SUSTAINABLE HOUSE? NATURALLY!

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Summary

In the paper I defined an idea called "sustainable house". I draw up a working version of energetic criteria of "sustainable house" with regard to Hungarian natural resources.

As a result of the idea I emphasize the growing importance of the regional energy consumption and the primer energy of building materials.

Keywords: sustainable house; sustainable building; sustainable use of renewable energies; energy policy; primer energy

1 Problem statement

It is a fact that the natural resources are limited for the mankind with the way of present use. The problem of ecological limitation of human activity is more important because the foreshows say that the population and the consumption of mankind will farther grow in the next 40 years. Reduction of environment load of building's, especially it's energy consumption, is a possible an important element how to solve the problem.

European countries use 40% of their national energy consumption for the operation of buildings. Because of this fact the building industry went through a large development in the past years. New construction systems has appeared (passive house, zero CO2 house, etc.), which need totally new knowledge of planning method, but make possible the significant reduction of energy consumption.

Nearby the operation energy of buildings it is important to deal with the manufacturing, or primer energy of buildings and building materials. Nowadays mainly academic experts deal with this problem, in the practical building planning process architects does not care with the primer energy of building materials. But it is with LCA methods provable, that in the future, when the operation energy will be reduced, the role of primer energy will be more important.

The European Union has made (Directive 2002/91/EC*)* and plane to take (passive houses standard for new buildings after 2020) different kind of action to reduce the energy consumption of buildings. I think it is questionable, if the EU will be able to draw up directives, which take care on the different economical and natural resources of member states.

In the following I am looking for the answer, if it possible to define from the point of view of ecology the definition and criterion system of "sustainable house".

2 Sustainable building

Before we would define the "sustainable house" we have to clarify its connection to the idea "sustainable building". The most frequently used definition in Hungary for "sustainable building" is the following:

„Creation and responsible operation of a healthy built environment with the effective use of resources regarding the ideas of ecology."

It is mainly evident what means the "creation and responsible operation of a healthy built environment", but we have to write more about the "effective use of resources regarding the ideas of ecology". During the planning of buildings regarding the ideas of ecology we have to consider the connections of the building and the four principle (fire, water, air, earth). We have to examine the connections of natural resources and consumer demand in the following fields (**Fig. 1**):

- the use earth of buildings and the surroundings of buildings,
- the energy management of buildings,
- the water management of buildings,
- the quality of building materials,
- the disposal of wastes during operation and housebreaking.

We have to examine the environment load of building during its whole life cycle.

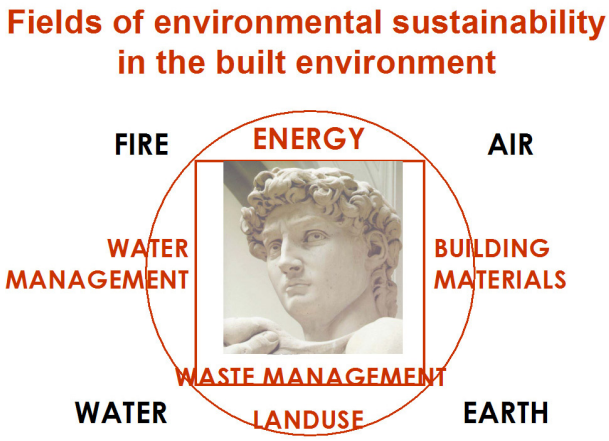

Fig. 1 The connections of built and natural environment from the point of view of ecology

In the following we examine the idea and criteria of "sustainable house" only from the point of view of energy. The reason why we restring our topic is, that the building energetic nowadays is the most important field of sustainable building, and we have several dates about energy consumption of buildings.

3 Definition of "sustainable house" and complementation to its energetic criteria system

It is clear, that on the phrasing of definition we have to take care on the natural resources and on the rate of resource consumption. It is very different if we have to define the sustainable criteria's of a single family living in a crowded forest or a large colony living in a rocky island. Therefore as we are looking for the definition of "sustainable house" we

cannot examine the building itself only as a part of a larger environment with its natural resources. The approach is similar to "ecological footprint" method, which determined how can calculate the territory need of an examined population. [1] We can define the "sustainable house" the following:

"Sustainable house" is a building the resource consumption of which throughout its life-cycle is not more than the resources available for that building in the examined area. [2]

By taking into account the broader aspects of sustainable building activity to define the energetic criteria system, at least two important complementary notes must be made:

- 1) Also the local environmental load must be studied in addition to the consumption of regional resources.
- 2) When erecting buildings, efforts must be made for cost-effective optimization – instead of minimization - of the environmental load (in this case energy use), subject to the regional conditions.

