

LEPENSKI VIR - THE PREHISTORIC ARCHITECTURE FOR SUSTAINABLE LIVING

Nenad B. Miloradovic, B. Sc.

www.miloradovic.rs

nesoni2@open.mts.rs

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Introduction – the approach and basic notions

- We could ask the following question: why is prehistoric architecture of our long-gone ancestors interesting to engineers and architects which pursue sustainable development nowadays?
- The reply is simple: the pre-historic society represents a society which was suited to the concept of sustainable development.
- In his presentation in Belgrade from three years ago, German engineer Helmut Krames asked the following question: “Did prehistoric people care about energy efficiency?”
- This presentation provided a positive answer to the question.

BIOCLIMATIC ARCHITECTURE

- When it comes to the notion and significance of **bioclimatic architecture**, it is best to quote the book on the matter, written by Serb author *Mila Pucar*:
- “Bioclimatic architecture is not a new style or direction in architectural endeavor of XX century. (...)”
- Integration of the house with the surroundings and natural energy streams, their utilization to achieve a higher level of comfort, without any damage to natural balance of the environment, are but a few objectives of bioclimatic architecture. (...)

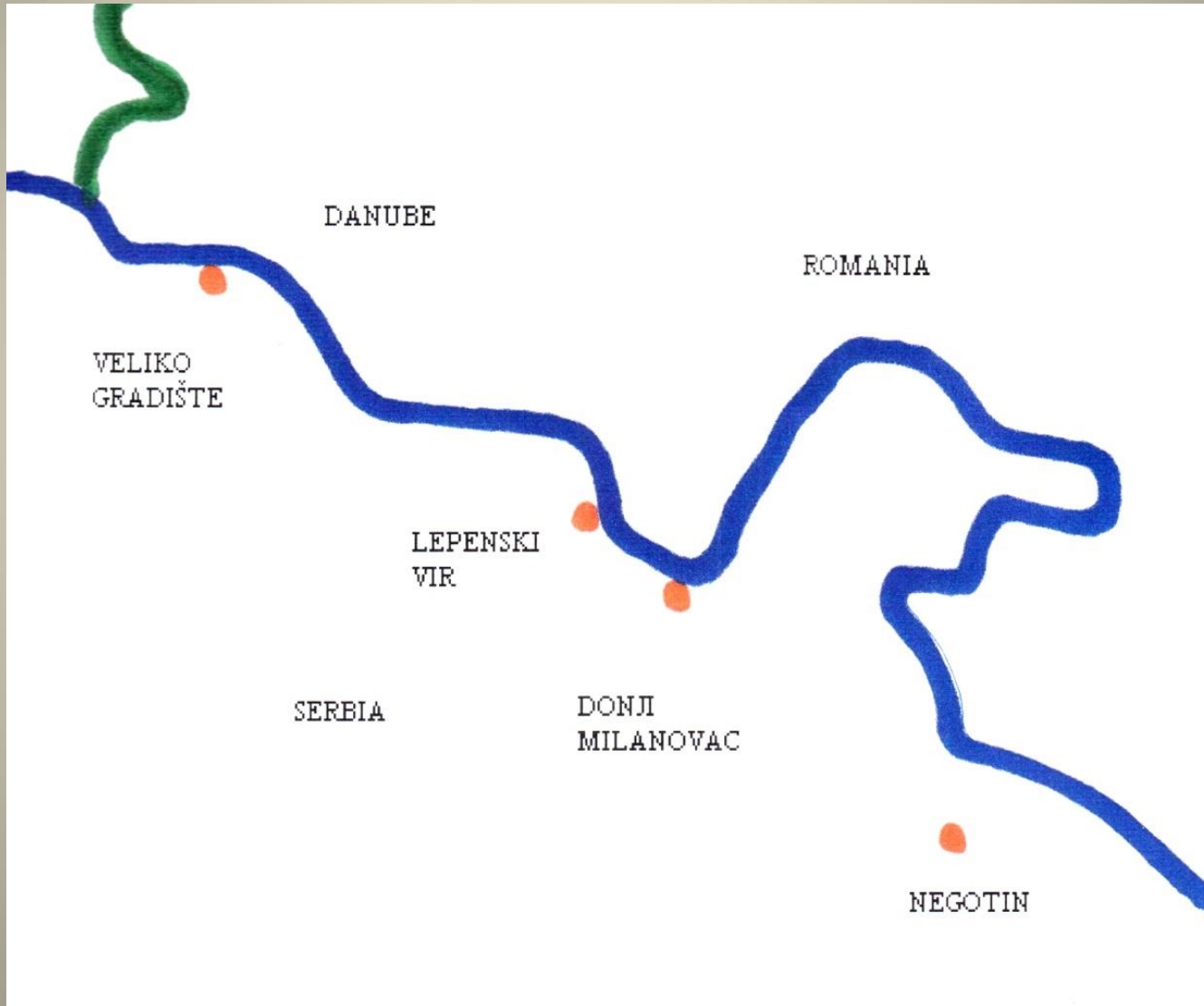
BIOCLIMATIC ARCHITECTURE

- Climate, in general terms, is an important element of bioclimatic architecture, and especially optimum utilization of its advantages, insolation being the first of them.
- The level of insolation may be deemed the most important climatic factor of a site, while adequate orientation of a house and its rooms, depending on insolation, is the first prerequisite for such a house to be called solar or bioclimatic. (...)
