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SOLUTION

Sustainable Oriented and Long-lasting Unique Team for energy self suffIcient cOmmuNities

Deliverable No. 2Hv.1.2, WP No. 2Hv.1

IMPROVED ENERGY EFFICIENCY IN BUILDINGS

Report on quality requirement schemes for public buildings

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TABLE OF CONTENTS:

1 Summary

Implementation of energy efficiency measures depends on preparing appropriate steps in building modeling in terms of heating, ventilation and air conditioning systems, sanitary hot water preparation, appropriate choice of building thermal insulation, as well as many other factors.

Suitable energy efficient measures in respective cases have proven to drastically lower the energy consumption while at the same time raising the comfort of residence in the building, thus achieving satisfying socio-economic impact on the community. Undertaking of appropriate energy efficiency measures is also determined with regulatory framework set to provide a standard for refurbishment as well as new building requirements. Croatia has adopted European regulations on rational energy use and heat retention in buildings, as well as other regulations concerning HVAC systems and construction requirements of buildings (NG 110/08 - implementation of Directive 2002/91/EC).

Determining building "weak spots" provides a clear insight into cost-effectiveness of the chosen project for achieving best cost-benefit ratio for respective projects. Both public and private buildings shall be examined in order to determine the most appropriate measures for achieving largest consumption reduction. Buildings in which refurbishment was considered have been obtained from previously received energy audits and divided into three categories:

+ historic buildings – 19^{th} century to 1950's
+ buildings from 1950's to 1980's
+ buildings from 1980's to 2000

2 ENERGY EFFICIENCY REQUIREMENTS FOR NEW BUILDINGS IN CROATIA

Croatia has adopted European regulatory framework for energy efficiency in the Technical regulation on rational energy use and heat in retention buildings (NG 110/08) to achieve the current EU standards in building construction. The mentioned regulation implements the Directive 2002/91/EC of the European Commission.

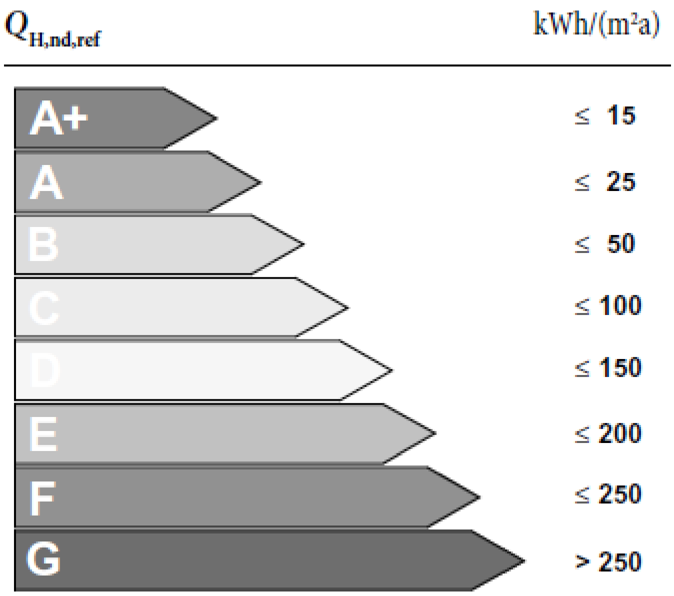
This regulation determines the technical requirements for rational energy use and heat retention which have to be accomplished while designing and constructing a new building. Requirements for new buildings are different for residential and non-residential buildings:

+ *RESIDENTIAL BUILDINGS:*
  - Depending on the building shape factor f_0 annual amount of energy used for heating must be from 51,31 kWh/(m^2·a) to 95,01 kWh/(m^2·a)
+ *NON-RESIDENTIAL BUILDINGS:*
  - Depending on the building shape factor f_0 annual amount of energy used for heating must be from 16,42 kWh/(m^2·a) to 30,40 kWh/(m^2·a)

The mentioned requirements for new and refurbished buildings do not include:

+ buildings which gain at least 70% of the necessary heating demand from renewable energy sources
+ buildings which gain more than 50% of the necessary heating demand from internal energy sources in technological processes

Energy class of each building is assigned by precise measurements and calculations according to NG 36/10 "Technical regulation on building energy certification". The classes are:



Also, prescribed minimal thermal protection requirements (overall heat transfer coefficient U [W/(m^2·K)]) for respective parts of building are:

Building element	Max. U [W/(m^2·K)] for Θi ≥ 18 °C
External walls, walls to garage, attic	0,60
Windows, balcony doors, skylights, transparent elements of the facade	1,80
Flat and oblique roofs above the heated space, ceilings to attic	0,4
Ceilings above outside air, ceiling above garage	0,4
Walls and ceiling to unheated space and unheated stairs with temperature higher than 0°C	0,65
Walls to ground, floors to ground	0,5
Outside doors, doors to unheated stairs	2,9
Ceilings between apartments	1,4

3 EXISTING BUILDINGS

Specific refurbishment measures have to be applied for buildings on Hvar Island in order to achieve satisfying results. Buildings have been divided depending on periods with characteristic construction materials:

+ historic buildings – 19th century to 1950's
+ buildings from 1950's to 1980's
+ buildings from 1980's to 2000

It is considered that the biggest problem persists in lack of proper thermal insulation of the building facade on buildings on Hvar and inefficient heating systems. In spite of Hvar's mild Mediterranean climate, heating energy demand is excessive and actions to reduce that demand must be taken.

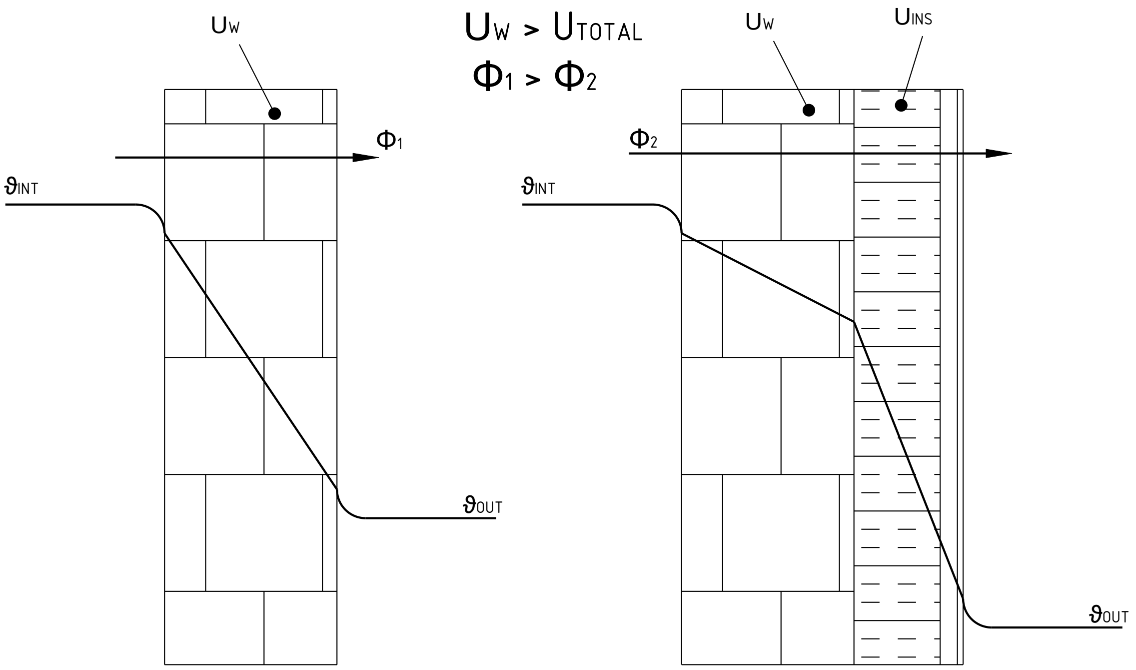


Figure 1 Heat transfer coefficient and temperature distribution of a non-insulated wall and a thermally insulated wall

The first step in reduction of energy used for heating is application of thermal insulation on walls according to prescribed technical requirements in Croatian law. As shown on the figure above, walls have no possibility of energy accumulation in the case with no thermal insulation (left), therefore a larger amount of energy is lost through the walls. The right figure displays that by applying thermal insulation building gains the possibility to accumulate energy inside the construction and has a lower heat transfer coefficient which results in lower heating demand compared to the non-insulated walls case. In case of insulated building the cooling demand is also reduced in a significant amount due to insulation which resists heat flow from outside to inside.

Also, significant savings in energy used for heating/cooling can be achieved through replacement of old and inefficient heating/cooling systems and application of new, high energy grade and efficient systems.

3.1 Historic buildings (19th century – 1950's)

Historic buildings on Hvar Island typically originate from the end of 19th century to 1950's. Buildings of such type are public and governed by the authorities. Majority of historic buildings are situated in older town centers.

Figure 2 Typical historic building in Stari Grad

Historic buildings have been built in distinctive and high quality design with materials available in that period (stone and concrete walls, wooden ceiling structure and roof tiles specific for Mediterranean area, wooden windows, etc.) and modest building installations which do not meet new energy efficiency requirements. A large number of historic buildings are in average occupied 8 hours a day.