Note 1) is important, as we must not lose sight of the objective, that is, to create a healthy built environment. There are numerous feasible technological solutions (e.g. outdated wood burning), which are based on renewable natural resources, but their use indoors or in a microenvironment results in high emission values.

On the other hand, Note 2) is important with regard to the economic and social "pillars" of sustainability. It is hard to deny that a building of higher (energetic) quality calls for higher investment costs. Moreover, in general it can be established that on European level the more developed regions of higher economic potential are densely populated areas, so they have limited natural resources. Consequently, it would be unfair in social terms and hardly practicable economically, if we'd specify the same requirements for all regions. The criteria system for the "sustainable house" must be specified on regional level and the applied technologies assessed in terms of cost-effectiveness, from time to time.

4 The energetic criteria system for "sustainable houses" in Hungary (version 2.1)

In the followings I present a definition of the energetic criteria system for "sustainable houses" in connection with a relatively large region, i.e. the whole territory of the country.

A "sustainable house" construed in the context of conditions prevailing in Hungary may only rely on the yield of the country's natural energy capital (sustainable consumption of renewable energy resources). The energy demand of buildings can be covered by the following sources, depending on the natural resources of the country and on the current technical potential:

- Heating: biomass utilization, thermal water utilization, solar energy;
- Domestic hot water production: solar energy, biomass utilization;
- Cooling: electricity gained from renewable sources, as required;
- Cooking: biomass, electricity from renewable resources;
- Lighting: electricity gained from renewable sources.

4.1 What does "sustainable consumption" of renewable energy resources mean?

4.1.1 Heating – domestic hot water production – cooking (thermal energy demand)

The solar energy available within the territory of the country exceeds the demands by far as Hungary could harness 1800 PJ solar energy, while the country's total primary energy consumption amounts to 1153 PJ. Both individuals and communities may use solar energy unlimited, although energy storage as well as the initial cost of equipment required for utilization does represent a problem.

The theoretical biomass potential of the country that can be utilized for energetic purposes is 203-328 PJ, of which 200 PJ energy can be utilized according to the calculations of the Hungarian Academy of Science, or 67 PJ energy according to the document prepared earlier on ministerial level. [3, 4] Currently a considerable part of the biomass is used for electric power production in power plants, however, the energetic efficiency of this process is questionable. In terms of energetics, it is more advantageous to use a major part of the biomass for thermal engineering purposes to ensure that at least 90 PJ biomass is recovered for heating of buildings and for domestic hot water production.

A further possibility is the recovery of thermal water energy, primarily for larger-scale usage. According to the Subcommittee of Technologies of Renewably Energetics in the Hungarian Academy of Science, 10 PJ energy of the theoretical 63 PJ potential is realistically utilizable. [4]

4.1.2 Electric energy

In Hungary, renewable energy resources such as solar energy, wind energy and biomass energy can be harvested and converted into electric energy. The theoretical potential is considerable; according to the calculations of the Hungarian Academy of Science the theoretical photoelectric utilization potential of solar energy is 1800 PJ/year and that of the wind energy is 530 PJ/year, however, without biomass utilization the realistically recoverable potential is low, only approx. 15-25 PJ/year. [4]

It must be noticed that this amount of energy is insufficient for meeting the current electricity demand. If this amount of energy will not cover the electricity demand of buildings even after realization of energy efficiency projects, biomass may and must be used for additional electric power generation.

4.2 What energetic standards a "sustainable house" has to comply with?

It is possible and necessary to divide the available energy into different segments in accordance with energy demands, and energetic criteria can be specified for each segment.

