The Prospective Assessment of Zero-Energy Dwellings

Jovana Dj. Jovanovic, Svetlana M. Stevovic

Abstract**—**The highest priority of so called, projected *passive houses* is to meet the appropriate energy demand. Every single material and layer which is injected into a dwelling has a certain energy quantity stored. The *passive houses* include optimized insulation levels with minimal thermal bridges, minimum of air leakage through the building, utilization of passive solar and internal gains, and good circulation of air which leans on mechanical ventilation system. The focus of this paper is on passive *house* features, benefits and targets, their feasibility and energy demands which are set up during each project. Numerous *passive house-standards* outline the very significant role of zero-energy dwellings towards the modern label of sustainable development. It is clear that the performance of both built and existing housing stock must be addressed if the population across the world sets out the energy objectives. This scientific article examines passive house features since the many passive house cases are launched.

Keywords—Benefits, energy demands, passive houses, sustainable development.

I. Introduction

CONTEMPORARY building techniques and practices lead to mainstream, sustainable demonstration projects such as numerous compilation projects in Sweden and Netherlands, Germany and Austria. There have been made considerable efforts to support and disseminate such ideas to create sustainable design, sustainable residential area and appropriate surroundings [1].

In the passive house concept, all energetic issues are on behalf of *ISO 7730, DIN 1946* and further legislations [2]. Prefabrication of building elements offers both a potential for cost reduction and allows for improved quality control. Passive Houses are rather similar in construction to standard buildings and no special construction type is required. Materials scientists and technologists perpetually wrestle with new building challenges. On behalf of passive house concept, dozen energy and economic retrofits are carried out. In the standards, sustainable categories are listed and awarded with credits.

There are rankings whereby better environmental performance is awarded with bigger quantity of credits (points) [3]. The sustainable categories are: land use, water, energy conservation, waste management, transport, sewage sludge, indoor environmental air quality... There must also be compliance between local governments and ordinances.

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Very often, ordinances are typical, time-consuming and redundant frontiers which do not permit any installation of new, auxiliary systems. Ordinances play a huge role on the sites of passive dwellings and are being very well incorporated in the action building plan [4].

Local communities invent new ordinances which need to be synchronized with the possibilities and circumstances of sites [5]. The following sections also insight the feedbacks among construction materials and legislative, a behavior of construction industry as much as some other entities such as other institutions and implementation barriers of new knowledge, with the main goals to save the energy and to protect the environment.

II. Respect to the Environment

Sensitive architectural and civil engineering solutions respect and should celebrate the environment. This includes an appreciation for the local (geographies, bioregions, seasons, microclimates, etc.) as well as a response to the global (energy sources and resources, etc.). Because buildings are energy consumptive, this is an arena in which architects and civil engineer have the opportunity to innovate, with the aim of achieving “carbon neutral” buildings by 2030, as posed by the Architecture 2030 Challenge [6].

Environmental dimensions of sustainability (energy saving, reduced waste, effluent generation, emissions to environment; reduced impact on human health; use of renewable raw materials; elimination of toxic substances) indicate to a particular approach to the project.

Actual architectural aesthetic and functional engineering design has the fundamental question: How to increase the close connection between built structures and environment? Or, which social and political ideas, technologies, materials and type of design should be promoted in order to increase the close connection between built structures and environment?

By learning from the past, learning from different cultures, and taking advantage of technological innovations, architects and civil engineers can design resourceful, delightful environments.

Sustainable design methodology aims to define the main criteria, methods and principles, whose implementation is realized positive interactions with internal object, local and global environment, in the spirit of sustainable development. The ultimate goal and challenge of sustainable design is the application of best practices that provide quantitative, qualitative, physical and psychological benefits for users of facilities.

Faced with increasingly diminishing resources, creating appropriate architectural environments is beyond choice: It is essential. The aim of this paper is to emphasize the role of the *passive houses* including optimized insulation levels with minimal thermal bridges, minimum of air leakage through the building, utilization of passive solar and internal gains, and good circulation of air. Passive house became paradigm and the optimal model of architectural and civil engineering design in the 21st century.

