

**izvleček**

V prizadevanjih za 20 % zmanjšanje rabe primarne energije do leta 2020 je energijska učinkovitost ključnega pomena. Velik potencial so prihrankih energije v stavbah. Glede na čedalje večje potrebe po energiji in rastočih cenah je nujno potrebno zmanjšati rabo energije v stavbah. Izbira gradiv za visoko energijsko učinkovite stavbe postaja čedalje bolj pomembna, prav tako postajajo ključne strategije za rabo primarne energije za proizvodnjo gradiv in komponent. Že v zgodnjih fazah načrtovanja bi morala biti v stavbe vključena regenerativna gradiva. Mednarodne smernice narekujejo uporabo lesenih konstrukcij, ki so pomembna osnova, ne samo za nizkoenergijske, ampak tudi za nizkoemisijske stavbe z izrednimi zdravstvenimi in varnostnimi učinki. V Evropi je najbolj celovit in najbolj pogosto uporabljen koncept energijsko visoko učinkovite hiše, t.i. pasivne hiše. Večina stavb v Sloveniji vključuje sodobne oblikovalske principe in energijsko učinkovitost, ki je blizu pasivnega standarda. Splošno je poznano, da je slovenska gradbena industrija relativno napredna na področju nizkoenergijskih stavb. V luči vse večje pomembnosti metod za ocenjevanje pasivni hiš lahko rečemo, da bodo pasivne hiše igrale v prihodnosti čedalje večjo vlogo.

**ključne besede**

lesene konstrukcije, energijska učinkovitost, pasivna hiša, trajnostni razvoj, Slovenija

**abstract**

*Energy efficiency is essential in the efforts to achieve a 20% reduction of primary power consumption by 2020. It is widely recognized that the potential of energy saving in buildings is large. Considering the tendencies of energy production and price, it is becoming urgent to reduce energy consumption in buildings. The choice of materials for a building with a high energy efficiency becomes much more important and strategies for reducing the use of primary energy for the production of materials and components becomes key. Renewable building materials should already be integrated into the early phases of building planning. The positive trend towards wooden construction is dictated by international guidelines, where a wooden building is an important starting point, not only for low-energy, but also low-emission building with exceptional health and safety aspects. In Europe, the most comprehensive and widely used is a concept of ultra-low energy house, more precisely, the passive house concept. Most Slovenian buildings combine contemporary styling with a degree of energy efficiency that comes close to passive house standards. It is widely recognized that the Slovenian construction industry is relatively advanced in the field of low energy buildings. In the light of the growing importance of energy-efficient building methods, it could be said that timber passive house would play an increasingly important role in the future.*

**key words**

timber construction, energy efficiency, passive house, sustainable development, Slovenia

**Introduction**

Timber as a material for load bearing construction represents a future challenge for residential and public buildings. Being a natural raw material, timber represents one of the best choices for energy efficient construction since it also functions as a material with good thermal properties if compared to other construction materials. In addition, it plays an important role in reduction of the CO<sub>2</sub> emissions [Natterer, 2009], has good mechanical properties and ensures a comfortable indoor living climate. Timber construction has better thermal properties than

conventional brick or concrete construction methods, even with smaller wall thickness. Considering the growing importance of energy-efficient building methods, timber construction will play an increasingly important role in the future.

The dominating methods of timber construction in Slovenia include a panel construction, wood frame construction and solid wood construction (Fig. 1).

Currently, most Slovenian companies offer houses with timber-frame construction. Timber panel construction has had its own production in Slovenia for more than 35 years. Over the past



Slika 1: Panelna konstrukcija, lesena skeletna konstrukcija, masivna lesena konstrukcija. Arhiv: (od leve) Marles hiše Maribor, Kager hiša, Smreka.

Figure 1: Panel construction, wood frame construction, solid wood construction. Archive: (from left to right) Marles hiše Maribor, Kager hiša, Smreka.

thirty years, timber construction has undergone major changes. The most important [Premrov, Žegarac Leskovar, 2013] are the following introduced changes: transition from on-site construction to prefabrication in a factory, transition from elementary measures to modular building and development from a single-panel to a macro-panel wall prefabricated panel system. All of these greatly improve the speed of building.

