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RECOMMENDATIONS REGARDING THE ACHIEVEMENT OF THE BETTER ENERGY PERFORMANCE IN THE CULTURAL HERITAGE AND MILIEU VALUABLE BRICK/STONE BUILDINGS

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1. Foreword

This report covers INTERREG IVB program project Nr 61"Co2ol Bricks" recommendations regarding the achievement of the better energy performance in the cultural heritage and milieu valuable brick/stone buildings as a part of the agreement between Hevac Ltd and Centre of Development Programs EMI-ECO.

The results of the energy performance study in Tartu brick/stone buildings conducted within "Co_2ol Bricks" program displayed, that cultural heritage and/or milieu valuable brick buildings average EPV is about 15% higher in comparison with other Tartu buildings.

It is important to stress the fact, that cultural heritage and milieu valuable brick buildings should be treated as unique buildings – to renovate and improve energy performance of them, each should be treated as an individual object, considering its originality. The solutions suitable for one building may not be suitable for the other. Therefore, it is hard to draw specific and detailed recommendations on improving energy performance for this type of buildings. In comparison to renovation of the basic buildings, the renovation of cultural heritage buildings requires extensive preliminary studies, skilled and experienced designers, high quality constructors and owner's supervision.

With respect to the Estonian Building Act §3, there is no demand to meet the minimum energy performance requirements in the following buildings with indoor climate control:

- buildings which, pursuant to the relevant comprehensive plan or detailed plan, are located within a built-up area of cultural and environmental value, or which have been recognised as a valuable monument
- buildings which have been designated as cultural monuments and which are located in a heritage conservation area pursuant to the Heritage Conservation Act
- buildings included in the UNESCO World Heritage List and in which compliance with established requirements would significantly alter their nature or appearance

Thus, in case of the reconstruction (including essential reconstruction), the buildings referred do not need to meet the minimum energy performance requirements after the renovation process. This means that, to apply for the building (refurbishment) permit, there is no need to provide calculations regarding the minimum energy performance. On the other hand, each owner/user should be interested in optimal future building energy consumption costs.

Recommendations regarding the achievement

2. Special conditions for building renovation

Prior starting to improve the energy performance of the specific building, its milieu value, limitations, and conditions should be defined.

Old brick buildings can be divided in the following groups:

- Monumental buildings
- Building located in a heritage conservation area

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- Buildings located in the milieu valuable area
- Buildings without any special status.

The design and refurbishment of buildings, which have been designated as cultural monuments, should consider heritage based specific conditions. Generally, specific conditions describe the requirements for internal and external refurbishment. The improvement of the energy performance for these buildings is very complicated and expensive.

In case of buildings, which pursuant to the relevant comprehensive plan or detailed plan and are located within a built-up area of cultural and environmental value, the requirements of the detailed plan and/or comprehensive plan, theme plan, local authority regulations, design conditions etc. should be followed. Generally, there are no restrictions for internal refurbishment in this type of buildings. However, exterior refurbishment should follow specific rules and conditions. The improvement of the energy performance for these buildings is way less complicated.

Requirements and conditions above does not affect the refurbishment of non-special status buildings. Therefore, there is a lot of room and options for refurbishment.

3. Recommendations on improving the energy performance in cultural heritage and milieu valuable brick/stone buildings

The description below gives general recommendations on improving the energy performance in cultural heritage and milieu valuable brick/stone buildings.

Energy performance improvement measures can be divided in the following two groups:

- The improvement of building envelope energy performance
- The improvement of HVAC systems energy performance

Generally, there are less restrictions in cultural heritage buildings regarding the improvement of HVAC systems in comparison to the building envelope refurbishment.

3.1. Building envelope

Cultural heritage and milieu valuable buildings envelope insulation is quite complicated, detailed requirements and options depend on the building originality, its location, special conditions and limitations.