- Bioclimatic architecture should give an answer for questions with place of urban planning and structure designing in connection with elements of climate.

The basic informations about archeological site LepenskiVir

- Lepenski Vir was discovered in the 1960s
- Well known by sculptures, architecture and graves
- Settled on the right, Serbian side of the Danube river in Djerdap Gorge, 15 km upstream from Donji Milanovac and about 160 km downstream from Belgrade
- The person deserving most merit for its discovery was Dragoslav Srejovic, archeologist, whose book *Lepenski vir – a new prehistoric culture in the Danube region*, published in 1969 by SKZ, is the main source of information on this culture
- The site is estimated to be about 8,000 years old.

Location of Lepenski Vir



LEPENSKI VIR TODAY – THE MUSEUM

The site was displaced due to sinking
The museum preserves the site from devastation due to climatic effects



STEEP HINTERLAND – SIDE VIEW

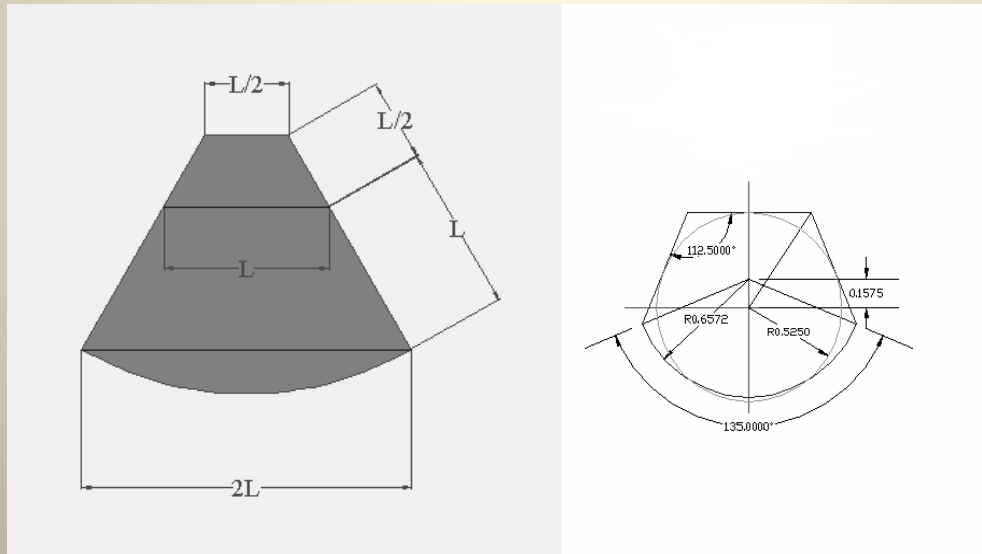


ARCHITECTURE OF LEPENSKI VIR

- Only bases of the houses, made from a hardened material resembling concrete, are preserved;
- The third dimension was constructed from perishable materials (wood, leather, mud) and is not preserved
- We can only assume what those houses looked like.

THE SHAPE OF THE BASE BY SREJOVIC AND OPTIMIZED BASE BY AUTHOR

The back side is significantly smaller, while the front side is shaped as a circular arch. Lateral sides are inclined.



Microclimatic conditions

- The microclimatic conditions are exceptionally favorable, as climate at Lepenski Vir site is more moderate than outside Đerdap area (in Đerdap, in July it is by 2-3°C colder, while in January it is by about 0.1-1.2°C warmer than in adjacent regions).
- It needs to be mentioned that climate in Đerdap is quite humid (precipitation is by 20% larger than in adjacent areas).

