LOW ENERGY AND SMART BUILDINGS – ANALYSIS OF ENERGY CONSUMPTION IN THE ALL LIFE CYCLE OF BUILDING

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Summary

The necessity of limiting energy consumption, also as far as building is concerned, is an obvious matter and it is an important element in the strategy of sustainable development. In temperate and frigid zones possibilities of considerable energy consumption decrease, connected mainly with heating and exploitation of the buildings, are big. The significance of the problem is stressed by the fact that about 30-40 % of the total energy used in such zones is used for this purpose. It should also be stressed that the effectiveness of the activities undertaken to decrease energy consumption is high. It refers both to the possibility of visible limit in conventional energy consumption and the economical effectiveness of the projects undertaken.

Keywords: Low energy buildings, intelligent buildings, LCA, energy-consumption

1 Sustainable development and building

“European Union Strategy of Sustainable Development” Goeteborg 2001 includes recommendations and principles collected in four thematic groups:

- Social and economic problems.
- Natural resources protection and management.
- Intensifying the role of the main social groups.
- Realization possibilities.

Leaving problems 1 and 2 to the politicians and economists, in sphere of technology the problems in the second group are of basic importance.

Principles in sphere of technological activities are as follows:

- planning and management of the areas as resources, through promotion of sustainable area consumption;
- providing atmosphere preservation through proper energy resources and the form in which they are used in building, transport and industry;
- realization of sustainable building;
- providing integrated protection of infrastructure, through proper management system of energy, transport, water, as well as sewage and waste treatment;
- waste and pollution minimization, among others through promoting systems of the so called clean production

Recommendations referring to legal and economic regulations:

- adjusting national legal regulations to the Sustainable Development strategy
- giving consideration to the problems of the environment and its development in legal acts, planning and management;
- preparing a system of economic and environmental accountability;
- developing clear legal and standardization regulations.

Let us stress that in the general recommendations the second in importance is the requirement: "providing atmosphere preservation through proper energy sources economy and the form in which they are used in building, transport and industry."

Conditions of sustainable development determine a new approach to evaluating activities relating to building. The goals, aims and methods of solving the problems in sustainable building have become the subject of worldwide congresses at which it is possible to exchange opinions and experiences. A congress in Tokyo is one of them.

Fig. 1 illustrates a change in principles (widening of criteria) of estimating activities within the sphere of building for Sustainable Building.

As it can be seen, one of the basic criteria is limiting energy consumption in the life - cycle assessment.

Tab. 1 gives a specification of categories and criteria applied in estimating habitat buildings, taking into consideration sustainable development conditions, in project E-Audyt/GBC 2000/02.

Let us observe that:

- 10 out of 26 criteria of estimating sustainable building is connected with limiting energy consumption,
- and, what is worth underlying, all these criteria are measurable and an explicit quantitative assessment is possible here.

Taking into consideration the fact that limiting conventional energy consumption is also one of the general conditions of sustainable development, it can be assumed that the following theorem is mathematically proved:

Each habitat building, being a sustainable development building, must be energy-saving.

Naturally it is an indispensable but insufficient condition and not every energy-saving building is a sustainable one.

Tab. 1 Specification of categories and criteria applied in habitat building estimation in E-Audyt/GBC 2000/02 project