Majority of such buildings have been refurbished and equipped during time (new equipment and installations, sanitary facilities, new windows and doors, etc.), but always partially and without assessment of all aspects of necessary investment (performing complete energy audits, needs assessment, rational utilization and maintenance cost assessment).

Such building management has resulted in high investment costs as well as high energy related costs.

3.1.1 Walls

Historic buildings on Hvar have thick stone or concrete walls with architecturally textured facades which are features of typical Mediterranean architecture for that period. Some historic buildings have textured facades only on the front. This type of construction results in high energy losses without applying energy efficiency measures (heat transfer coefficient ranging from 1.5 W/m^2K to 4 W/m^2K). Roughly, 75% percent of the public buildings taken into consideration have stone and concrete construction, while others have either stone or concrete construction, as shown on the figure below.

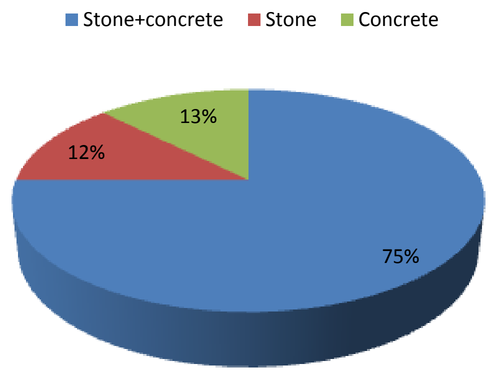


Figure 3 Construction materials in historic buildings

Wooden single-glass windows and doors have been partially replaced on 50% of the buildings, depending on financial situation of the investor, with new aluminum or PVC windows and doors. Partial replacement of windows and doors has reduced energy consumption in a small scale but further reductions can be accomplished. Old wooden windows remaining on buildings have very high heat transfer coefficients ranging from 2 W/m^2K up to almost 5 W/m^2K which do not meet the current energy efficiency requirements.

3.1.2 Heating and cooling

Heating systems in historic buildings are typically central oil-fueled but mostly local electric heating devices which present a large amount of total building energy consumption. Hvar Island has mild winters and temperatures rarely drop below 0°C therefore new efficient systems must be installed. Also, some buildings have several heating systems installed, each covering only a part of the heating demand, i.e. only one floor.

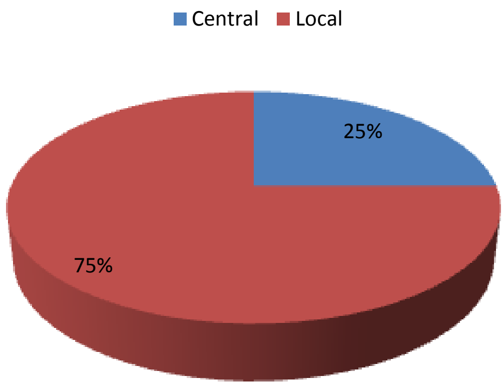


Figure 4 Types of heating and cooling systems in historic buildings

Cooling systems due to Mediterranean climate have the biggest influence on total energy consumption of the building. Most of the buildings do not have a cooling system installed. The cooling needs are met with air conditioning units.

3.1.3 SHW preparation

All historic buildings have electric boilers for sanitary hot water preparation. In most cases, sanitary hot water consumption is rather low, due to occupation regime. Of course, there are several exceptions where i.e. cafes are situated in the building. In such cases hot water consumption is higher.

3.2 BUILDINGS BUILT FROM 1950-1980

Characteristic buildings dating from 1950-1980 were built from concrete construction which has proven to be the cheapest investment due to weak connections with the mainland. Also, a significant number of stone buildings have been upgraded with concrete constructions.

Figure 5 Typical building from 1960's

Majority of such buildings do not have proper thermal insulation which results in high energy losses. Energy efficiency measures such as windows and doors replacement in these cases do not present sufficient effort for reduction of energy losses and costs.

In spite of efficient HVAC systems installed in some of the buildings, investments into buildings refurbishment are necessary in order to improve residential conditions. Cost-effectiveness of the proposed measures greatly depends on occupation regime which is similar for all public buildings taken into consideration, varying from 8-12 hours a day.

3.2.1 Walls

As previously stated, majority of buildings were built out of concrete with no thermal insulation. Such building management results in high energy losses due to high overall heat transfer coefficient of unprotected concrete construction ranging from 1,5 W/m^2K to 3 W/m^2K. Also, some buildings have thermal daub applied which does not meet new energy efficiency requirements.