Microclimatic conditions

- According to observations in Negotin and Veliko Gradište, the mean insolation value for the period between 1992 and 2011 amounted to 2,156.7, i.e. 2,240.9 h.
- Negotin is located 54 km from Lepenski Vir towards south-east by air, while Veliko Gradište is located 46 km on the north-west.
- This data is an important parameter for bioclimatic architecture, and is of importance in evaluation of the need for heating and cooling in Lepenski Vir.

Methodology of calculation

- This paper presents results of calculations of heat loads and needs for heating and cooling in these dwellings by direction which include geographical and astronomical data of Lepenski Vir site, while the meteorological data adopted relates to Negotin.

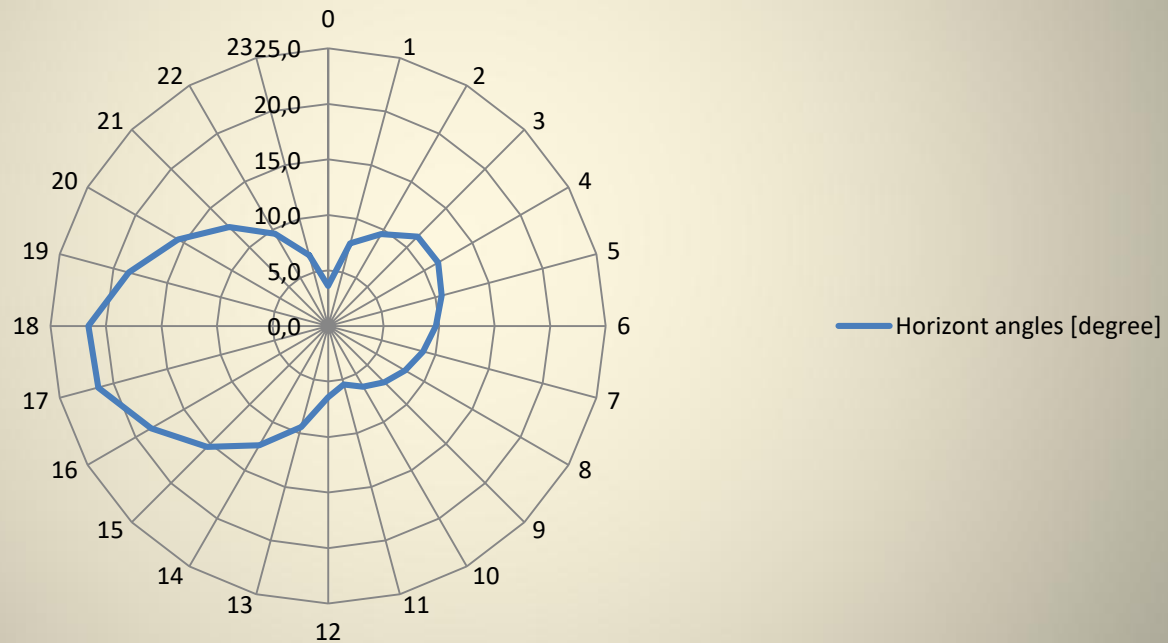
Methodology of calculation

- The sums of hourly data relating to heat loads were added up for the whole year and presented in radar diagrams by hour.
- The radar diagram was chosen as hourly data it comprises may be compared with the orientation and world's sides in the field.

Geographical input data

- Data on the latitude and longitude of Lepenski Vir site was taken from literature Bajić-Pavlović where the location of the current museum, $44^{\circ} 33' 40''$ N (44.55672° N) and $22^{\circ} 01' 27''$ E (22.026984° E) was determined with assistance of Google Earth.
- The assumed approximate line of the horizon assumed for the purpose of the paper was based on drawings of D. Srejović based on which it is possible to determine the height of the western horizon of about 23° from the altitude of 65m.

Horizon angles at LepenskiVir



Astronomical input data

- For the adopted line of the horizon and geographical coordinates, hourly positions of the sun were calculated for the whole year:
- the hour angle,
- the height of the Sun, and
- the azimuth angle.
- If the height of the Sun is lower than the line of the horizon, only diffuse solar radiation was taken into consideration.