In timber-frame buildings the basic vertical load bearing elements are panel walls consisting of load bearing timber frames and sheathing boards. Dependent on the wall dimensions, one can distinguish between single-panel and macro-panel wall systems. The single-panel was based on the individual smaller elements in dimensions of 1.30 m (1.25 m) x 2.5 m to 2.65 m (Fig. 2a). The height of the wall elements was meeting the height of the floor and the length of the ceiling elements the span of the bridged field.

The macro-panel system was developed from the single-panel system in the last two decades and represents an important milestone in panel timber frame building. The aim of the system is that whole wall assemblies, including windows and doors, are totally constructed in a horizontal plane in a factory from where they are transported to the building-site. Prefabricated timber-frame walls as main vertical bearing capacity elements, of usually typical dimensions with a width of 1.25 m and a height of 2.5–2.6 m, are composed of a timber frame and sheets of board-material fixed by mechanical fasteners, usually staples, to one or both sides of the timber frame (Fig. 2c).

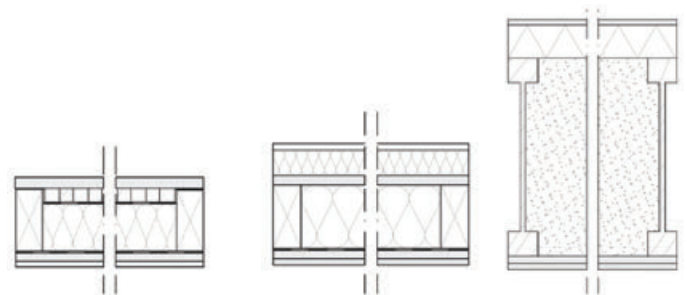
Between the timber studs and girders a thermal insulation material is inserted the thickness of which depends on the type of external wall. Composition of wall elements is in detail presented in Table 1 [Žegarac Leskovar et.al, 2012; Premrov, Žegarac Leskovar, 2013].

The first single-panel systems in Slovenia were used by company Marles hiše Maribor and company Jelovica. Those first prefabricated houses built in the early 70's had very good thermal properties of external envelope. Thermal transmittance of the best panel types was always much lower than it was defined by the regulations; for example thermal insulation was nearly three times better from 1963 to 1972, and after the year 1992 almost four times better than it was defined by the current national regulation (Fig. 3).

Because of the reduction of energy losses in the newly built residential objects, the first measure introduced by the producers was gradual reduction of the thermal transmittance of the external wall elements, resulting in the increase of the timber-frame wall elements thickness, thus enabling thicker thermal insulation installment. Detailed composition of the older single panel external wall elements construction, as well as newer macro-panel system, are explicitly presented in the Table 1, with additional graphic presentation in Fig. 2.

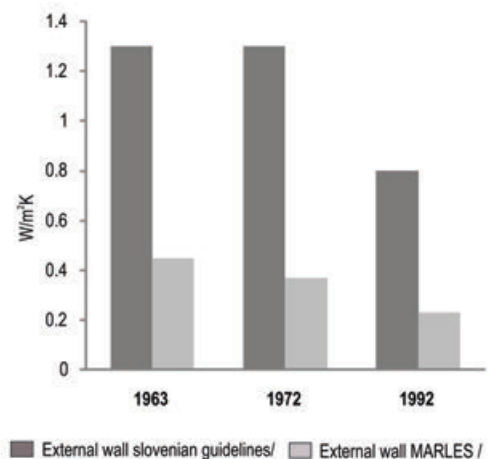
Fig. 3 shows data only till the year 1992, when external wall elements for the first time, even at any rate, met nowadays Slovene legislation regarding energy efficient construction, so that the thermal transmittance of external walls was for the first time lower than now prescribed limit value  $U=0.28 \text{ W}/(\text{m}^2\text{K})$ , i.e. it has nearly reached the value for light constructions, which is  $U=0.20 \text{ W}/(\text{m}^2\text{K})$ .

Therefore, all prefabricated timber framed objects set up before the year 1992 are considered as a fund needing energy efficient renovation till the year 2020. The latter refers to the wide-ranging package on climate change adopted by European Union, the overall 20-20-20 targets, which are binding for buildings as well. Therefore, energy performance of existing buildings has to be improved through a complex process of energy efficient renovation likewise the sustainable new construction of energy-efficient buildings with the use of renewables has to be performed.