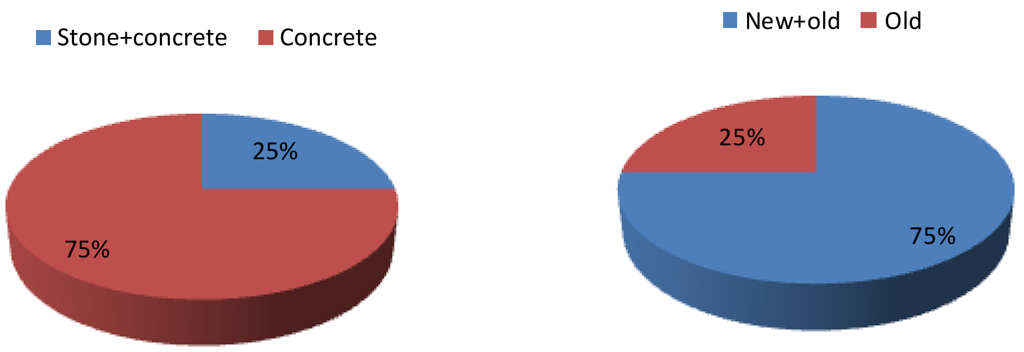


Figure 6 Types of construction and types of windows

Many old windows and doors have been replaced with new ones, so some reduction of energy losses has been achieved, although in comparison with losses due to lack of proper thermal insulation on concrete walls, such losses present a minor part of potential energy savings.

3.2.2 Heating and cooling

Heating and cooling systems often consist of air conditioning units instead of applying central system and in that manner achieving optimal energy performance of the building, but most of public buildings taken into consideration have central systems installed.

3.2.3 SHW preparation

As well as in many other types of buildings, SHW preparation is mostly carried out with electric boilers.

3.3 Buildings built from 1980-2000

In general, buildings built in this period are mostly concrete/hollow brick buildings with a rather high percentage (around 40%) of thermal insulation applied, nevertheless, as in other types of buildings, thermal insulation must be applied where missing.

SHW preparation is carried out with electric/oil/LPG boilers with low level of renewable energy sources application.

As in other cases, low-efficiency heating/cooling systems such as electric heaters exist.

4 GUIDELINE FOR REFURBISHMENT OF EXISTING BUILDINGS AND CONSTRUCTION OF NEW BUILDINGS

This guideline has been developed solely for advising appropriate solutions for implementation of energy efficiency measures in various types of buildings suitable for application during Concerto Solution program, as well as other island communities. In general, this guideline will provide sufficient guidance for achieving long term community development and energy self-sufficiency. Energy efficiency requirements of technical regulations in effect must be met (if applicable on historic buildings). Suitable material requirements, systems and equipment requirements must be chosen for each building respectively in order to achieve optimum energy reduction resulting in lower building operation and maintenance costs, as well as higher level of comfort.

Guidelines for each previously mentioned type of building are provided, taking into account building, location occupation regime and general conditions related to building.

4.1 HISTORIC BUILDINGS

Majority of historic buildings, as mentioned before, provides no space for external walls insulation due to architecturally textured facades, therefore internal wall insulation should be applied. Of, course external wall insulation is preferred on buildings where textured facade is only on one face of the building.

A calculation with specialized software has been made to discover the effect of applying thermal insulation, internal and external. The case of building with stone walls and no insulation shows that the annual heating demand per square meter is 118 kWh/m^2·a. This amount will be compared with calculations where insulation has been applied.

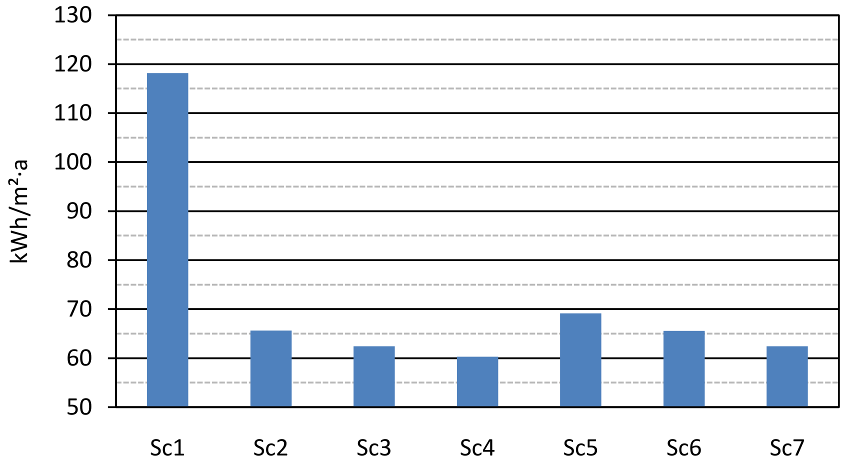


Figure 7 Annual heating demands per square meter – scenarios

Scenario 1 (Sc1) shows the previously mentioned calculation with no insulation applied on the walls. Scenarios Sc2, Sc3 and Sc4 display heating demands per square meter in case of internal thermal insulation of 6, 8 and 10 cm applied. Significant savings in these cases are already noticed. The annual heating demands has been reduced from 118 kWh/m^2·a to 65, 62 and 60 kWh/m^2·a, respectively. These cases show reductions of