	E Audyt / GBC 2000/2001
NATURAL RESOURCES UTILIZATION	**COEFFICIENTS OF SUSTAINABLE DEVELOPMENT**
Energy	Primary energy consumption connected with* building exploitation
Area	Area taken by the building and its surrounding
Water	Water consumption in building maintenance
	Annual emission connected with building exploitation*
MATERIALS	**RESOURCES CONSUMPTION**
	Energy consumption cycle*
	Water consumption
	Materials consumption*
ENVIRONMENTAL LOADINGS	**LOADINGS**
Air pollution	Emission*
	Ozone layer destroying emission*
	Emission causing acid rains*
Waste materials	Waste materials*
Sewage	Sewage
Other loadings	Influence of the object on the area and neighborhood
INDOOR ENVIRONMENT	**INDOOR ENVIRONMENT QUALITY**
Air quality	Air quality and ventilation
Thermal climate	Thermal climate*
Visual comfort	Daylight, brightness and eye-contact with the surrounding
Noise and acoustics	Noise and acoustics
DURABILITY	**QUALITY OF SERVICE**
Adaptability	Elasticity and adaptability
Functionality maintenance	System's susceptibility to check-up
	Function maintenance
	Quality of the surrounding and area management
BUILDING REALIZATION AND EXPLOITATION	**GUIDELINES FOR CONTRACTORS AND MANAGERS**
Project and its realization	Construction process planning
Exploitation plans	Supervision
	Exploitation planning
	Means to limit private transport
OTHERS	**ECONOMY**
Localization and transport	Building's costs in LCA
strenuousness for the surrounding	

2 Energy-saving and low energy buildings

Adjusting national regulations to the strategy of sustainable development, which is now gradually realized in the European Union, introduced into habitat building, at the turn of centuries, standardization regulations visibly limiting energy demand necessary for exploitation in this building sector. Effects were mainly due to sharpened requirements in the range of thermal insulation of external partitions and to defining the limits for the maximum values of the coefficient of annual energy consumption for heating. In spite of some differences in the regulations of member states, it can be generally admitted, in the context of commonly at present used materials, products and technologies, that buildings designed in agreement with these requirements are energy saving ones (**Fig. 2b**).

It is yet necessary to notice that in the new member countries there is a serious problem of heating energy consumption in the existing habitat buildings built in previous years. It is 70-80 % of the exploited buildings. This also refers to Byelorussia, Ukraine and European part of Russia (**Fig. 2a**). To heat those buildings a very big amount of energy is consumed. Therefore in these countries limiting energy consumption in habitat buildings is very urgent and can be solved by thermo-modernization of the existing buildings. The problem is only signalized here. In Poland the problem is appreciated and thermo-modernization of the existing buildings is gradually progressing. Yet the financial means are still insufficient.

Apart from buildings fulfilling present standard requirements, there are now realized buildings with considerably lower energy consumption and this is not only heating energy consumption. Such buildings belong to low-energy ones. Possibilities here are big, which can be proved, among others, by buildings realized in piloting programs. The buildings realized at present (not experimental ones) have final energy consumption of 120-130 kWh/m² (**Fig. 2c**). Heating energy consumption in such buildings is 60-70 kWh/m² a. As experience of piloting programs indicates it is possible to further limit the consumption.

Further increase of standard requirements can be postulated. They should define total energy consumption requirements and in the next stage define it as e.g. 120-150 kWh/m² a.

On the other hand, through credit policy (interest) low-energy buildings should be promoted. Limits for such buildings, on the basis of present knowledge and piloting programs experience, can be defined on the level of 70-80 kWh/m² a.

However, it seems that passive ($E \leq 40$ kWh/m²a and $E_o \leq 15$ kWh/m² a) and zero-energy buildings, for the considered climate zone, will remain experimental ones for a relatively long time. They will also be the buildings for verification of the new concepts within the form and function, as well as in solving material and technological problems and process steering in the exploitation stage.

3 Low-energy intelligent buildings

Nowadays, more and more habitat buildings, both one and multi-family ones, are realized with the systems steering their exploitation. The basic element, also a marketing one, in favour of applying these systems is safety (**Fig. 3** right side). At present the cost of such systems is not low. Introducing them makes the costs of the investment increase up to 7.8 %. However, developing them by adding additional functions is no longer expensive. On the basis of the analyses carried out it can be stated that introducing the whole program of steering energy consumption allows to lower it by about 20-30 %. In consequence the costs of installing the whole system will pay back in 4-5 years.

