Nenad KAŽIĆ[*]

RENEWABLE SOURCE OF ENERGY (RES) VERSA HEATING& COOLING (H&C) OF BUILDINGS

Abstract: It is known that buildings represent one of the main "destroyer" of exergy. That is consequence of the low-temperature nature of buildings. Heating&Cooling processes in building are inevitably followed by energy production causing, besides the direct expenses related to fuel consumption, the additional "external" costs expressed through impact to environment and health of people. On the other side, increasing the energy efficiency (EE) and applying RES is one of possible measures in order to reduce damage. As in Montenegro there is approximately *13* 10^6 m^2 of buildings space, one of the most interesting question is: what is the potential of RES use in building H&C processes?

Key words: *building, energy, exergy, heating, cooling, renewable, solar*

Sažetak: Poznato je da zgrade predstavljaju jednog od glavnih "ubica" eksergije. To je direktna posledica relativno niske temperature zgrada pri kojoj se obavlja transformacija energije. Procesi grijanja i hladjenja zgrada su nezbježno praćeni proizvodnjom energije, tako da kao posledicu imamo ne samo direktne troškove vezane za potrošnju energije, već i dodatne troškove zbog štetnog uticaja procesa proizvodnje na prirodu i zdravlje ljudi. Sa druge strane, povećanje energetske efikasnosti i primjena obnovljivih izvora energije (RES) su mjere kojima se može smanjiti šteta. Kako u Crnoj Gori ima oko *13* 10^6 m^2 stambenog prostora, jedno od najinteresantnijih pitanja je: koliki je potencijal primjene RES za grijanje i hlađenje zgrada?

INTRODUCTION

When talking about RES &Cooling&Heating, primarily it is in mind processes in buildings. Today, many new concepts of building expressed through terminology like Low Ex house, Low E house, Passive house, Zero Energy house are, in fact, derivations of the II Law of Thermodynamics. There are many definition of this fundamental low and one of them is:

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"The potential (exergy) of every isolated system decreases" *(Fig. 1).*

Consuming energy, building in fact consumes exergy. It transforms any form of input energy into heat, Q, at relatively low temperature T_i *~300 K* (inside the building) close to external T_o. (outside of the building). Exergy of heat at this temperature is defined by Carnot relation *Ex=Q (1-To /*T_i*)*, (*Fig. 1*). It is obvious that buildings degradation factor of exergy, (*To/*T_i*)*, is more than *90%*. Therefore, energy is conserved, but potential is destroyed [5].

Building is in a fact the "big destroyer" of exergy. Every form of energy ends as heat at T_i temperature, i. e. ends as low potential. It means that every potential delivered to building will be degraded to T_i level. What is the solution?

The solution is to follow some of the modern concepts, s. c." LowEx (ergy) building". The basic idea of this approach is based on the speculation: as building degrades any exergy to low level T_i, the building should be supplied with exergy as low as possible. Of course it has to be able to perform desirable process. In other words, best strategy is: supply the building with energy at low temperature as much as possible.

