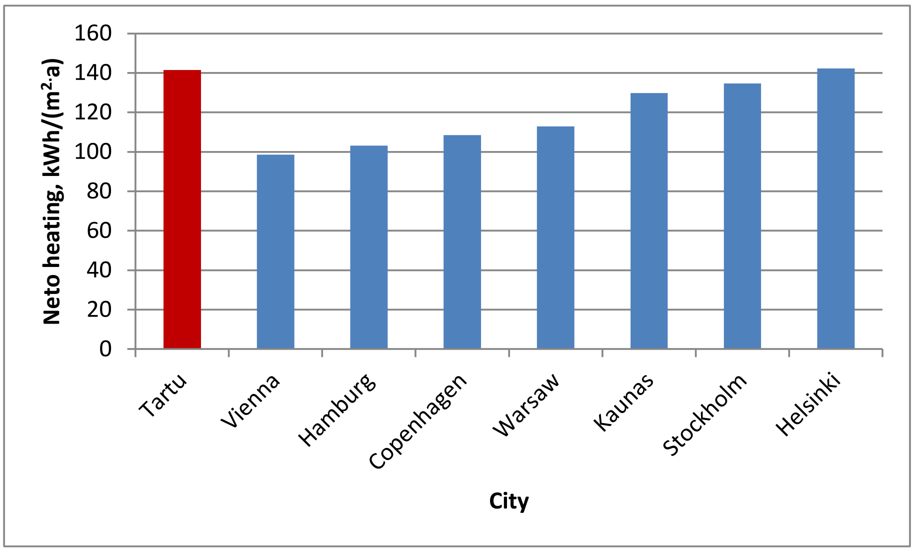

Figure 10: Adapting the weighted average heat consumption of Tartu brick buildings to the climatic conditions of other cities

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For example in Hamburg, heat consumption of 103 kWh/(m^2·a) would correspond to the 141 kWh/(m^2·a) of that in Tartu, in Helsinki the heat consumption would be practically the same as in Tartu.

In the study report by TREA the net heat consumptions are not presented separately. Using approximate methods, we can say that the weighted average of the net heat energy consumption of the analyzed brick buildings is estimably larger than the average of the TREA study by about 30…40 kWh/(m^2·a).

The following graph (Figure 11) depicts the dependence of the net heat energy of the Cool Bricks selection of buildings on the size of the heated area. On the graph the educational buildings are marked in blue, the residential buildings in yellow and other types of buildings are marked in red.

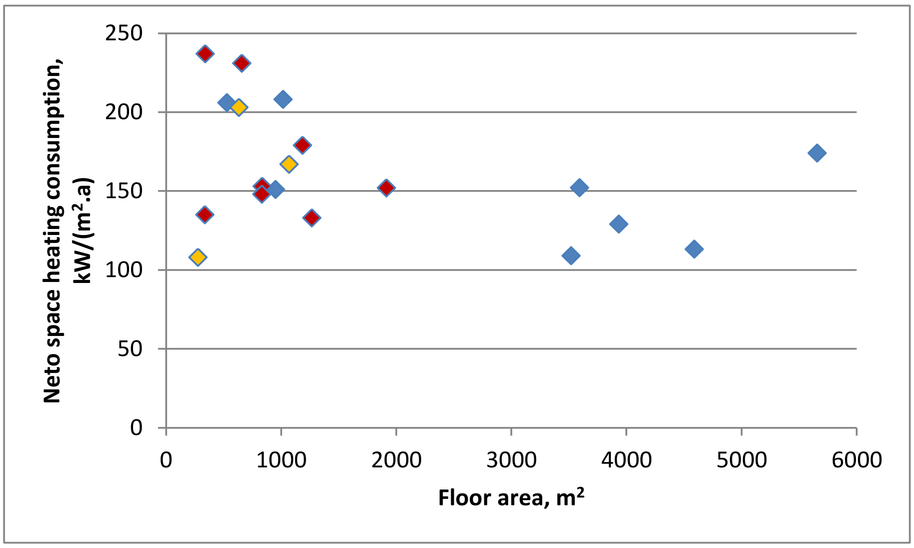

Figure 11: Dependence of the net heat energy consumption on the size of the heated area (blue: schools, red: other buildings, yellow: residential buildings)

The net heat energy consumption of a building in the buildings that participated in the study did not depend considerably on the size of the heated area.

5.3. Electricity consumption

The following table (Table 4) displays the electricity consumption of the buildings participating in the study without a weighting factor for the heated area.

Table 4: Electricity consumption of the buildings

Building	Electricity, kWh/(m^2·year)
ED1	46
ED2	25
ED3	35
ED4	17
ED5	27

Building	Electricity, kWh/(m^2·year)
ED6	28
ED7	21
O1	40
O2	88
O3	26
O4	55
O5	22
O6	33
O7	51
O8	42
Res1	80
Res2	36
Res3	24
Res4	38
Weighted Average	36
Average	39
Median	35

The table 4 is illustrated by the following graph (Figure 12).