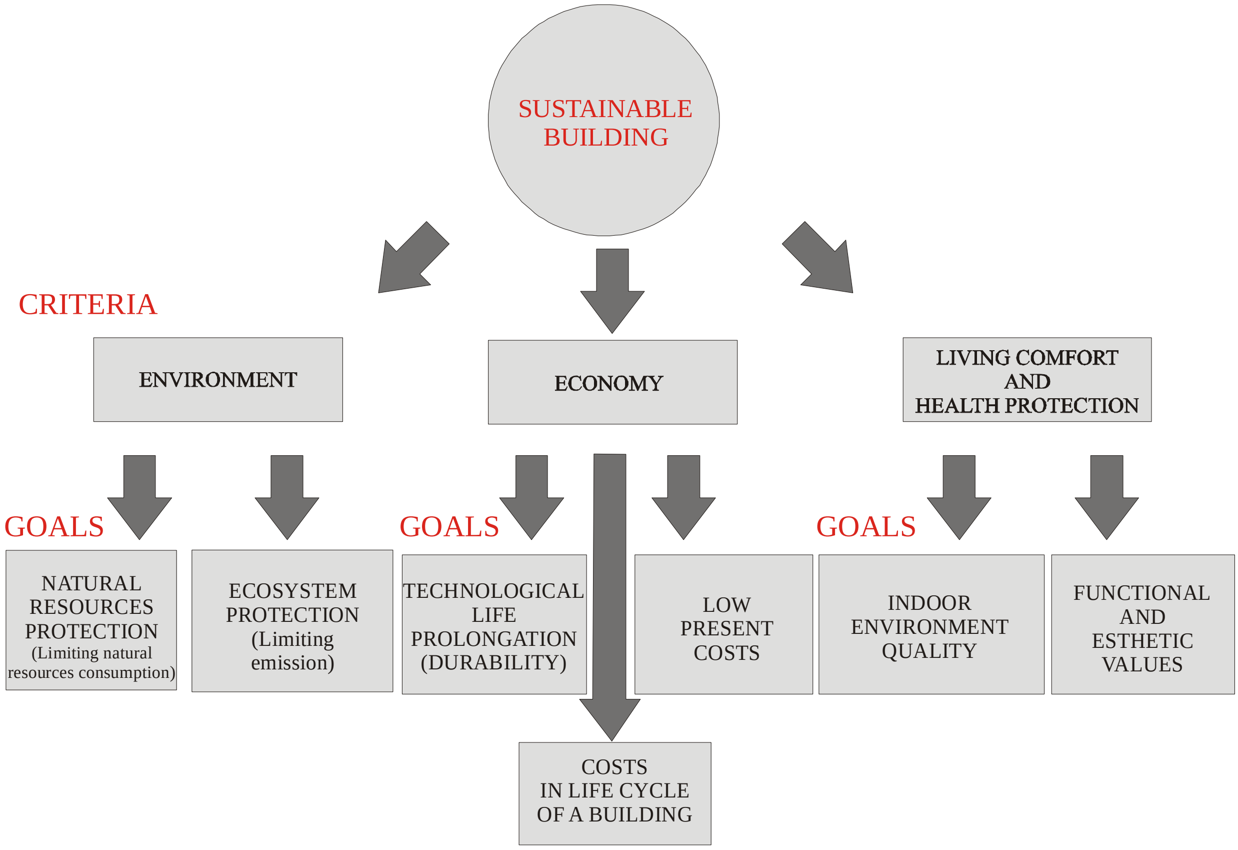

Fig. 1 Sustainable building – estimation criteria

The low-energy building requirements can be fulfilled through rational structural (design) constant solutions, which are such solutions in which features (parameters) do not change in the process of exploitation, as well as the variables whose parameters have to change during exploitation:

Exemplary set {X} of solutions used in low-energy and passive buildings (which can be recognized as features of these buildings) and its division into classes:
{X1} constant solutions, unchangeable during exploitation,
{X2} solutions whose parameters change during exploitation, shown in **Tab. 2**.

There are also given the most frequent subdivisions of class {X2}:
{X 21} – solutions whose parameters can be steered manually or automatically,
{X 22} – solutions whose parameters can be steered interactively.

Analogical procedure can be adopted in passive buildings on condition that here there can be considerably more solutions, which need active steering.