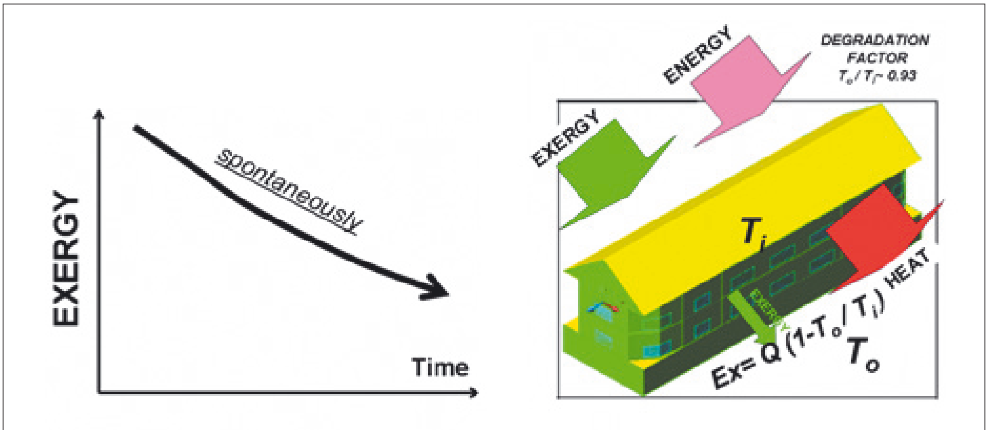


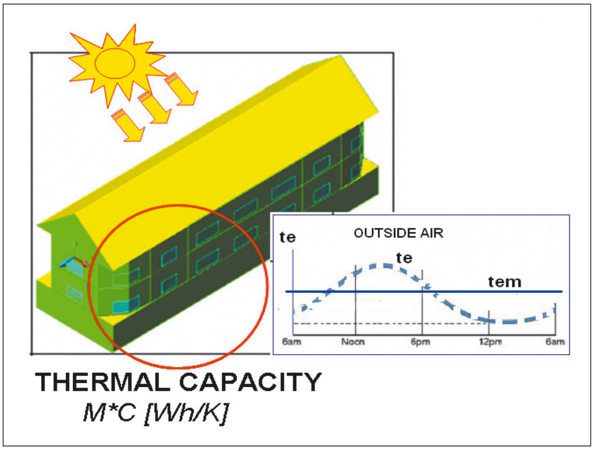
Figure 1.

ENERGY ANALYSIS

Energy analysis of building is the balance between: Thermal gains, Losses and Additional energy. In general, there are 3 types of approach: Steady, Dynamic and Quasi-Dynamics.

– *Steady model* is relatively rough model, where the dynamic nature of object is not considered. Energy balance is based on algebraic equations, while climate is presented by Heating and Cooling Degree Days (HDD&CDD). The resolution of the calculation used by this method is the month.

– *Dynamic model* treats building as complex structure of many parts in interaction. Solving diferential equation by numerical computer methods, the trajectory of bulding state throgh the time could be found. This model needs hourly me-



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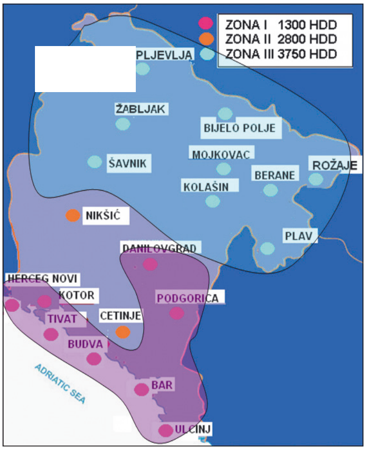


Figure 3.

teorological-data obtained from "Referent Meteo Year". The calculation resolution of this model is hour.

– *Quasi-dynamic (monthly) model* is defined in EU 13790 standard. This model is the compromise between Steady and Dynamic approach. In calculation it uses algebraic equations, monthly averaged Meteorological data (temperature, solar radiation, humidity etc). Dynamic nature of object is considered through Thermal capacity of building *(Fig. 2)*. Resolution of this model is month.

– *Meteorological data of Montenegro*

Strongly speaking, in this moment we do not have meteo data classified in an appropriate way as EU 13790 standard needs. Missing the official data, available meteo-data are classified in 3 Zone: Mediterranean (1-red), Central (2-yellow) and Continental (3-blue) and its will be used in energy analysis. Zones are established following the spirit of "old YUS Standard" and classification is based on HDD (*Fig. 3*).

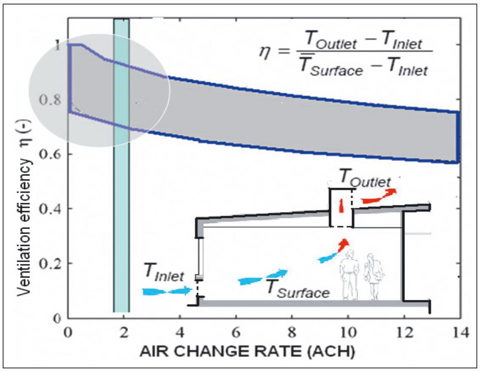
HEATING&COOLING&RES

Heating&Cooling are the most energy consuming processes in building. Here it will be analysed some of them, firstly processes related to RES application.