III. A Paradigm Shift towards Passive Houses

There were more than 16 accepted definition of the passive house. One of them says that the term of passive house refers to a construction standard, that aims to reduce the heating needs in housing to a point where conventional heating systems are no longer necessary [7].

The term passive house refers to a construction standard, as well, that can be met using a variety of technologies, designs and materials. It is basically a refinement of the low energy house standard. Passive houses are buildings which assure a comfortable indoor climate in summer and in winter, without needing a conventional heat distribution system. To permit this, it is essential that the building's heating load does not exceed 10 W/m^2 [8].

The label passive for objects is very demanding. Aim of the passive house is to construct such building envelope that will minimize heat losses (transmittance) [9]. In a conventional residential dwelling, by contrary, there are junctions which are envisaged through cold bridging which enhances the rate of a thermal loss. According to the building codes, the standard space heating requirement for passive houses is 15 kWh/m^2 [10]. The passive houses which exist in severe and cold climates are not able to meet these criteria of heating. Such dwellings are not designed to handle with abrupt changing of temperature and humidity [11]. All until recently, 2012-2013, for thermal insulation of passive house is used polystyrene foam. However, it is revealed that the process of making polystyrene foam demands huge quantities of energy and emits CO_2 a lot. Originally, passive house is developed for a German, moderate climate.

There are endeavors to adjust American building codes to European building legislative and standards [12]. American building codes often dictate totally different design and standards for passive objects [13].

Typical passive house indicators are: thick insulation, high energy performance of windows and doors, thermal bridges eliminated, reduced structural air infiltration, optimal usage of internal heat gains... Thermal insulation is approximately 40-60 cm thick. Insulation must be settled in external walls, slabs, floor-boards, roof and windows. For ducts which supply the passive houses with fresh air, the thermal insulation is 6-10 cm.

Heating demands in a passive dwelling are typically met through passive solar gain glazing (40-60%), internal heat gains (20-30%) and through auxiliary heating systems (10-40%) [14].

Energy efficiency requires a tight shell that will not permit a lot of air leakages. Functional, illuminated surfaces are surfaces with double, triple glazing effects and fillings. Details of the roof corner in the connection to the wall are presented on Fig. 1.

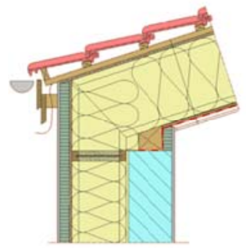

Fig. 1 Thermal insulation of the roof connection point

There were different construction materials and thickness of insulation materials applied through the past time. Construction and insulation details are presented on Fig. 2.

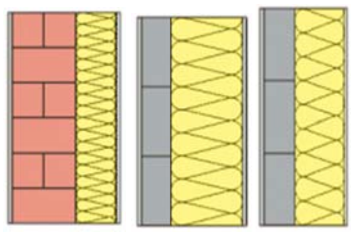

Fig. 2 Thermal insulation of wall slabs in the period of construction a. 1990-2005, b. 2005-2010 and c. 2015 (solid walls - brick walls and masonry walls)

Comparative analysis of heat losses and heat gains in obsolete and newest dwellings built according to the Passivhaus Standard are presented on Fig. 3. It is graphically presented that it is possible to reduce heat losses until 73% and to reduce heat requirement by 86%, with appropriated design solution.

IV. German Case

Germany is a very good case study with extensive experience in developing and application of all contemporary criteria for energy-efficient design and construction. The passive house energy standard in Germany is now the leading standard in the world. According to the statistic, about 1000 passive house units have been built in Germany in 2007 and this amount sensibly doubles every year [16]. At the same time (2007) this number in whole Europe was [17].

Besides using of thermal ground energy for passive house heating [16] and other renewable resources, the German scientists and engineers analyzed models of energy loss and developed different and efficient protective measures for saving the energy [18].