Building envelope (windows, doors, roof, walls etc.) heat loss is defined by the specific type of structure and is characterized by structure thermal transmittance (U-value). The higher the U-value, the more heat transmits through the structure during winter and the higher the energy consumption is. Nowadays buildings wall and roof structure U-values vary in the 0,1…0,2 $W/(m^2 \cdot K)$ range and windows U-values vary in the 0,8…1,2 $W/(m^2 \cdot K)$ range. In general, the non-refurbished brick building envelope U-values are much higher in comparison to listed above. In example, non-insulated 1 meter thick limestone wall thermal transmittance is about 1,5…2 $W/(m^2 \cdot K)$, in other words 10 times higher than in nowadays structures In order to achieve the wall/roof U-value of 0,15 $W/(m^2 \cdot K)$, the wall/roof

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should be insulated with about 20…25 cm thick thermal insulation layer. However, the additional 25 cm layer of insulation should not affect the exterior appearance of the building.

With additional insulation of the structure or replacement of the old windows thermal transmittance (U-value) of the structure decreases and therefore building heating consumption decreases as well.

The following graph illustrates approximate estimation of energy savings based on 1 m^2 structure area depending on the structure thermal transmittance decrease. The graph is prepared based on the thermal energy rate 70 €/MWh.

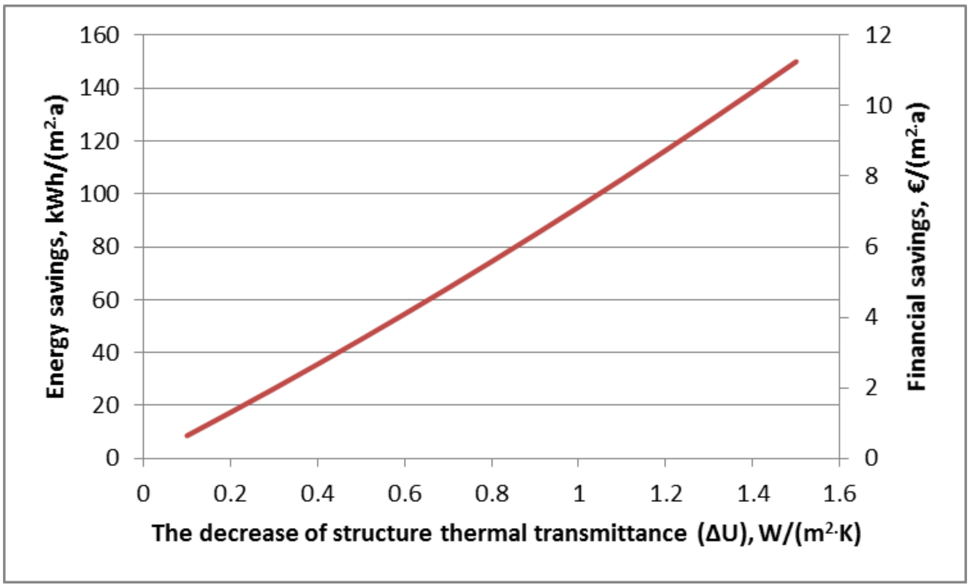

Figure 1 Energy and financial savings based on 1 m2 structure area depending on the structure thermal transmittance decrease (Energy rate 70 €/MWh)

An example regarding the roof structure insulation. The roof structure with its prior thermal transmittance of 1,15 $W/(m^2 \cdot K)$, about 20…25 cm thick thermal insulation layer is required to achieve U-value of 0,15 $W/(m^2 \cdot K)$ and the decrease of structure thermal transmittance is ΔU=1,15-0,15=1 $W/(m^2 \cdot K)$. ΔU=1 would provide the annual energy savings (Figure 1) of 95 $kWh/(m^2 \cdot a)$ (6,7 €/($m^2 \cdot a$)) for 1 m^2 of roof structure. In case of the 100 m^2 roof, the annual energy savings are equal to 95 * 100 = 9500 kWh/a (670 €/a).