45%, 47% and 49%, respectively. Of course, internal insulation on all walls should be applied only on buildings where textured facade covers all of the building faces due to issues with moisture and no energy accumulation possibility.

Also, three different scenarios with external insulation on three faces of the building and one face with internal insulation have been calculated. Thermal insulation with different thickness has been considered (5, 7 and 10 cm) in order to assess the best solution for appropriate buildings. The heating demand is reduced to 69, 65 and 62 $kWh/m^2 \cdot a$, respectively.

All of the calculated scenarios show that reduction from grade D (≤150 $kWh/m^2 \cdot a$) to grade C (≤100 $kWh/m^2 \cdot a$) can be achieved. The optimal scenario would be Sc5 where the total reduction (with applying external wall insulation of 5 cm on three faces of the building and internal wall insulation on one face of the building) of energy used for heating would be around 42%. Other calculated scenarios would require higher investment with longer payback periods.

All old windows and doors with single glass must be replaced with new ones with double/triple glass whose overall heat transfer coefficient is under the prescribed value of 1,8 $W/m^2 \cdot K$.

Electric heating elements must be removed and replaced with central heating system in order to further reduce electricity consumption and apply energy efficient heating systems where applicable.
All of the considered buildings should be refurbished to meet the requirements of the prescribed overall heat transfer coefficients for building elements and to meet the requirement for the grade C (≤100 $kWh/m^2 \cdot a$) building.

GUIDELINES

+ with application of *5-10 cm* of inside thermal insulation (outside where possible) reduction of energy used for heating from *30-50%* and reduction in energy used for cooling from *10-30%* can be expected (replacement of windows and doors included)
+ efficient ventilation systems should be installed due to moisture problem related to application of inside thermal insulation
+ replacement of old and inefficient heating/cooling/SHW preparation systems could contribute to reduction of energy consumption up to *20%* (replacement of local units with central system)
+ replacement of incandescent lighting bulbs with efficient ones (LED, fluorescent, …) can contribute to reduction with up to *5%*
+ historic buildings must at least satisfy grade C (≤100 $kWh/m^2 \cdot a$) of the Building energy certification regulation

4.2 Buildings from 1950 - 1980

Scenario assessment of this category of buildings will include only ones made out of concrete. The same calculation has been conducted as in previous chapter in order to provide approximate results and to gain insight into heat losses in various types of buildings. The scenario with no insulation applied on walls (Sc1) provided approximate value of annual heating demand, almost 135 kWh/m^2·a. Buildings with concrete walls have the largest annual heating demand per square meter, as it will be shown in the summary.

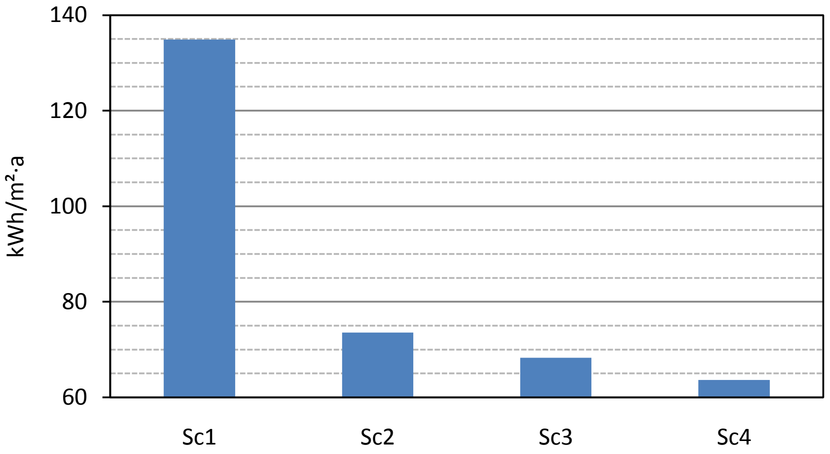


Figure 8 Annual heating demands per square meter – scenarios

Very high heat losses must be reduced, especially in buildings with concrete construction. Scenarios Sc2, Sc3 and Sc4 display annual heating demand with thermal insulation applied on walls, 5 cm, 7 cm and 10 cm respectively. Building of the same net area built from concrete, in comparison to the one built from stone, would consume up to 13% more energy for heating in one year. Sc2, Sc3 and Sc4 have shown significant energy savings can be achieved (45%, 49% and 52% respectively). All concrete buildings must be properly insulated in order to achieve Solution objectives.