Slika 2: a) Osnovni malopanelni sistem (TFCL2); b) Nadgrajeni malopanelni sistem (TFCL 3), c) Stenski element z I-profilu (TF 3, od leve proti desni).

Figure 2: a) Single-panel system (TFCL2); b) Renovated single-panel system (TFCL 3), c) Timber-frame wall element with I-studs (TF 3), from left to right.



Slika 3: Toplotna prehodnost  $U$  zunanjih stenskih elementov - primerjava Marlesove stene in stene, ki jo je določala slovenska zakonodaja med 1963 in 1992.

Figure 3: Thermal transmittance  $U$  of external wall elements - comparison of the Marles' wall with the Slovene legislation in the period from 1963 to 1992.

TF		TFCL 2		TFCL 3 – renovation	
material	d[mm]	material	d[mm]	material	d[mm]
rough coating	10	wooden planks	22	rough coating	10
wood fibreboard	60	/	/	mineral wool	40
/	/	TSS*** /open air gaps /	0.5	gypsum fibreboard	15
cellulose fibre / TF*	360	TSS*** /open air gaps /	20	mineral wool / TF*	100
		bitumen sheet cardboard	0.5		
		mineral wool / TF*	80		
OSB**	15	aluminium foil		aluminium foil	
gypsum plasterboard	12.5	particleboard	13	particleboard	13
		gypsum plasterboard	10	gypsum plasterboard	10
total thickness [mm]	457.5	total thickness [mm]	146	total thickness [mm]	188
$U_{\text{wall}}$ -value [ $\text{W}/(\text{m}^2\text{K})$ ]	0.102	$U_{\text{wall}}$ -value [ $\text{W}/(\text{m}^2\text{K})$ ]	0.48	$U_{\text{wall}}$ -value [ $\text{W}/(\text{m}^2\text{K})$ ]	0.30

Tabela 1: Sestava zunanjih stenskih elementov: velikopanelni (TF 3) in malopanelni elementi (TFCL 2, 3).

Table 1: Composition of analyzed macro-panel (TF 3) and single-panel (TFCL 2, 3) timber-frame wall elements.

## Energy-efficient buildings

Researching energy efficiency of buildings is not a matter of the last decade only, since the first intensive studies related to energy and buildings were already carried out in the seventies and eighties of the last century.

Many studies focusing on the research of specific parameters influencing energy performance of buildings, such as Johnson et.al. [1984] and Steadman and Brown [1987], have been performed since then. From the existing research findings we summarize that the process of defining the optimal model of a building is very complex.

The most important parameters influencing energy-performance of buildings are listed below: location of the building and climate data for the specific location, orientation of the building, properties of installed materials, such as timber, glass, insulation, boards etc., building design (shape factor, length-to-width ratio, window-to-wall area ratio, building's envelope properties, windows properties), selection of active technical systems.

According to the Slovene legislative framework, particularly to the Energy Act, the system of energy performance certification is defined in Rules on the methodology of construction and issuance of building energy certificates [2009]. On the basis of these rules, the classification of energy-efficient houses was carried, which is listed in Table 2.

Table clearly shows that energy efficient objects can be constructed only by adequate combination of external envelope efficient insulation and high quality glazing installation. Respecting climate change conditions and the subsequent European directions related to energy performance of buildings, which are forcing the building industry into constructing a nearly zero energy house by 2020, searching for the optimal model of an energy-efficient house has therefore become of major importance.

## Passive house

In Europe, the most comprehensive and widely used concept of ultra-low energy, more precisely, the passive house concept [Feist, 1998; Galvin and Sunikka-Blank, 2012]. It sets forth the

maximum permissible energy consumption for the heating of the building and limits the total primary energy consumption. In its essence, it is an upgrade of the low-energy house standard.

Passive houses are buildings that ensure a comfortable indoor climate during summer and winter without requiring a conventional heat distribution system [Feist, 1998].

The passive house standard means that the space heating peak load should not exceed 10 W/m<sup>2</sup> living area in order to use supply air heating. The resulting space heating demand is under 15 kWh/m<sup>2</sup>. [Feist, 2005]

The term "passive house" refers to a construction standard that can be met through a variety of technologies, designs and materials such as solid (masonry, concrete, and aerated concrete) and wood structures. Different timber passive house technologies are presented in Fig. 4.