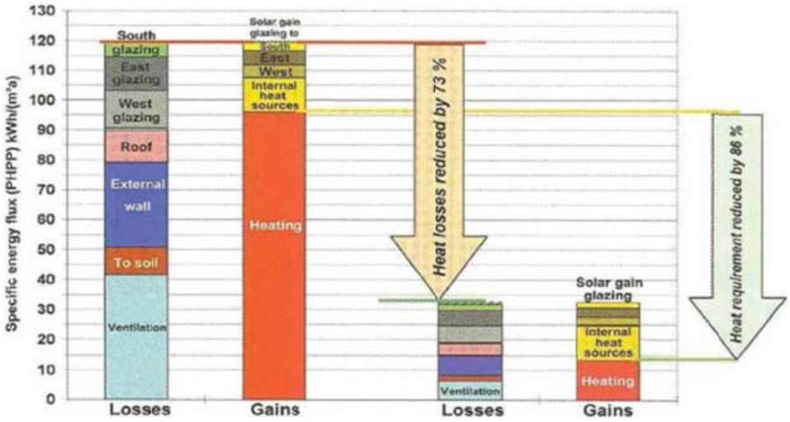

Fig. 3 Comparative analysis of heat losses and heat gains in obsolete and newest dwellings built according to the Passivhaus Standard [15]

Certain thermographic illustrations are a layout of ranking different thermal insulation thicknesses. Heat loss through the building slabs is highlighted by green, yellow and red color. Green color represents good joints structurally and a solid insulation, while red color represents insufficient insulation and the biggest transmittance. In the passive house, the heat loss through external walls is a very low. The biggest transmittance of heat in the passive houses is through openings, windows etc. In the conventional house, there can exist significant heat loss through the whole building envelope. For a passive house is important thermal bridge free design. This concept can also be applied in the case of old dwellings, and then it is a modernization of existing thermal coating. Thermal transmittance U is an ordinary data for gaining energy conservations. Modern measurements of thermal transmittance are „in-situ" measurements (Fig. 4). In-situ measurement of thermal transmittance requires the following instructions: Proper placing of the flow meters and sensors on the representative wall slab, avoiding such placing on the edges of the wall and pointing it more to the centre, avoid direct solar irradiance on the sensors, maximize the temperature difference. Some British research carried out on residential dwellings and its solid and masonry walls, shows that this data has approximately value of 2 W/m²K.

- U=> (W/m²K), thermal transmittance
- λ=> (W/mK), thermal conductivity
- ϕ=> (W/m²), thermal flow
- $U= \phi/T=\lambda/m$

Research study results on British energy policy [19] show a critical issue with solid-walled dwellings. Historically solid-walled dwellings have a thickness of approximately 230 mm, which is far less from a standard insulation for a passive unit. It is estimated that around 70% of dwellings have such thickness. These narrow brick or masonry walls emit around 45 Mt CO_2 per year or 36% of total stock emissions. Such objects offer a very low thermal performance and they have very low inner temperatures. That is why are recommended window panes with a high energetic performance (Fig. 5).

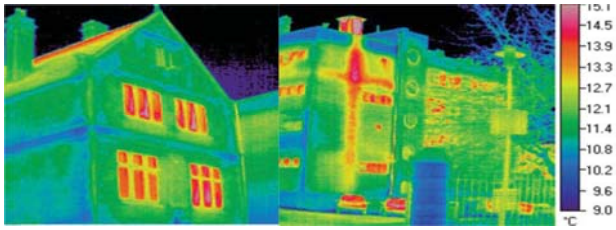

Fig. 4 The thermo graphic depiction of heat loss in a conventional dwelling and passive dwelling

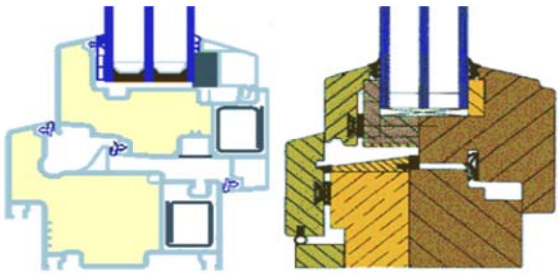

Fig. 5 Passive House window panes with a high energetic performance

As a matter of fact, British national zero carbon targets are founded for 2050 legislative and 80% emissions reduction. All these objects should be additionally insulated by 2022 in order to meet interior temperature aims.