Non-insulated buildings built out of concrete are classified as grade D (≤150 kWh/m^2·a) but with proper thermal insulation would fall in grade C (≤100 kWh/m^2·a).

GUIDELINES

+ with application of *5-10 cm* of outside thermal insulation reduction of energy used for heating from *40-60%* and reduction in energy used for cooling from 10-30% can be expected (replacement of windows and doors included)
+ replacement of old and inefficient heating/cooling systems could contribute to reduction of energy consumption up to *20%* (replacement of local units with central system)
+ replacement of incandescent lighting bulbs with efficient ones (LED, fluorescent, …) can contribute to reduction with up to *5%*
+ application of RES, especially solar thermal, can contribute to further reduction of energy used for heating with *10-25%*
+ amount of energy used for SWH preparation can be reduced from *50-90%* with installation of a solar thermal system of the corresponding capacity

4.3 Buildings from 1980 - 2000

With development of transport lines from mainland to Hvar, a variety of new materials became available and cheaper to transfer to the Island. A very large number of buildings have been upgraded with hollow brick construction, but a large number of new constructions have also been erected during this period. Since two previous calculations have been made for stone and concrete constructions, only hollow brick will be taken into consideration here.

Almost 35% of the considered buildings (private and public) have been either upgraded with constructions out of hollow brick or constructed out of hollow brick. A large number of such buildings still lack proper thermal insulation which results in high amount of heat losses.

In the figure below, scenario Sc1 displays the case of hollow brick building without proper thermal insulation with annual heating demand of almost 133 kWh/m^2·a.

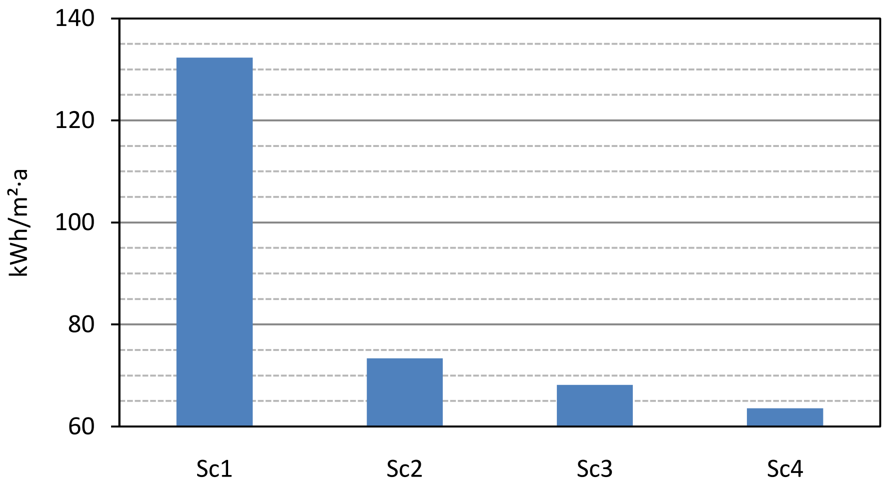


Figure 9 Annual heating demands per square meter – scenarios

Scenarios Sc2, Sc3 and Sc4 display hollow brick construction with applied thermal insulation with 5 cm, 7 cm and 10 cm thickness, respectively.
Calculations have displayed that 45% savings can be made by applying 5 cm thick thermal insulation, 49% savings by applying 7 cm thermal insulation and 52% savings by applying 10 cm thermal insulation. Such practice would result in far lower annual heating demand of 74 kWh/m^2·a, 68 kWh/m^2·a and 64 kWh/m^2·a, respectively.

Non-insulated buildings built out of hollow brick are classified as grade D (≤150 kWh/m^2·a) but with proper thermal insulation would fall in grade C (≤100 kWh/m^2·a).

Guidelines for HVAC systems and windows and doors are the same as in chapter 4.1 with addition of renewable energy sources application, where possible (PV, solar SHW, solar heating and cooling systems) depending on location, investment cost and overall energy consumption.