From the exemplary statement in **Tab. 2** it is clearly visible that in order to continue limiting energy consumption in habitat buildings, and looking wider in the so called buildings from ”municipal-vital sphere”, it is necessary to design them as intelligent buildings.

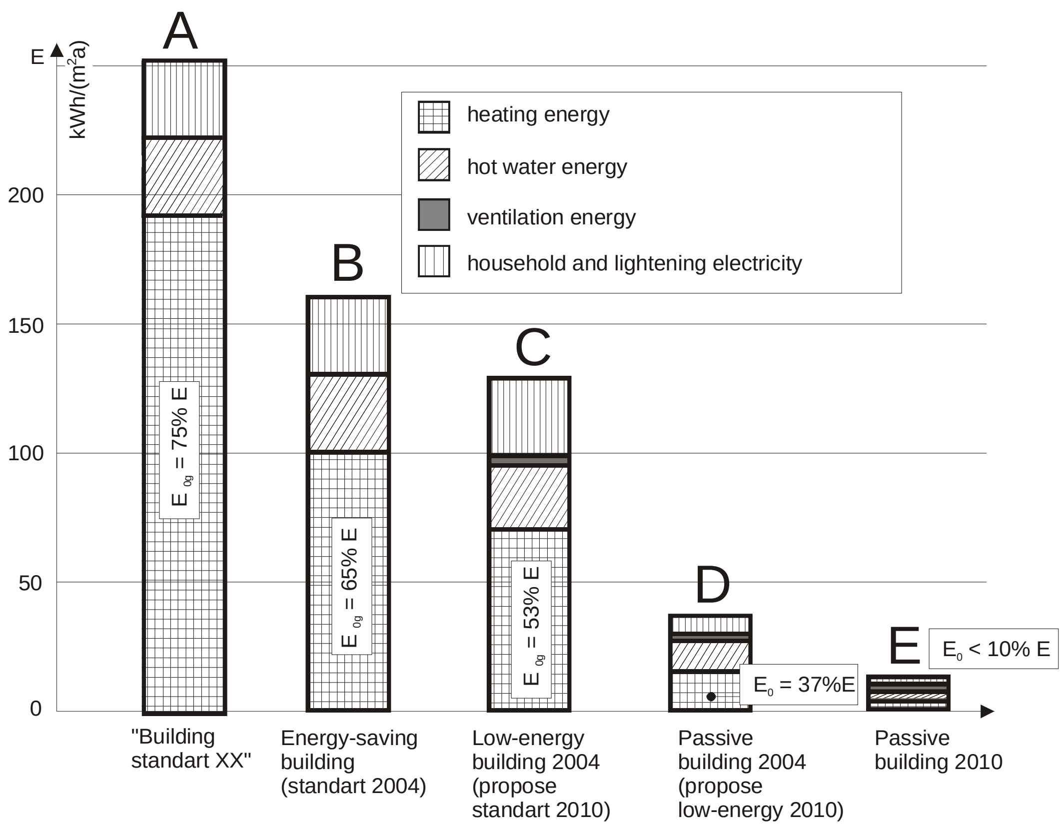

Fig. 2 Habitat buildings energy consumption

Tab. 2 Decision variables to estimate energy consumption in buildings exploitation

No	Design solution (feature) Set {X}	Constant parameters in exploitation Class {X1}	Variable parameters in exploitation Class {X2}	
			Manual or automatic steering subset {X21}	Intelligent system of steering subset {X22}
1	Localization in the area and orientation to quarters of the globe (decision variable of great importance in piloting buildings and if necessary in dispersed development, yet in common building often limited by circumstances of localization)	+		
2	Form and function of building (shape ,size and distribution of windows – maximum southern wall glazing, functional zoning, buffer spaces – these may be strongly limited by investor's requirements)	+		
3	Optimum thermal insulation of external partitions (high thermal insulation, transparent insulations, tightness, modern solutions of windows with high insulation and low emission)	+		
4	Securing tight coating of building, elimination of optimum thermal bridges < 0.01 W/mK	+		