For the purpose of this concept we don't specify benchmark values for the use of sustainable resources in the building material industry on account of two reasons:

- On the one hand, the energy used for the production of building materials in Hungary amounted to 10.6 PJ in year 2005, compared to the 643 PJ energy used in the residential building and communal services sector, thus it is of secondary importance as far as the present energy consumption is concerned. [5] However, the primary energy demand of applied building materials calls for further research work. Recent research results prove that natural materials have attributes that help to minimize the environment load imposed by building material production. [6]
- On the other hand, there are no statistical data regarding the ratio of applied materials manufactured in Hungary, nor is an overall data on energy demand available. Later

the below described criteria system must be corrected with the criterion relating to the production energy of building materials.

In what follows we define the criteria for the "sustainable house" only with regard to building operation. The available primary energy can be divided differently from the method described below; it is subject to political decision which energy should be used for which purpose.

4.2.1 Thermal energy: domestic hot water demand

Although the energy demand of heating constitutes the greatest part of the energy consumption of buildings, it is the domestic hot water production, for which we first specify a standard, when we determine the criteria of "sustainable house". The reason we do this is because the quantity of hot water cannot be decreased for hygiene considerations. The rate of use of the necessary renewable resources can only be rationalized by improving the efficiency of building machinery systems.

In Hungary the average hot water consumption runs up to 40-50 l/day/person in the residential and to approx. 0-10 l/day/person in the communal sector. Renewable energy resources (60 % solar energy, 40 % biomass or thermal water) can be used to satisfy the domestic hot water demand. Considering the total population of the country and 10,000.000 "unit consumers", and assuming 85 % efficiency of building machinery at net 12.5 PJ, the gross energy demand of domestic hot water production amounts to 14.5 PJ.

Based on the above it can be established that in a "sustainable house" the energy demand of domestic hot water supply can be satisfied in Hungary by harvesting solar energy in the conventional way, and at maximum 1.45 GJ or 400 kWh biomass or thermal energy use per annum per person. Assuming 85 % efficiency of building machinery and considering the typical domestic hot water demand of households and communal buildings (4:1) and with regard to the area ratio of residential and communal buildings (2:1), gross 10 kWh/m^{2}a biomass or thermal energy is required in case of residential buildings and gross 5 kWh/m^{2}a in case of communal buildings.

4.2.2 Thermal energy: heating energy demand

Having defined the renewable energy required for hygiene purposes, we can proceed to determine the energetic criterion for the heating systems of buildings, which have the highest energy demand.

According to section *„What does sustainable consumption of renewable energy resources mean",* potentially 90 PJ biomass, 10 PJ geothermal energy and unlimited wind and solar energy can be harvested in Hungary. Since we have to use 14.5 PJ energy for domestic hot water production, only 86.5 PJ biomass and geothermal energy can be utilized for heating purposes. Direct use of solar energy and wind energy for thermal, i.e. heating purposes is not economic according to the present state of knowledge and professional recommendations.

Therefore, we use two hypotheses to calculate the heating energy demand:

- a) According to the per capita amount of energy: Dividing the available energy by 10,000,000 (the population) the per capita energy is 8.6 GJ or 2,400 kWh/year/person, which means about 5 q firewood per year per person. Considering that this amount must cover the heating demand of both households and job sites, 3.5 q/year/person firewood can be calculated for the heating of dwelling houses.

- b) According to the energy demand per square meter: The building stock of Hungary represents about 480,000,000 m^2 (4,000,000 flats of average 80 m^2 area, and about half as much office and public buildings). With regard to the heating energy demand of this sector, the gross primary energy demand of the „sustainable house“ runs up to 50 kWh/m^2a biomass or thermal water energy. The benchmark value can be specified as net heating energy demand of 43 kWh/m^2a, with reference to the energetic quality of the building and assuming 85% efficiency of building machinery.

The followings must also be considered for specification of the heating energy demand:

- 1) It is recommended to determine the benchmark value according to method b). For building design purposes it cannot be defined how many persons will occupy a given building, which – in case of method a) – would require different benchmark values to be considered by the designer.
- 2) The benchmark value can be considered an average value. Later the benchmark values should be made more specific for new buildings, existing buildings to be modernized in terms of energetics or for existing buildings that cannot be modernized (historic buildings).