3.1.1. Insulating the roof structure

The insulation of the roof and attic structure does not affect exterior appearance of the building. Therefore, additional insulation of the roof structure is one of the easiest energy performance improvement measure. Insulation design should consider building moisture condition requirements (i.e. when insulating attic floor, ventilation of the floor structure should be considered).

3.1.2. Insulating the plinth structure

Sometimes it is possible to insulate the plinth structure or basement ceiling structure.

3.1.3. Windows refurbishment

The measure with potentially high-energy savings is old windows replacement/refurbishment with the windows that consider the originality of old ones or by adding energy saving window package from the inside. There are two energy performance improvement aspects involved in the windows replacement measure. First is the decrease in window structure thermal transmittance (U-value) and

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the second is increase of building air tightness. The study of brick buildings in Tartu within “Co2olbrick” project showed that essential energy wasteful air leaks (Figure 2) occur near windows structure.

3.1.4. Insulating the exterior wall structure

Generally, exterior walls area proportion to other envelope structures in the building is the highest. However, additional insulation of this type of buildings wall structure is the most problematic.

As a rule, insulating the wall structure from the inside is not recommended due to the high risk of moisture damage. Prior the start of insulating works of the inside wall structure, it is important to conduct moisture and thermal engineering calculations. The decision of adding the insulation layer from the inside or not should base on the results of these calculations.

Insulating the wall structure from the outside is the recommended feasible solution. However, exterior walls insulation affects building exterior appearance. Most of the time cultural heritage buildings are not allowed to insulate this way. In milieu area, to insulate exterior wall structure from the outside some trade-offs with surveillance officers are required. In example, with the insulation of exterior walls from the outside, roof structure has to be refurbished to meet new wall thickness. Often it becomes necessary to shift windows into additional insulation layer. Even when insulating from the outside, moisture calculations are required. Wrong structural solutions can become a cause of moisture damage.

3.1.5. Air leaks reduction

The study of brick buildings in Tartu displayed, that air leaks in measured buildings were essentially higher in comparison to basic buildings. Most air leaks occurred in the wall-window joints (Figure 2) and wall-wall joints (Figure 3).

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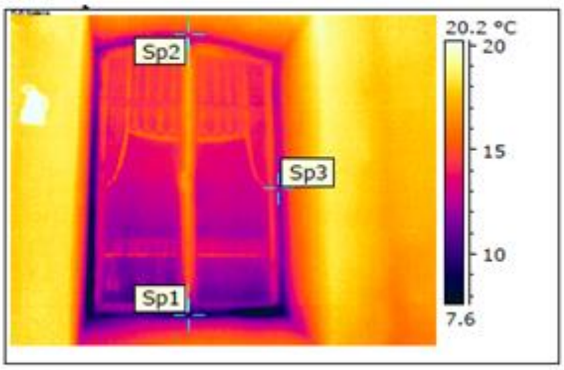
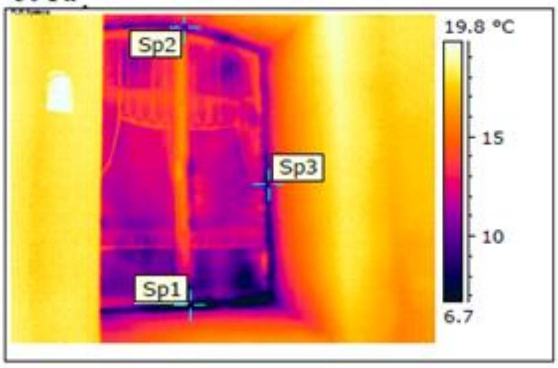
±0 Pa



IR Text Comment	Value
Indoor air temperature, +°C	20
Outdoor air temperature, +°C	0
Label	**Value**
Sp1	8.8 °C
Sp2	13.3 °C
Sp3	11.6 °C