5	Securing building thermal inertia	+		
6	Selection of optimal heat sources in respect of efficiency and pollution	+		
7	Use of passive solar systems and energy storage (collector walls, storing energy in the ground using phase changing materials from wax group, and the like)	+		
8	Use of passive systems for ventilation energy recuperation	+		
9	Use of passive systems for sewage energy recuperation	+		
10	Securing energy-saving equipment		+	+
11	Steering of internal temperatures(depending on time, function and way of using)		+	+
12	Variable elements of external partitions, including those connected with passive solar use (venetian blinds, roller blinds, external shading, thermal shutters)		+	+
13	Lighting regulation		+	+
14	Active solar systems, (photothermical or photovoltaic conversion, systems with liquid collectors)		+	+
15	Active systems for ventilation energy recuperation		+	+
16	Heating systems with heat pump (which use natural environment and wastes as a lower heat source)		+	+
17	Use of active, unconventional forms of energy conversion and storage		+	+

An intelligent building should fulfill the following conditions:

- it must be controllable, that is it must be equipped with the active elements which would allow a change in its status
- its controlling system may include automatic steering, based on programmed process or on direct decisions of the user, but it also must possess active (interactive) steering system, that is the building must be equipped with sensor system which would register external signals, thus realizing monitoring and steering (according to the scheme: signal - data transformation – starting active installation – actors – steering);
- it must have hardware network as well as common control system installed

Variable elements of low-energy buildings require control, most of this control must be an active one.

Variable elements of the external partitions should be steered, for example, on the basis of measurement parameters of external environment, such as insolation, temperature, humidity and wind speed.

Another example is the heating system (which should be steered by the external and internal environment parameters). It can be controlled on a few levels: global level, for instance, means steering the whole building, while individual level covers separate spaces. Thus it is possible to introduce heating zones independent from each other. Measured signals sent to the main unit allow to modify the amount of energy needed in a given place and moment. In this case optimal steering can be introduced at a minimum of energy consumption. In large buildings such heating system can reduce energy consumption even by 50 %.

It must be stressed, however, that in habitat buildings controlling energy consumption, or air-conditioning of the interior, realized by intelligent systems, should be possible to be wholly or partly switched off and replaced by manual steering. In fact a house is not a “machine for living in” and it should be the person living in it who decides about his own comfort. And his individual, subjective feelings may be for some time different than the standard. There are cases that “oversteering of the intelligent systems” made the users unwilling to live in passive houses.