The Passivhaus Institute has certified and approved a number of glazing and door units that are appropriate for using in passive dwellings. Triple glazing is three panes of glass with fillings between which provide high solar irradiance and transmission, eliminate the possibility of condensation at the bottom of the glass… Fillings help in keeping the heat concentrated through the glass frame. Typical U values for passive house windows fluctuate from 0.6W/m²K up to 0.8W/m²K. Fillings are usually gases such as krypton and argon.

In Table I are shown U values for several construction insulation materials.

TABLE I
EXISTING CONSTRUCTION INSULATION MATERIALS

Insulation material type	Thickness for U value of 0,15 W/m²K	Thickness for U value of 0,10 W/m²K
Polyurethane	145 mm	220 mm
Polystyrene, sheep wool	220 mm	340 mm
Cellulose, Hemp and Rockwool	250 mm	400 mm
Wood	825 mm	1,250 mm

TABLE II
STANDARD FOR SUSTAINABILITY RATING

Code level	Standard % better than 2006	Points awarded	Standard l/person per day	Points awarded	Other points awarded
1*	10	1.2	120	1.5	33.3
2**	18	3.5	120	1.5	43.0
3***	25	5.8	105	4.5	46.7
4****	44	9.4	105	4.5	54.1
5*****	100²	16.4	80	7.5	60.1
6******	A zero carbon home	17.6	80	7.5	64.9

Notes
1. Building Regulations: Approved Document L (2006) – 'Conservation of Fuel and Power.'
2. Zero emissions in relation to Building Regulations issues (i.e. zero emissions from heating, hot water, ventilation and lighting).
3. A completely zero carbon home (i.e. zero net emissions of carbon dioxide (CO2) from all energy use in the home).
4. All points in this document are rounded to one decimal place.

V. AMERICAN SUSTAINABILITY CODE AND ITS SPECIFICATIONS REGARDING ZERO ENERGY DWELLINGS

Passive house research, results and criteria applications from United States of America are also very significant and important for dissemination of knowledge. American sustainability code and its specifications regarding zero energy dwellings are shortly described in this paragraph.

American Sustainability Code uses a sustainability rating system to demonstrate the overall sustainability performance of dwelling. That rating system rewards each sustainable category with stars. Sustainable categories within a code are water, CO_2 emissions, waste, pollution, surface water runoff, ecology, management, materials...

Minimum standards exist at each level of a code and they are ranked with one star. According to the code, energy efficiency and water efficiency have minimum standards that must be achieved at each step of the Code. New homebuilding American industry is founded on sustainable schemes, graphicness... All sustainable categories have different measurement criteria. Standards for achieving sustainability rating are presented in Table II [20].

One of sustainable categories, ecology, has different hints within to tackle with such as ecological value of the site, ecological enhancement, protection of ecological features, ecological value change and building footprint. Measurement criteria for ecological value of the site are either the BRE Ecological Value Checklist or a report prepared by a qualified ecologist.

Waste management means all the activities and actions necessary to manage waste from its inception, treatment, to its final disposal.

In the category of materials, environmental impact of materials and sourcing of materials are discussed which are linked with basic and finishing sorts of materials. Generally, every sustainability code has its own zero emission targets, including zero complex nitrous oxide emissions, other global warming potential emissions.

VI. THE FEEDBACK AMONG CONSTRUCTION MATERIALS AND LEGISLATION IN THE CONSTRUCTION INDUSTRY

The building legislative in Netherlands and Germany already requires a whole-life carbon assessment, while some UK practitioners require measuring of embodied carbon through Zero Carbon building regulations. What is a typical attempt is to contribute to the reductions in operational carbon emissions and carbon intensity, even on site, and to increase operational performance of materials (Fig. 6).

Alternative materials are hardly approachable to the practitioners because of the lack in marketing, dissemination of information about new products and lack of knowledge. Ordinances are key drivers in addressing environmental issues and they are core elements in commencing new processes and techniques in construction industry. The construction industry very hardly accepts new items related to carbon content, policy makers, ingredients of materials. The materials which are mostly recycled and impromptu in construction industry are aggregates. The awareness of many alternative materials such as cross laminated timber, straw bale, bamboo, reclaimed steel and concrete and other recycled materials is high, but the usage is at a very low rate.