Night Ventilation

Night ventilation could be understood as "a heat from environment". It is obvious that one way of reducing cooling load in building could be based on "pre-cooling" thermal mass during the night. Is the air ventilation rate able to pick-up heat which is accumulated in walls during the day? Results obtained in some research projects [7] are represented at picture below (*Fig. 4*).

Diagram shows efficiency of night ventilation as function of air flow rate (air change per hour, *ACH*). It could be seen that for flow rate *ACH=2*, the ventilation efficiency is close to 1. It means that the air at outlet of the building is "saturated"



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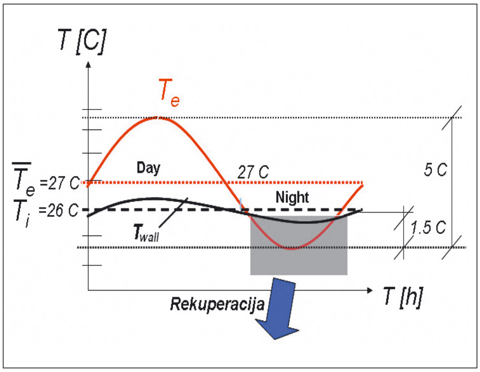


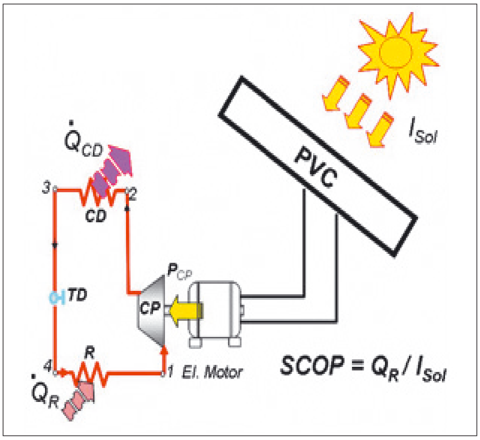
Figure 5.

by heat and its temperature is equal to wall surface temperature inside the building. So it could be expected that the ventilation air will removes max. heat from building structure as it is able to. So, it can recuperate energy in shadow region shown at *Fig. 5*, between internal-wall and external air temperature.

Analysis of meteorology data for Zone 1 in Montenegro shows that in July & August mean daily temperature of outside air is 27 C with amplitude of 5 C. It means that if the inside temperature of building is 26 C and surface temperature of the building wall oscillates about average temperature 26 C with amplitude +-1 C, night cooling thermal potential is not too high (*10–15%*).

Solar Cooling-Photovoltaic

In this case the classic cooling unit is supplied by electricity instead from electric grid, from *PVC* (with inverter) (*Fig. 6*). Solar *COP (SCOP)* is by definition Q_R/Q_{Sol}. It is obvious that the *PVC* presents additional investment.



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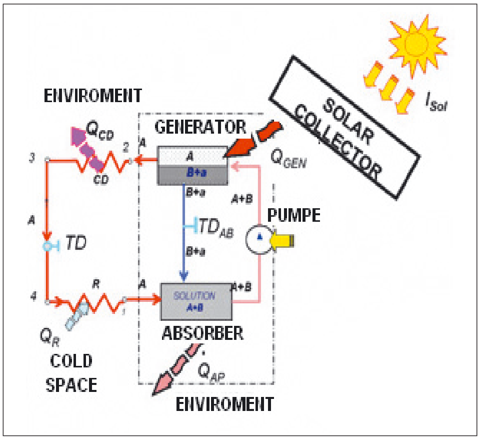
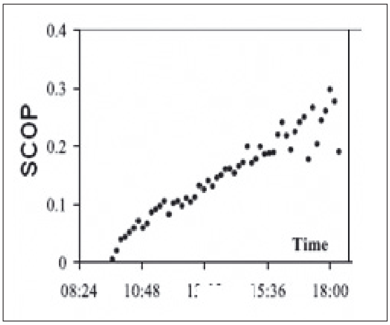


Figure 7.