4.2.3 Electricity demand: cooling, household appliances

According to the conservative hypothesis outlined in section *„What does sustainable consumption of renewable energy resources mean“,* for meeting the electric energy demand required for building operation, where we did not took into account biomass utilization, 15-25 PJ energy can be harvested from renewable energy sources. This amount of energy is available for meeting the energy demand of cooling, lighting and household appliances. As the energy consumption of dwelling and communal buildings currently amounts to 83 PJ, the energy consumption must be radically reduced.

In case of family houses, adequate architectural and structural design can completely eliminate the energy demand for cooling under the present climatic conditions. As for offices and multi-level dwelling houses, the energy required for cooling the buildings could be an order of magnitude lower by applying recuperative ventilation systems or systems for cooling the structure or geothermal heat pumps instead of conventional air-conditioning systems. Even the energy demand of lighting systems and household appliances must be further reduced, since the annual energy consumption of an average dwelling house in Hungary without cooling amounts to 1,500 kWh, which means 20 kWh/m^2a for a flat of average size.

If we wish to provide electric power for the „sustainable house“ only from regionally harvested water, wind and solar energy, 25 PJ energy is available. Considering the typical electricity consumption of households and communal buildings (1:1) and the area ratio of households and communal buildings (2:1), gross 11 kWh/m^2a in case of dwelling houses and gross 22 kWh/m^2a in case of communal buildings must be provided by harvesting the water, wind and solar energy to meet the cooling, lighting and other electric energy demand of the buildings.

5 Case study

5.1 Hungary's first non-qualified passive house

The family house of 300 m^2 area was constructed in accordance with the recommended passive house technology (**Figure 2**). The walls are made of concrete by using polystyrene falsework, and the floor structure is heat-insulated slab with polystyrene concrete filler. The windows have 3-pane heat-protection glazing, thus the air-tightness of the building meets the passive house criteria. A recuperative ventilation system fitted with ground collector is operated in the building. A ground source heat pump provides supplementary heating and domestic hot water production. Currently two adults and three children occupy the building.

The total annual energy consumption of the building is 11,400 kWh. Two components make up the energy consumption related to heating and domestic hot water production: annual current drain of the heat pump is 4,000 kWh, and the recuperative ventilation system requires 1,700 kWh energy. Consequently, the building's energy consumption per area is 19 kWh/m^2a for heating and domestic hot water production, and 19 kWh/m^2a for other electric appliances.

The building does not comply with the energetic criteria specified for the „sustainable house". Of the total 38 kWh/m^2a consumption only 12.5 kWh/m^2a can be considered as gained from renewable energy resources. If we wish to produce the remaining 25.5 kWh/m^2a energy using biomass in the ordinary thermal plants currently operated in Hungary, we would need at least three times as much primary energy sources. This way the house would require 75 kWh/m^2a energy from renewable energy sources, while in accordance with section „*What energetic standards a "sustainable house" should comply with?*" only 60 kWh/m^2a energy of the country's resources can be used by sustainable utilization of renewable energy sources. It must be noted, however, that by using solar collectors for hot water production the house could meet the energetic criteria of „sustainable house".

Fig. 2 Building constructed using the passive house technology

6 Evaluation of the „sustainable house" concept

The followings must be considered for evaluation of the concept:

- relation between the present status of energy consumption and the computed potential,
- regional characteristics of energy supply, and
- technical and economic possibilities of realization.

Table 1 shows that the total residential and communal thermal heat demand (heating, domestic hot water production) is approx. 427 PJ, while currently the total utilization of thermal biomass and geothermal energy amounts to about 43.5 PJ (approx. 40 PJ biomass and 3.6 PJ geothermal) according to the 2009' data published by the Hungarian Central Statistical Office. Comparing the electric energy demand and potential reveals an even higher disproportionateness. **Table 1** shows that present consumption is 84 PJ, while we produce 6.8 PJ (5.7 PJ biomass and 1.1 PJ wind and water) by harvesting biomass, wind and water energy. [7]. Thus the utilization rate must be significantly increased to achieve the renewable energy utilization assumed for the criteria system!