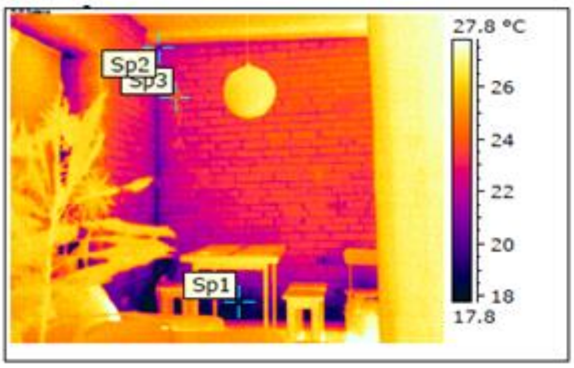
-50 Pa



IR Text Comment	Value
Indoor air temperature, +°C	20
Outdoor air temperature, +°C	0
Label	**Value**
Sp1	6.8 °C
Sp2	9.7 °C
Sp3	8.8 °C

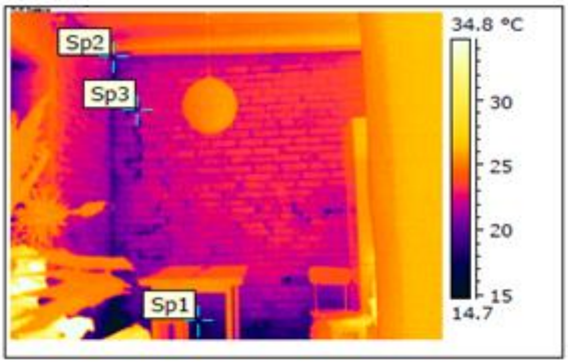
Figure 2 The picture below describes surface temperatures at the 50 Pa negative pressure condition. Surface temperatures at window-wall joints are lower on the picture below because of the air leak.

±0 Pa



IR Text Comment	Value
Indoor air temperature, +°C	26.1
Outdoor air temperature, +°C	2.9
Label	**Value**
Sp1	18.2 °C
Sp2	20.0 °C
Sp3	23.9 °C

-50 Pa



IR Text Comment	Value
Indoor air temperature, +°C	26.1
Outdoor air temperature, +°C	2.9
Label	**Value**
Sp1	16.9 °C
Sp2	18.8 °C
Sp3	18.1 °C

Figure 3 The picture below describes surface temperatures at the 50 Pa negative pressure condition. Surface temperatures at wall-wall joints are lower on the picture below because of the air leak.

Reducing the air leaks (windows and walls air tightness improvement) results in the lower heating energy consumption.

3.2. HVAC systems

3.2.1. Energy source replacement

Old ovens/stoves/fire places are inefficient from energy performance perspective. They should be replaced by the new more efficient energy sources whenever it is possible.

The recommended heating system in building is the central hot-water heating system. The district heating network connection is more preferable than local heat supply.

If the building is located in non-district heating area, the local heat supply should be considered. The boiler house (gas-, wood-, pellets-fuelled) is an option of the local heat supply. For the buildings supplied with heat from the old boiler house, it is relevant to measure its efficiency. In case of low efficiency, the combustion process should be adjusted/the boiler should be replaced with the higher efficient one.

Some cases involve the heat pump option of the heat supply solution: availability of enough existing ground amount to implement the horizontal collector, fair environmental conditions to implement vertical collector. Air-source heat pump application in this type of buildings is problematic, due to the exterior appearance changes involved. Heat pump design should consider the maximum supply water temperature of 60…65 °C. Low-temperature heat carrier temperature expects greater heating surfaces of the radiators at the heat loss of the non-refurbished building structure. If the building envelope thermal resistance prior the heat pump installation will not be improved, the heat pump might not meet the heating demand and/or more radiators will have to be installed.

There are cultural heritage buildings in Estonia, where solar energy plays the heat supply role (Figure 4 and Figure 5).