Absorption Solar Cooling

Instead of compressor, this technology has a cycle with liquid solution (NH_3/H_2O or H_2O /*LiBr*) (*Fig. 7*). Water solar collectors supply generator of absorption unit with heat. By the way, the price of absorption unit is approximately 3 times higher compared to classic refrigeration (compressor) unit (~*70 Eu/kW_Cooling* versus *200 Eu/kW_Cooling*). Also, for solar collectors additional investment is necessary. Although, *SCOP* of absorption unit varies depending on thermal conditions, diagram at *Fig. 8* [4] could be assumed as representative.



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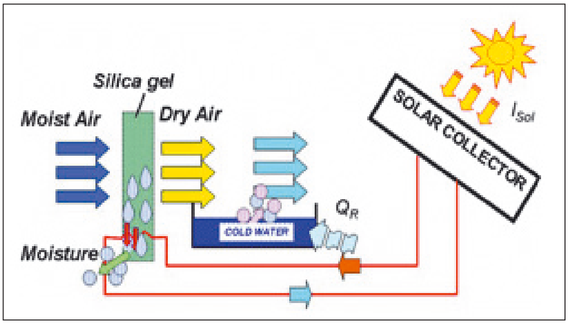

Figure 9.

Desiccant Solar Cooling

This technology is based on evaporative cooling process. It is known that interaction between air and water can produce "two cooling limits": wet bulb and dew point temperature, (*Fig. 9*). The basic rule in this process is: as air is dryer, cooling effect is stronger. Because of that, the moisture of air at inlet is reduced by silica gel, increasing its cooling capacity. In interaction with water, it cools the water. Solar collector produces heat energy for process of extraction moist from silica gel, i. e. for its cooling capacity regeneration. This is one of the most promising technology in the field of low energy cooling process.

Solar Coefficient of Performance (SCOP) – Comparison

One integral *SCOP* diagram of presented technologies at *Fig. 10* is shown [3]. It could be seen that *SCOP* of all is around *0.5* near application temperature *0 C*. As general recommendation the next rule should be used: in AC application – H_2O/*LiBr*, for *5/12 C* systems; *PVC* about *0 C*; for low temperature – NH_3/H_2O. Pay back period is 10 to 15 years and investment compared to classic (compressor) unit is 5 to 10 times more.

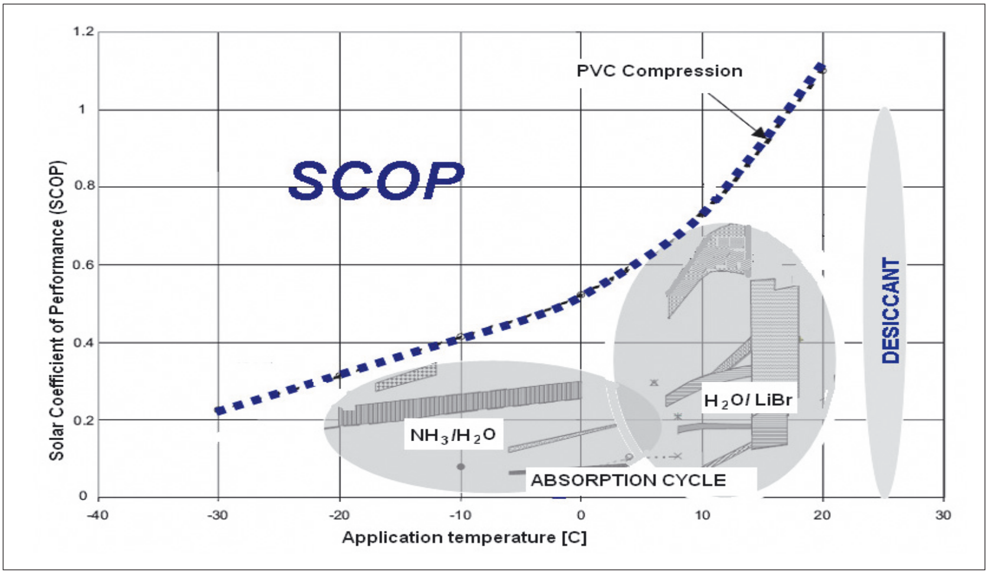

Figure 10.