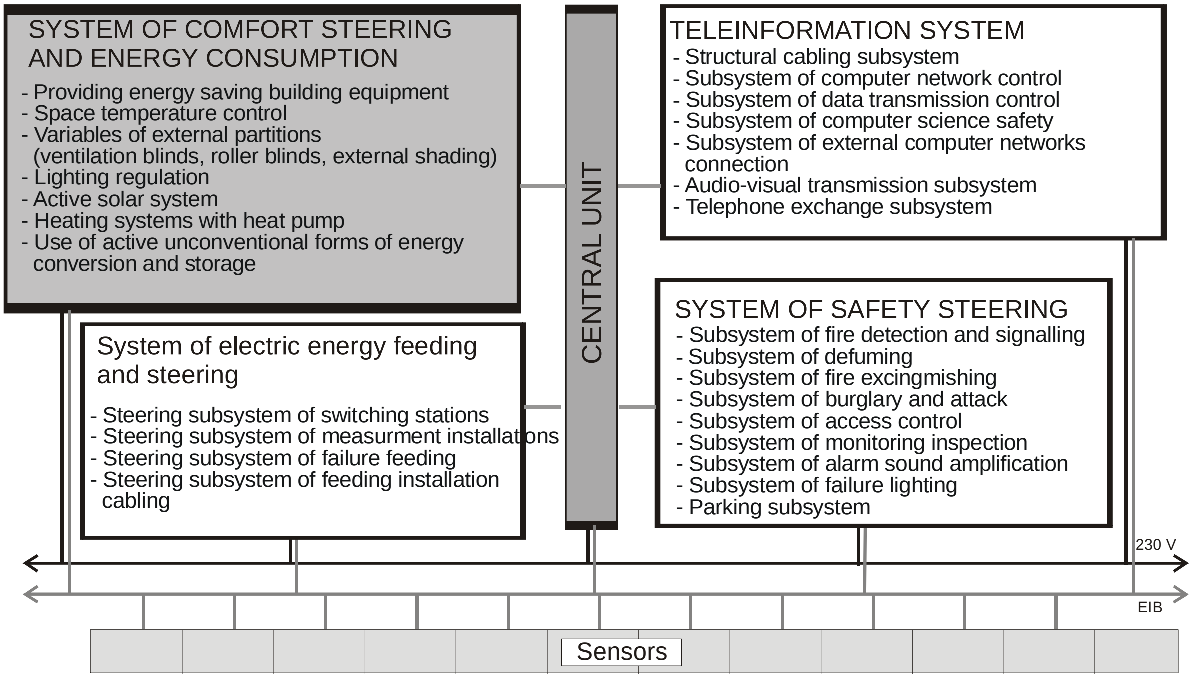

Fig. 3 A system of exploitation steering of a habitat building

4 Estimation of heating energy consumption in the whole life cycle of the building

Estimation of the whole cycle for materials, in accordance with ISO 14000 fully answers the problems of habitat buildings estimation. Generally these are products of a long usage cycle. The basic problem here is to estimate the costs of exploitation (**Fig. 4**)

Considerable differences in energy consumption of construction – material solutions can be shown (Fig. 5). However, these are of marketing value rather. On the basis of extensive analyses it can be stated that the differences in energy consumption in properly designed constructions do not exceed 20 %. In comparison to the energy indispensable in habitat building exploitation the difference is small.

Yet the basic condition here is that designing, material and construction solution should be, in the meaning of engineering art and present knowledge, a proper one.

On the other hand, estimation within the sphere of demolition, disassembly and waste utilization, seems at present not to be wholly reliable. Putting aside habitat buildings of light wooden construction (domineering in the USA) where this problem is practically solved, the analysis of these problems in the perspective of 50-70 years of habitat buildings exploitation, seems to be an activity on the border of futurology. If this problem finds proper place in legal norms, then technologically, in this period of time, it will be solved. It will be rather difficult to “transfer it to the areas where such normalizations are not in force”. It can be illustrated by the progress, in the last 20-30 years, in respect of disassembly and utilization of reinforced concrete.