GUIDELINES

- with application of *5-10 cm* of outside thermal insulation reduction of energy used for heating from *40-60%* and reduction in energy used for cooling from 10-30% can be expected (replacement of windows and doors included)
- replacement of old and inefficient heating/cooling systems could contribute to reduction of energy consumption up to *20%* (replacement of local units with central system)
- replacement of incandescent lighting bulbs with efficient ones (LED, fluorescent, …) can contribute to reduction with up to *5%*
- application of RES, especially solar thermal, can contribute to further reduction of energy used for heating with *10-25%*
- amount of energy used for SWH preparation can be reduced from *50-90%* with installation of a solar thermal system of the corresponding capacity

4.4 NEW BUILDINGS

Majority of new buildings have been built in accordance with the technical regulations in act, but several have non-satisfactory construction properties such as lack of proper thermal insulation or inefficient HVAC systems.

Climate conditions on Hvar provide sufficient natural resources for high level of renewable energy sources penetration. Hvar ("sunniest island in Croatia") has great solar energy exploitation potential, as well as great biomass potential with large amount of forest areas. Such practice must be a part of Hvar Island energy policy in order to achieve self-sufficiency and sustainable development.

New buildings that are to be built should have solar SHW preparation with support in order to reduce electricity/fuel consumption during the touristic season on Hvar. Also, big consumers of cooling energy (i.e. hotels, large apartment houses) should install solar absorption cooling systems in order to reduce total costs.

Building heating systems should be designed so that completely/partially renewable energy is used (i.e. solar floor heating with support, biomass).

Proper thermal insulation on buildings, windows and doors must be applied in order to fulfill the requirements of at least grade C (≤100 kWh/m^2·a), but grade B (≤50 kWh/m^2·a) requirements are preferred. Hvar also has great potential for construction of passive houses (≤15 kWh/m^2·a heating energy) which should be a practice in such climate conditions.

GUIDELINES

+ new buildings must be built in such manner to meet the prescribed technical regulation requirements for wall, windows, doors and roof properties
+ new buildings must meet the maximum allowed heating energy demand defined in technical regulations
+ new buildings, with Hvar climate conditions taken into account, must have RES systems applied for SHW preparation/heating and/or cooling
+ RES systems can cover up to 50% of total energy consumption (heating/cooling/SHW preparation/lighting), resulting in significant savings
+ new buildings must satisfy grade B (≤50 kWh/m^2·a) of the Building energy certification regulation

4.5 SUMMARY

All of the proposed energy efficiency measures of applying thermal insulation on external walls are in compliance with the technical regulations in act. As shown in the figure below, the overall heat transfer coefficient of walls on stone buildings is reduced from 1,664 W/(m^2·K) in Sc1 (non-insulated) to 0,384 W/(m^2·K) and 0,540 W/(m^2·K) in Sc2 (only inside insulation) and Sc5 (one wall inside insulation and external insulation on three walls), respectively. Both of these cases meet the requirements of the technical regulation in act.

As for concrete walls, the overall heat transfer coefficient is reduced from 2,07 W/(m^2·K) in Sc1 (non-insulated) to 0,577 W/(m^2·K) in Sc2 (external insulation of all walls). The values for walls built from hollow brick are similar to the ones in case of concrete, as shown in the figure below.

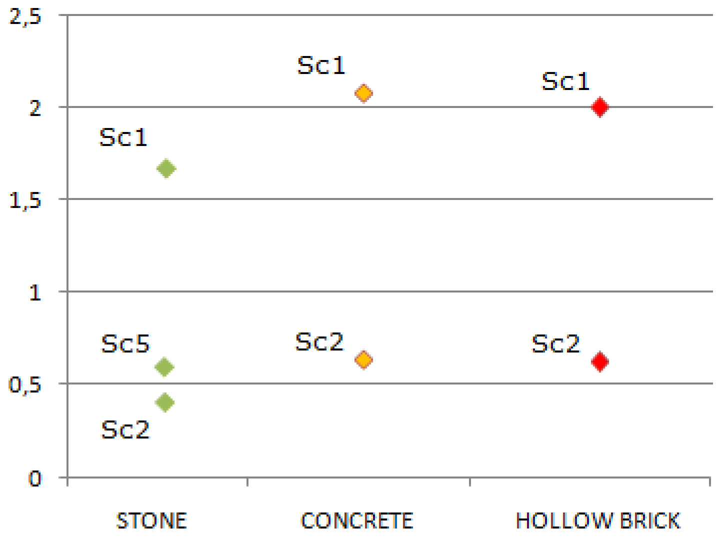


Figure 10 Overall heat transfer coefficient for insulated and non-insulated walls for respective materials

These approximate calculations show that significant progress can be achieved in all types of buildings. Of course, as mentioned before a complete assessment of all faulty elements of the building must be made to achieve maximum result.