Ground Coupled Heat Pump (GCHP)

In that system, ground plays a role of big heat exchanger. Heat exchange is provided by tubes buried in trenches (*horizontal)* or in boreholes (*vertical*), or by *open* loop (*Fig. 11*). In the last case tubes are disconnected and water flows through ground between tubes ends.

Following the theory of heat transfer [1], it is possible to estimate the ground temperature profile with depth in MNE. Extreme values of temperature swing around mean year temperature in interval ±*10 C* for all zones. In Zone 3 at depth of *2 m* extreme temperatures are *3* and *13 C*.

The convenient fact is that Minimum temperature of air and ground are shifted, so the maximum demands are not synchronized with minimum ground tem-

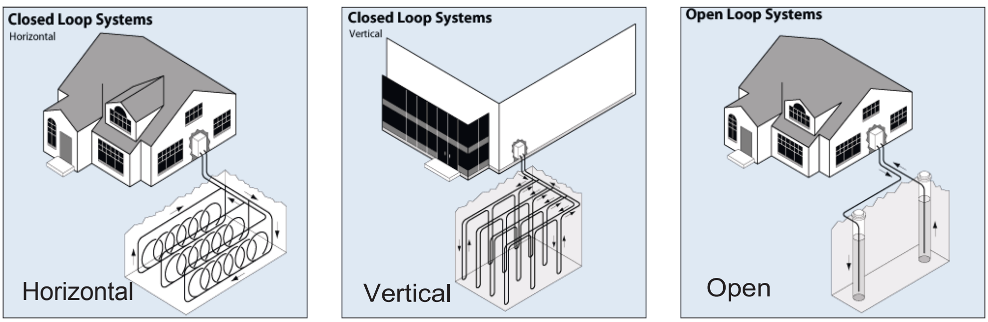

Figure 11.

perature. Vertical boreholes are usually *50 m* long each, so it is stable underground temperature.

Linear Thermal flux delivered from tube in ground is *30 W/m* for horizontal, i. e. *50 W* for vertical system. It was found that ground at far field radius ~ *1.2 m* is undisturbed [2].

If there exists underground water, the open loop could be efficient solution. For example under Podgorica at approximately *30 m* depth, there is a cold underground "river" (velocity $1.5\ 10^{-5}\ m/s$, temperature *12–14 C*). Cooling capacity of this "river" is around *60 GWh* for 3 summer months [6].

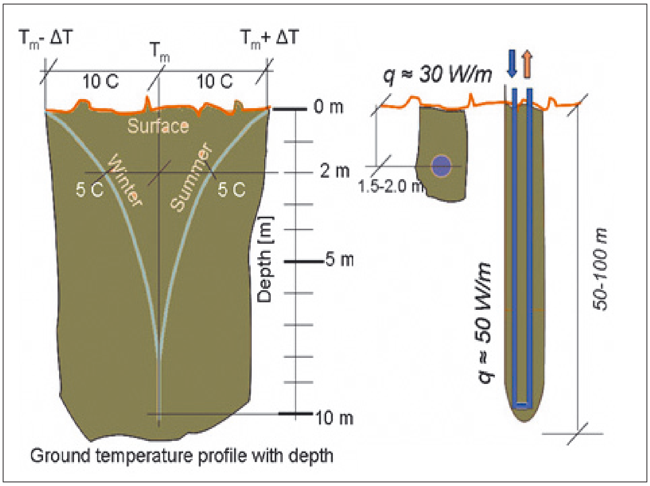

Figure 12.

EEB-PRESENT VERSA FUTURE SITUATION (IP)

Combining some statistical data it is possible to estimate energy consumption in Montenegro per dwelling.

Number of dwellings through Zones are not uniform: *53% Zone I, 16% Zone 2, 31% Zone 3*. Using HDD and dwelling distribution as weighting factors, it is possible to estimate final energy consumption which could be expected in different Zones.

But, defining *IP* (Index of Performance) as consumption of prime energy per sqm ($kWh/m^2 g$), it is needed to estimate it. Without available data, as first iteration it could be assumed that in Zone I electric energy is dominantly in use, while in Zone 3 coal (*50%*) and biomass (*50%*) are dominant fuel. With these assumptions the estimation of *IP* for Zone I and III was done (*Fig. 13*).