Many wastes, industrial, agricultural, waste rooting from building demolition, are not adequately and sufficiently used. One of the significant items in construction industry is supply chain of products and their declarations.

There are many created databases such as EU database of Environmental Product Declarations, which could influence on suppliers to provide data about products. Also, there are barriers for implementing alternative materials and they are recognized as institutional, technical, practical, economic... The construction industry tries to overcome these barriers by changing contracts and tender documentation, by additional training programs for practitioners, whole life costing, more triggering supply chains and declarations of building products.

The construction industry should also encourage stakeholders to take part in embodied carbon appraisal, should share all reports about functioning of certain projects. Every point along with rate of embodied carbon differs from one specific project to another one. That is why a large multidisciplinary team of researchers, engineers, economists and lowers should be involved in developing new methods and standards for saving the energy and saving the planet from pollution and global warming. Not only new methods are the goals for the scientists, but development of a new interdisciplinary and intradisciplinary field for the research of saving the energy and constructing such a buildings that do not use the energy from outside [21].

VII. Criteria in Correlation with the Climate

Specific passive house solutions must be adapted for each territory and climate under consideration. Californian passive solar building techniques were copied and directly applied to construction projects in the European climate in the past [15].

Regardless different climate conditions, in different regions, general Passive House concept and the laws of physics remain the same implying that the construction techniques need to be adapted.

The challenge to build nearly energy self-sufficient homes, i.e. passive housing, is well defined. The physical equations remain the same – only the construction conditions vary. The first step towards starting a passive house development in a specific region is to use the passive house method. The proven passive house process can be used to determine the appropriate passive house design solutions for each region and climate [22].

After defining the goals for passive houses in various countries with different climates, the next step is to perform a computer based parametric study with respect to building design solutions, energy demands, financial investment and healthy indoor climate. In accordance with the methodology of passive house concept, in the next steps construction elements need to be modified (external walls, roofs, windows, floor slabs).

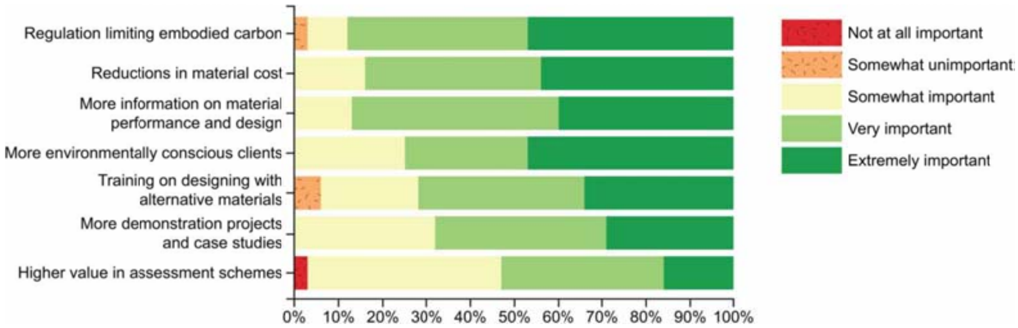

Fig. 6 Future indicators of alternative materials use (based on inquiry) which trigger the exploitation of Zero Energy Dwellings

VIII. Conclusion

Within contemporary architectural discourse and practice, there is a wide consensus on the urgent need to promote environmental protection, by creating new construction details, designing approach and innovation in overall building design.

The goal was to reduce energy consumption by designing the building in an energy conscious way, in terms of architecture and building techniques as well as exploiting the local sunshine and climate conditions.

Climate change and fuel consumption dictate new conditions in the manner of construction of buildings, in terms of construction of low-energy buildings. Considering that 40% from overall energy consumption belongs to the construction, it should be evident that energy consumption in construction business has a very important role. To achieve this goal and to satisfy a number of preconditions on the issue of saving energy and decreasing losses, new design and construction with emphasis on the passive construction has to be developed and accepted as common. The term passive techniques indicates that the building behaves as a power object, i.e. that any additional investment for electricity is not necessary for the operation of the facility. Natural environment factors should be taken as the most important elements of the receipt of energy. Passive houses constitute a first step towards a culture of sustainable and responsible construction.

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