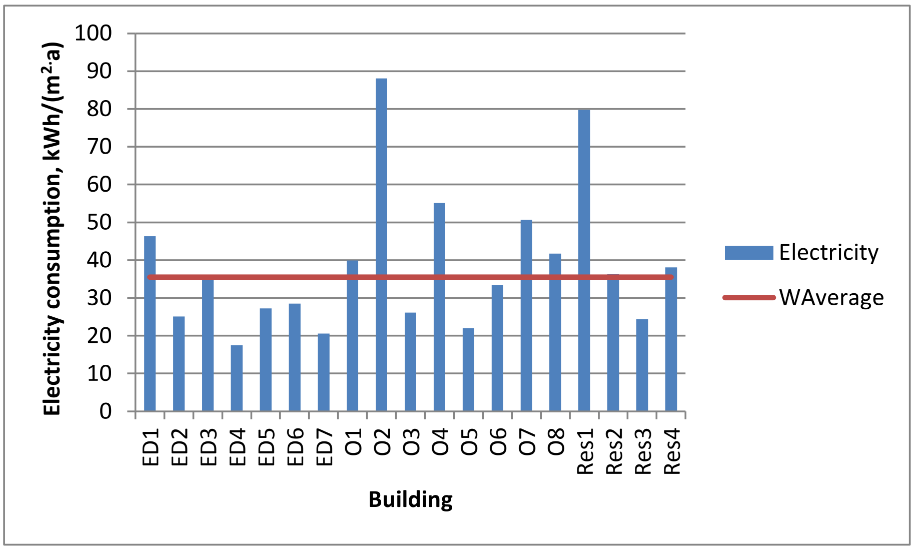

Figure 12: Electricity consumption of the buildings.

Energy consumption fluctuates in a wide range over the entire selection as well as within the types of buildings.

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The weighted average electricity consumption of the analyzed buildings was 36 kWh/(m^2·a). The electricity consumption of two of the buildings was exceptionally high. In the case of those two, it could possibly have to do with partial use of electricity for heating, as well as some other substantial use of electricity (e.g. outdoor lighting).

The average electricity consumption according to the study by TREA was 44 kWh/(m^2·a). This means that the electricity consumption of the brick/stone buildings was somewhat less ((8 kWh/(m^2·a)) than of the selection of buildings in the study by TREA.

5.4 Water consumption

The following table presents the water consumption per heated floor area in the analyzed buildings.

Table 5: Water consumption of buildings

Building	Water, m^3/year
ED1	0,333
ED2	0,205
ED3	0,304
ED4	0,492
ED5	0,208
ED6	0,157
ED7	0,191
O1	0,138
O2	0,227
O3	0,157
O4	0,218
O5	0,062
O6	0,177
O7	0,255
O8	0,277
Res1	1,249
Res2	0,404
Res3	0,352
Res4	0,586
Weighted average	0,273
Average	0,315
Median	0,227

The table 5 is illustrated by the following graph (Figure 13):

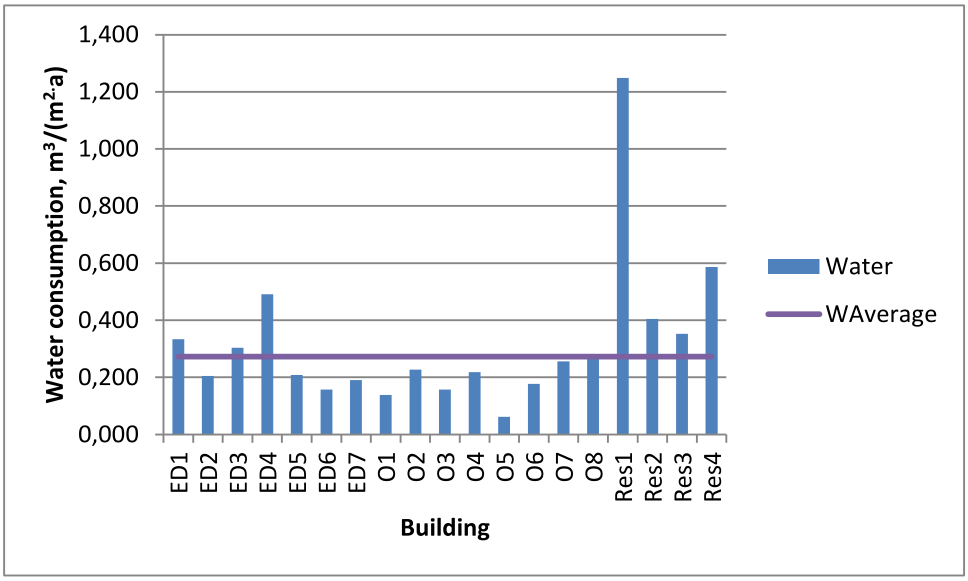

Figure 13: Water consumption of buildings.

The average water consumption of buildings fluctuated in a wide range, but generally fell within 0,15…0,4 $m^3/(m^2 \cdot year)$. The weighted average consumption was 0,27 $m^3/(m^2 \cdot year)$. In one building the water consumption was anomalously high. As water consumption is not handled separately in the study by TREA then we cannot compare the water consumption of the brick buildings with the other type of buildings. In principle the water consumption of brick buildings should not differ from that of buildings of other type with similar use.

6. Summary

The Energy Performance Value (EPV) of the analyzed brick and stone buildings which are part of the architectural heritage or located in milieu valuable areas, fell in the range of 131-375 $kWh/(m^2 \cdot a)$. The average EPV of those buildings was 227, the weighted average by heated floor area was 193 and the median 220 $kWh/(m^2 \cdot a)$. Compared to the EPV of 64 buildings in Tartu, the weighted average EPV of the brick and stone buildings was higher by 16 % (31 $kWh/m^2 \cdot a$) and the median was higher by 23 % (41 $kWh/(m^2 \cdot a)$).

A substantial part of the EPV of the analyzed buildings was comprised of heating (70%). Compared to 64 buildings in Tartu, the average heat consumption of the heritage/milieu valuable brick/stone buildings participating in this study was considerably greater.

Compared to 64 buildings in Tartu, the average electricity consumption of the analyzed heritage/milieu valuable brick/stone buildings was somewhat smaller.

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