Tab. 1 Areas of residential and communal energy consumption, based on 2005' data published by the Hungarian Central Statistical Office [5, 8]

Sector	**Residential**		**Communal**		**Total**
	PJ	**%**	**PJ**	**%**	**% (nationwide)**
Heating	229.7	54	141.5	65.0	32.19
Transport	110.6	26	19.6	9.0	11.29
Cooling, lighting, cooking, other electric power	38.3	9	45.7	21.0	7.28
Hot water production	46.8	11	10.9	5.0	5.00
Total of above items	425.4	100	217.7	100.0	55.77
Total energy consumption in Hungary	1153.2				100.00

It is important to emphasize that the „sustainable house" criteria must be determined on regional level. Let's consider the example of heat pumps or passive houses, that is, the electric energy based heating systems. Although these technologies might be supported in certain EU member states or even on EU level, in my opinion they are not ideal for Hungary. **Table 2** shows that while the present value of renewable electricity production is 183 PJ in Austria and average 38 PJ in the EU, the same value is only 7.2 PJ in Hungary, considering 10,000,000 inhabitant-equivalent. Furthermore, with regard to the electric energy based heating systems in Hungary it must be taken into consideration that according to section „*What does "sustainable consumption" of renewable energy resources mean?"* the economically feasible potential of electric power generation using renewably energy sources runs up only to 25 PJ even over the medium term, without taking into account the power plants using biomass. This amount of energy fails to meet even the present typical household energy demand, so even application of state-of-the-art electric energy based heating and domestic hot water production systems would not facilitate sustainability, if we consider the present technical and natural conditions.

Tab. 2 Primary energy consumption of EU and certain member states [9]

	EU27	Germany	Austria	Hungary
Primary energy consumption (PJ)	75 626.17	14 214.19	1 415.14	1 130.44
Population (million inhabitants)	495.00	82.30	8.30	10.10
„Hungary scale“ measurement of primary energy consumption measured " (PJ)	1 543.08	1 744.39	1 722.04	1 130.44
"Hungary scale“ measurement of renewable energy usage (PJ)	120,45	144,38	407,58	59,45
"Hungary scale" measurement of electric power generation (PJ)	246,77	281,35	277,62	143,76
"Hungary scale" measurement of electric power generation using renewable resources (PJ)	38,58	41,38	183,03	7,20
Informative data: assuming the buildings in Hungary, electric energy per square meter (kWh/m^{2}a)	22,34	23,96	105,97	4,17

Decisions have to be made on regional professional political levels to specify which building operation systems should be supported by utilization of which natural resources. Based on these decisions the utilization of renewable energy sources must be increased up to the limits defined in the criteria system. Having achieved this level, we'll be able to establish that there are benchmark values, based on which it is technically feasible to realize operation of all Hungarian buildings using the country's own resources.

As for the heating energy demand, the 43 kWh/m^{2}a heating energy demand calculated as an example is higher than the 15 kWh/m^{2}a specified for passive houses in case of new buildings or the 30 kWh/m^{2}a proposed for restoration. Making the most of the lesson learned from the technical solutions applied in passive houses, it is possible to design buildings, which meet the criterion of sustainability both in case of new constructions and restoration projects. Hereby it must, however, be emphasized that building machinery systems must be applied in „sustainable houses“, which can be maintained using the country's own existing resources.

Although further research is required to investigate the possibilities of economic realization of „sustainable houses“, it is likely that because of lower energetic benchmark values, „sustainable houses“ can be constructed at a lower cost than passive houses.

7 Conclusion

The most important fundamental element of the „sustainable house“ concept is the use of construction and building operation technologies, which can be operated by using existing own inherent resources. The following assertions and tasks can be stated with a view to the application and further development of the concept:

- 1) Sustainability criteria must be defined for all areas of environmental sustainability as well as for energetics.
- 2) It is theoretically proven that – considering the regional conditions of Hungary – an energetic criteria system can be defined for the „sustainable house“, which is technically feasible and in case of realization the country's own renewable energy resources can cover the energy supply demand of the country's buildings.

- 3) To meet this criteria system it is essential to radically reduce the present energy consumption and significantly increase the utilizable renewable energy sources.
- 4) It is proposed to define the sustainability criteria system on regional or micro regional level, subject to local conditions.
- 5) In case of building sustainable houses, the task is cost-effective optimization not minimization of the energy demand of buildings, subject to local conditions. Applicable technologies must be studied and evaluated from time to time also with a view to their cost efficiency rate.
- 6) „Natural“ building materials of low environment load must be applied as far as possible.

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