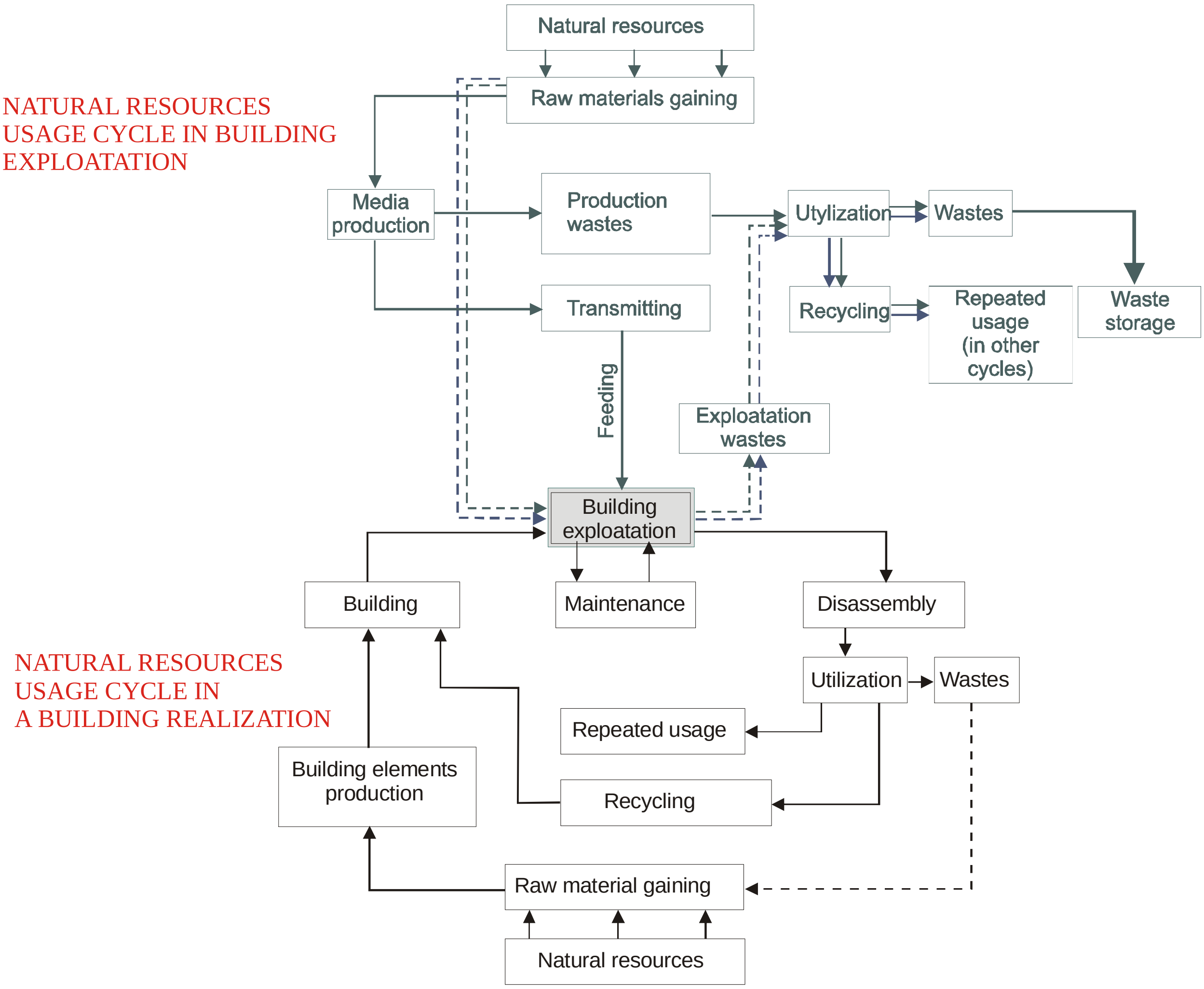

Fig. 4 Life cycle estimation for habitat buildings

material	energy consumption for production 1 m^3 material
CONCRETE	540 - 720 MJ
PRECAST CONCRETE	600 - 800 MJ
STEEL	1800 - 2200 MJ
ALUMINIUM	2900 - 3200 MJ
PLASTIC	1700 - 2500 MJ
TIMBER	30 - 100 MJ

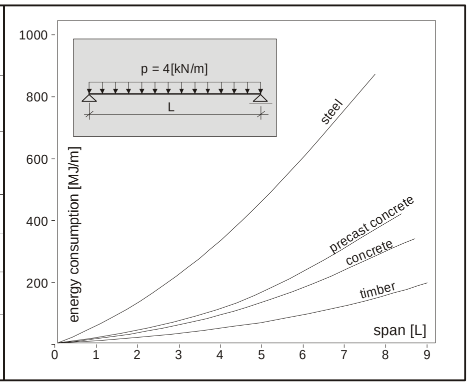

Fig. 5 Materials and structures energy consumption .

5 Final remarks

From the above considerations and analyses results it appears that:

- Each habitat building, being a sustainable development building, must be energy-saving.
- The basic problem in estimating energy consumption, as well as environmental relations in habitat building, is the problem of energy consumption in the process of exploitation.
- An important effective way to solve this problem is to design habitat buildings as intelligent buildings.
- Bringing about effects on the global scale depends on common acceptation of the rules of sustainable development (who signed the Kyoto convention where the requirements within sustainable development are brought into the normative regulations?)

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