The following considerations are particularly important when choosing the material and the construction type: the construction type should be standardized; the construction system should be based on natural and environmentally-friendly materials; the thermal envelope should meet the standards of a passive house; the construction should be wind-tight, airtight and diffusion open.

In order to design and implement a high-quality passive house project, attention should be paid to the materials used. The choice depends on personal preferences, in particular on the cost. There is a growing movement especially in Germany, Austria and Switzerland to build passive houses that are based on energy conservation measures and an efficient mechanical ventilation system with heat recovery. Over the past few years, the number of different types passive houses has been seen a continuous increase in Europe (Fig. 5 a-c) and also in Slovenia (Fig. 5 d-f and Fig. 6).

The greatest challenge facing civil engineers, wood science and technology engineers and architects today is how mitigate and adapt to climate change. They have recently focused their efforts on finding environmentally-friendly solutions and construction methods that bolster energy efficiency and thus reduce the environmental burden.



Slika 4: Stenski elementi pasivnih hiš, od leve proti desni: lesena okvirna konstrukcija z I-profilii in toplotno izolacijo iz celuloznih vlaken (Sistem Lumar IG); panelni konstrukcijski sistem s toplotno izolacijo iz lesnih vlaken (sistem Marles hiše Maribor); panelni konstrukcijski sistem s toplotno izolacijo iz mineralne volne (sistem Marles hiše Maribor).

Figure 4: Passive house wall element, from left to right: Timber-frame with I-joists and cellulose thermal insulation (System Lumar IG); Panel construction system with wood fibre thermal insulation (system Marles hiše Maribor); Panel construction system with mineral wool thermal insulation (system Marles hiše Maribor).

Degree / Classification in accordance with the rules	Generally used classification in practice	Q <sub>h</sub> * (kWh/m <sup>2</sup> a)	Variation of execution
Class C	minimal requirements for low-energy house	35 – 50 (60)	classical prefabricated construction, conventional heating system, contemporary windows (doors), no central ventilation system
Class B2	low-energy house	25 – 35	thermally improved building envelope conventional heating system, contemporary windows (doors), central
Class B1	very low-energy house	15 – 25	thermally improved building envelope + HRV** + improved U-value of windows (doors)
Class A2	passive house	10 – 15	additionally thermally improved building envelope + HRV + improved U-value of windows (doors)
Class A1	passive house	≤ 10	additionally thermally improved building envelope + HRV + improved U-value of windows (doors)

Tabela 2: Razvrstitev energijsko učinkovitih stavb po Pravilniku o metodologiji izdelave in izdaji energetskih izkaznic.

Table 2: Classification of energy-efficient houses on the basis of "Rules on the methodology of construction and issuance of building energy certificates".

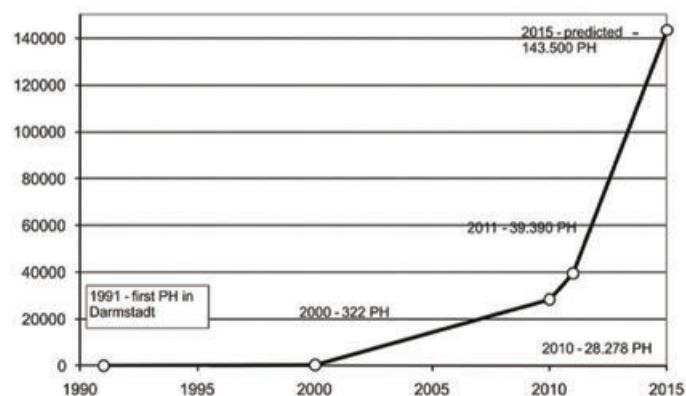


The choice of a construction material is one of the most important decision with long-term consequences for the owner of the building [Johnson, 1990]. The analysis by Kitek Kuzman et al. [2013] showed that wood as a renewable raw material is one of the best choices for energy-efficient construction, because it is also a good thermal insulator, has good mechanical properties, and ensures a comfortable indoor climate.



Slika 5: Različni tipi pasivnih hiš: a) Enodružinska pasivna hiša; b) Večnadstropna pasivna hiša; c) Industrijski objekt. Pasivne hiše v Sloveniji: d) Poslovna zgradba (Ekoprodukt d.o.o.); e) Vrtec (Jelovica d.d.); f) Enodružinska hiša (Marles hiše Maribor d.o.o.).