This includes a complete examination of windows and doors on the building to discover which of them meet the prescribed requirements. Further reduction of thermal and cooling energy is envisaged with application of proper thermal protection in windows and doors.

A two-step design must be applied to assess building heat demand after application of thermal insulation on walls and replacement of old windows and doors that are proven to be inadequate. Central heating/cooling systems should be applied where possible with as high as possible penetration of renewable energy sources for such purposes. All of the inefficient electric heaters must be removed.

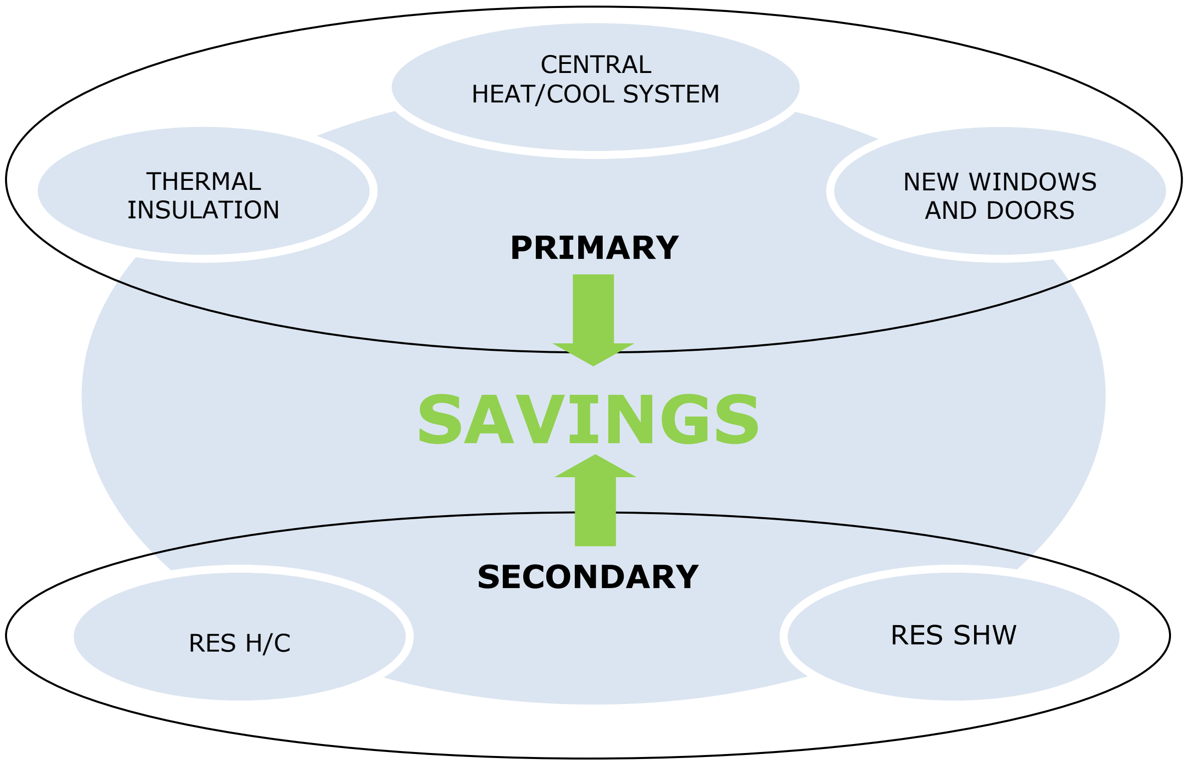
As for sanitary hot water preparation, Hvar island has great solar potential. The highest demand for hot water is during summer in touristic season when the population doubles, therefore the biggest potential lies in that period.

5 CONCLUSION

Low energy efficiency on island of Hvar causes high energy consumption which can significantly be reduced to achieve island self-sufficiency. Resources available on the island (solar energy, biomass) must be used to lower the total island energy consumption.

Maximum result will be achieved by applying energy efficiency measures:

+ PRIMARY
  - thermal insulation of the building envelope
  - replacement of windows and doors
  - application of energy efficient heating/cooling systems
+ SECONDARY
  - application of renewable energy sources for purposes of heating/cooling
  - application of renewable energy sources for purposes of SHW preparation



Although primary energy efficiency measures have higher investment requirements, technical regulations in act must be complied. Secondary energy efficiency measures have in some cases lower investment costs and result in very high impact on energy savings, especially in case of solar energy usage.

Therefore a carefully designed mix of primary and secondary energy efficiency measures must be applied to achieve optimal cost-benefit ratio for investors, all in accordance with technical regulations.