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Figure 3 Vihula mõisa conference centre. Part of the hotel DHW is prepared using solar collectors. Building heat supply is ground-source heat pump. Source: Restor

Figure 4 Mäetaguse mõisa conservatory-bathhouse. Glass-roof is covered with solar panels that produce electricity and let the light in, while protecting the space from overheating. Source: Restor

3.2.2. Heating system and indoor air temperature control

Hydraulic balancing

The heating system water circulation have to overcome friction losses. In general, the far is the radiator located from the flat station, the more is the overall system pressure drop. If the system is not hydraulically balanced, the highest amount of the heat carrier will circulate to the nearest circuits with less pressure drop, resulting in the less amount of heat carrier reaching the farthest circuit. This will cause air temperatures fluctuations in rooms: rooms near the flat station will have higher air temperature than rooms far away from the flat station. To balance the heating system, the balancing valves should be installed to maintain the required (design) flow amount. The valves to consider are pre-set thermostat radiator valves and/or zone balancing valves.

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Heat carrier supply temperature control depending on the ambient air temperature

The cooler the ambient air temperature is, the higher the heating system supply water temperature should be. To prevent building overheating and low indoor air temperatures, the control of the supply water temperature depending on the ambient air temperature value should be implemented. The solution involves the use of special control valve and automation of the flat station. The automation system must be tuned based on the building specifics.

Thermostat radiator valves (TRV)

To sustain indoor air temperature heating set point, thermostatic radiator valves should be installed. The action of the valve is described in the next example: Whenever people come into room, turn on computers, lights etc. the heat gain starts to heat up the room air temperature and the thermostat reacts to avoid the overheating in the room by closing the valve and controlling the amount of heat carrier passing through the radiator. Thermostat radiator valve helps to utilize the heat gain to heat up the air, resulting in energy savings and comfort. If the building has the cooling system installed, simultaneous work of heating and cooling system should be avoided by using automation system.

Avoiding the overheating

The study of Tartu brick buildings within this project has showed, that buildings are being overheated – indoor air temperature is too high. During the cold period in office and apartment rooms recommended air temperature set point is 21 °C. Every additional 1°C added to the average heating season indoor air temperature provides a gain of 7…8% in the heating energy consumption. As follows, if the average indoor air temperature in building is 23 °C, then in comparison to building with the set point of 21 °C, heating energy consumption will be about 15% higher. Overheating in the rooms should be avoided.

3.2.3. Sufficient air exchange and exhaust air heat recovery

The study of Tartu brick buildings within this project has showed that room air exchange (especially in apartment building) is not sufficient. Poor air exchange can be a cause of human health problems, poor work productivity, poor envelope moisture conditions etc. Apartment buildings air exchange rate should be at least 0.5 times per hour (room air should change once in two hours). Office building air exchange should be 1…2 l/s per one meter square floor area.

The refurbishment of building should definitely consider the installation of the mechanical air ventilation system to produce required indoor air exchange. Air handling units should be equipped with exhaust air heat recovery system, which will heat up the supply air with exhaust air heat during the cool ambient air periods. Nowadays heat exchangers can save up to 90% of the annual heat consumption used to heat up the supply air.

3.2.4. Air handling units operation in accordance with building usage schedule

Frequently in non-apartment buildings operation of air handling units (on/off, variable amount of air etc.) does not correlate to the building usage schedule. The automation of the non-controllable mechanical ventilation system should be considered. The operation of mechanical ventilation system should be tuned to meet the real building usage schedule.

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3.2.5. Energy efficient lighting

To decrease the building electric energy consumption LED lights should be considered prior basic bulb lighting. In addition, the automation of the lighting system to meet the real usage of the building is another source of energy conservation (motion sensor, dim switches etc.). However, decreasing electrical energy use for lighting purposes will lead to increase in the building heat consumption.

3.2.6. HVAC systems automation and smart control

Study of Tartu brick buildings within the “Co2olbrick” project program showed, that the level of the automation in studied buildings is relatively poor. The update of building automation systems does not essentially affect the interior and exterior appearance of the building. Therefore, it is very important measure to improve building energy performance and is especially suitable for cultural heritage and milieu valuable buildings.

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