Following *EU 13790* standard, it was calculated *IP* for different objects in different Zones (*Fig. 14*). Calculation was done using a new proposed buildings cod. According this calculations, the main savings could be expected in Zone II and III. But before final conclusion is made, we should have in mind that present consumption doesn't provide appropriate comfort. But in any case we can conclude that potential of energy saving in Montenegro is significant.

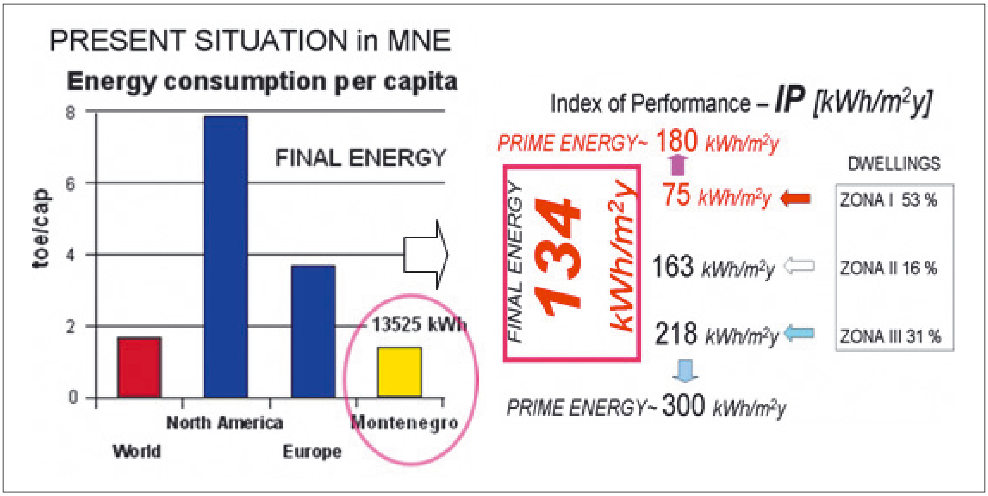

Figure 13.

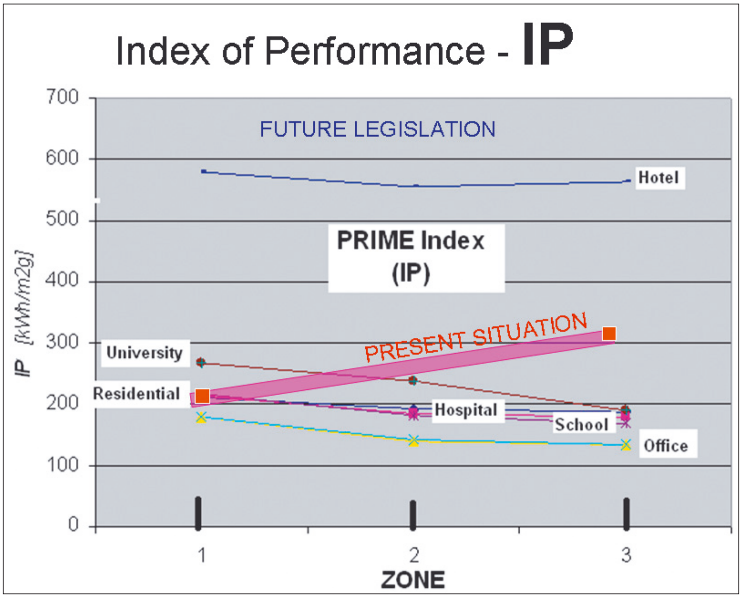

Figure 14.

CONCLUSION

Although know days concept of society, strongly insists on use of RES, on the other side calculations show that this concept is not cheap: average pay-back period is usually 10 to 20 years. Also, before any final conclusion, we should have in mind that present and future consumption very often doesn't provide same comfort in buildings., i. e. the new conditions prescribed by new building code are more demanding comparing to present. But in any case it could be concluded that potential of RES use and energy saving in Montenegro is significant.

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