Figure 5: Different types of passive houses: a) Single family passive house; b) Multi storey timber frame passive house; c) Industrial building. Passive houses built in Slovenia: d) Commercial building built (Ekoprodukt d.o.o.); e) Kindergarten (Jelovica d.d.); f) Single-family house (Marles hiše Maribor d.o.o.).



Slika 6: Število pasivnih hiš v 31 državah Evrope.

Figure 6: Number of passive houses in 31 countries of Europe.

## Certificates

In recent decades several methodologies have been developed to assess the quality of buildings: in the UK there is BREEAM [BRE Environmental Assessment Method] in France HQE [Haute Qualite Environnementale], the USA has LEED [Leadership in Energy and Environmental Design], Germany has DGNB [Deutsche Gesellschaft für Nachhaltiges Bauen] and so on. These certificates demonstrate the environmental and energy indicators of buildings, as well as the economic, socio-cultural and technical aspects of construction. For those buildings in the highest energy class, for instance passive houses, special systems of certification have been developed: in Switzerland the Minergie P [Minergie P] and in Germany the Passive House Certificate [Passivhaus Institut Dr. Wolfgang Feist]. In some countries (Germany, Austria and Switzerland), the two certificates are the basis for allocating subsidies for passive houses. Within the profession they are highly valued – as a good promotional tool representing a market advantage.

In the Slovenian market there are already a large number of components bearing the Passive House Certificate. Components with this certificate are most commonly manufactured by large foreign firms that have representatives in Slovenia, but also by a number of Slovenian firms that is growing each year. Currently there are few houses in Slovenia built with the Passive House Certificate and with the Minergie P certificate.

## Case study: The Active House

Based on the active house concept, this highly energy-efficient structure makes best use of solar energy and offers utmost living comfort [Schnieders, Hermelink, 2006]. The built-in smart home installations, the ceiling-mounted heating and cooling system, and the rooftop photovoltaic installations and solar collectors in combination with skylights are only one part of the concept. The idea of an environmentally friendly house is completed with an outside rainwater collector; collected water is used for flushing toilets, washing machines and the automatic garden watering system. The design follows the strict requirements set out by the municipal site plan for this area. The longer side of this two-story house with a symmetrical gable roof faces the southeast, ensuring a maximum gain from sun energy. All blinds, skylights, the watering system, and all mechanical and electrical installations are computer-controlled and automatic, allowing for maximized energy efficiency. Energy consumption can also be monitored online. (Fig. 7 and Fig. 8).

Location | Dragočajna, Year | 2013

Architect | Jernej Gartner, Brigita Babnik, Gregor Košorok, KOŠOROKGARTNER ARHITEKTI d.o.o.

Surface | 151 m<sup>2</sup>

Construction time | 1 year

Structural engineer | dr. Luka Pavlovčič, Lumar IG d.o.o.

Energy efficiency | plusenergy (PHPP 15 kWh/m<sup>2</sup>a)

U-value (W/(m<sup>2</sup>K)) | wall 0,1; roof 0,1; floor 0,12; window 0,87; glass 0,6; frame 0,86

Construction system | timber frame

Construction company | Lumar IG d.o.o.

Price | best practice Zeleni svinčnik 2013, ZAPS

House technique | air to water heat pump, floor heating, solar collector, photovoltaic power station, comfort ventilation with heat recovery, rain water collector.

### Conclusion

Most Slovenian buildings combine contemporary styling with a degree of energy efficiency that comes close to passive house standards. It is widely recognized that the Slovenian construction industry is advanced in the field of low energy buildings. In the light of the growing importance of energy-efficient building methods, it could be said that timber passive house would play an increasingly important role in the future.



Slika 7: Hiša je v celoti zgrajena iz okolju prijaznih materialov, ki imajo največji vpliva na okolje v fazi izdelave. Hiša vključuje fotovoltaično elektrarno, sončne kolektorje za toplo vodo, strešna okna, zbiralnik deževnice za sanitarno vodo in zalivanje, ter pametne inštalacije.

*Figure 7: The house is built entirely of environmentally-friendly materials, which have the biggest impact on the environment in the stage of production. The house includes photovoltaic power station, solar collectors for hot water, skylights, rainwater gathering for sanitary purposes and watering as well as smart installations.*



Slika 8: Osnovni koncept aktivne hiše je bilo zgraditi promocijski stanovanjski objekt, ki obravnava vidik bivalnega ugodja, vpliv na okolje in vidik rabe energije. Aktivna hiša je je plod premišljene izbire posameznih komponent ter integracije znanj različnih strokovnjakov za zgradbe prihodnosti.

*Figure 8: The basic idea in the design was to produce a demonstration dwelling house used for the promotion and relevant explanation about 3 topics energy, indoor climate and environment. Active House is a network for knowledge sharing and demonstration of the feasibility of comfortable buildings in the future.*

## References

- Feist, W. (1998): *Das Passivhaus – Baustandard der Zukunft?*. Protokollband Nr. 12, Passivhaus Institut, Darmstadt.
- Feist, W. (2005): *Qualitätssicherung beim Bau von Passivhäusern*. Protokollband Nr. 18, Passivhaus Institut, Darmstadt.
- Galvin, R., Sunikka-Blank, M. (2012): Including fuel price elasticity of demand in net present value and payback time calculations of thermal retrofits: Case study of German dwellings. In: *Energy and Buildings*, 50, pp.219-228.
- Johnson, K. (1990): *Timber Bridge Design, Engineering and Construction Manual*. Wheeler Consolidated. St. Louise Park.
- Johnson, R. et al. (1984): Glazing energy performance and design optimization with daylighting. In: *Energy and Buildings*, 6, pp.305–317.
- Kitek Kuzman et al. (2013): Comparison of passive house construction types using analytic hierarchy process. In: *Energy and Buildings*, 64, pp. 258–263.
- Natterer, J. (2009): *Massivholz-Konstruktionen: Herausforderung für eine nachhaltige Ökobilanz*. In: Kitek Kuzman (Ed.): *Building with Timber, Challenge and Opportunity for Slovenia*. UL, Biotechnical Faculty, Ljubljana, pp. 18-21.
- Premrov, M., Žegarac L., V. (2013): *Energy-Efficient Timber-Glass Houses*. Springer, London.
- Rules on the methodology of construction and issuance of building energy certificates, Official Gazette RS, 77/2009.
- Schnieders, J., Hermelink, A. (2006): CEPHEUS results: measurements and occupant's satisfaction provide evidence for Passive Houses being an option for sustainable building. In: *Energy Policy*, 34, pp.151–171.
- Steadman, P., Brown, F. (1987): Estimating the exposed surface area of the domestic stock. In: *Energy and Urban Built Form*, pp. 113-131.
- The International Passive House Association. Passive house. Darmstadt, Germany.  
<http://www.passivehouse-international.org/>, <September 2014>.
- Žegarac Leskovar, V., Premrov, M., Kitek Kuzman, M. (2012): Energy-efficient renovation principles for prefabricated timber-frame residential buildings = Energetski učinkovita načela obnove montažnih stambenih zgradb s drvenim okvirom. In: *Drvena industrija*, 63, p. 3.
- BREEAM,  
<http://www.breeam.org/>, <September 2014>.
- HQE,  
[http://www.interfaceflor.co.uk/web/sustainability/green\\_building/hqe](http://www.interfaceflor.co.uk/web/sustainability/green_building/hqe), <September 2014>.
- LEED,  
<http://www.usgbc.org/DisplayPage.aspx?CategoryID=19>, <September 2014>.
- DGNB,  
<http://www.dgnb.de/>, <September 2014>.
- Minergie P,  
<http://www.minergie.ch/>, <September 2014>.
- Passivhaus Institut Dr. Wolfgang Feist,  
[www.passiv.de](http://www.passiv.de), <September 2014>.

Assist. Prof. PhD. Manja Kitek Kuzman  
UL Biotechnical Faculty  
[manja.kuzman@bf.uni-lj.si](mailto:manja.kuzman@bf.uni-lj.si)

Assist. PhD Mirko Kariž  
UL Biotechnical Faculty  
[mirko.kariz@bf.uni-lj.si](mailto:mirko.kariz@bf.uni-lj.si)

Assoc. Prof. PhD. Martina Zbašnik-Senegačnik  
UL Faculty of Architecture  
[martina.zbasnik@fa.uni-lj.si](mailto:martina.zbasnik@fa.uni-lj.si)