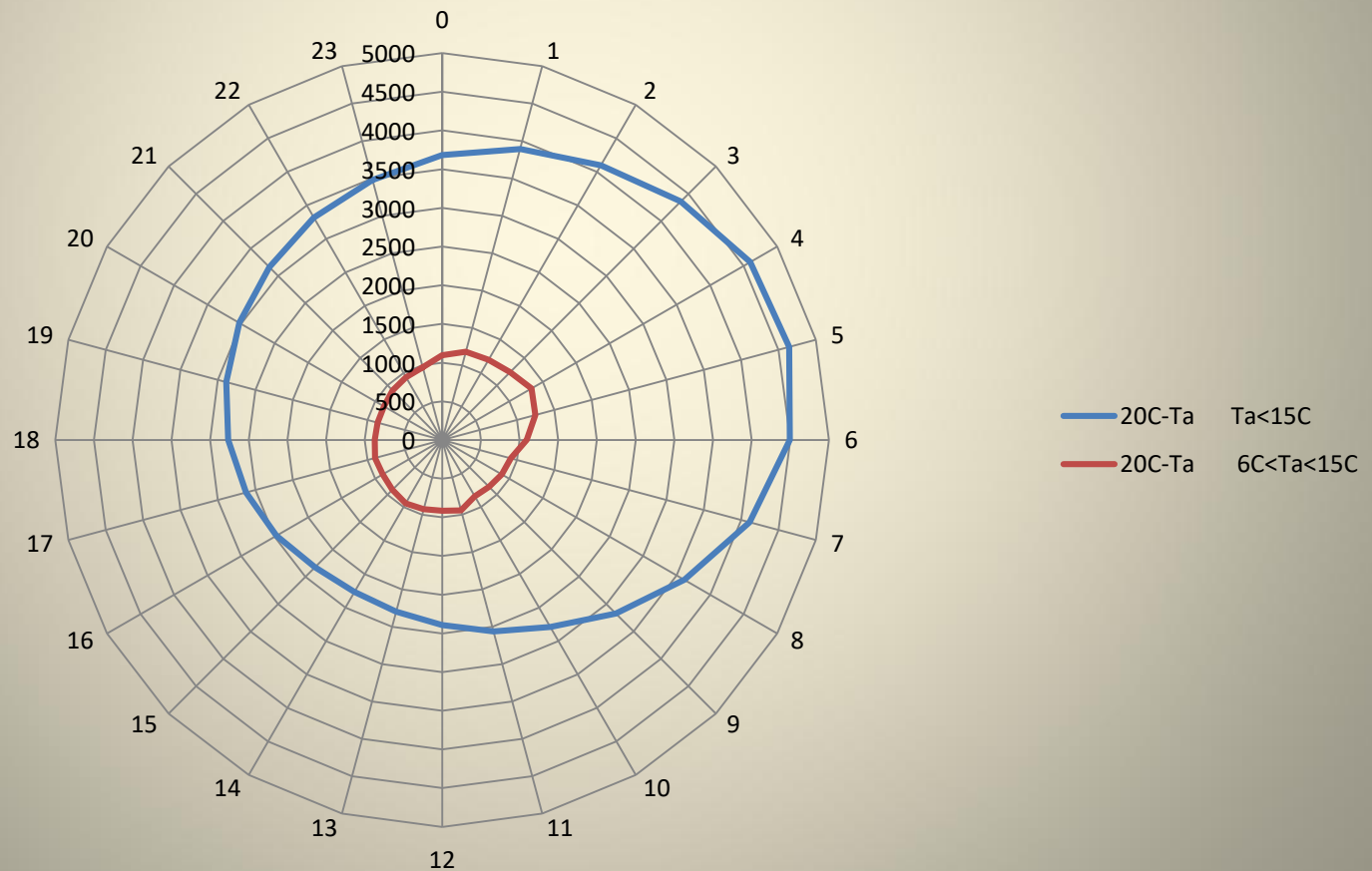
Meteorological input data

- The data base used for meteorological data was the data base from the METEONORM programm comprising data from typical meteorological year (TMY) in Negotin taken on hourly basis.
- The data used for the purpose of the paper comprises data on global, direct, and diffuse solar radiation on a horizontal flat surface, outdoor temperature, and the direction and speed of wind.
- All this data (geographical, astronomical, and meteorological) is provided in 8,760 rows in the Microsoft Excell sheet;
- Thus, it is possible to present data on annual level by hour in a radar diagram.

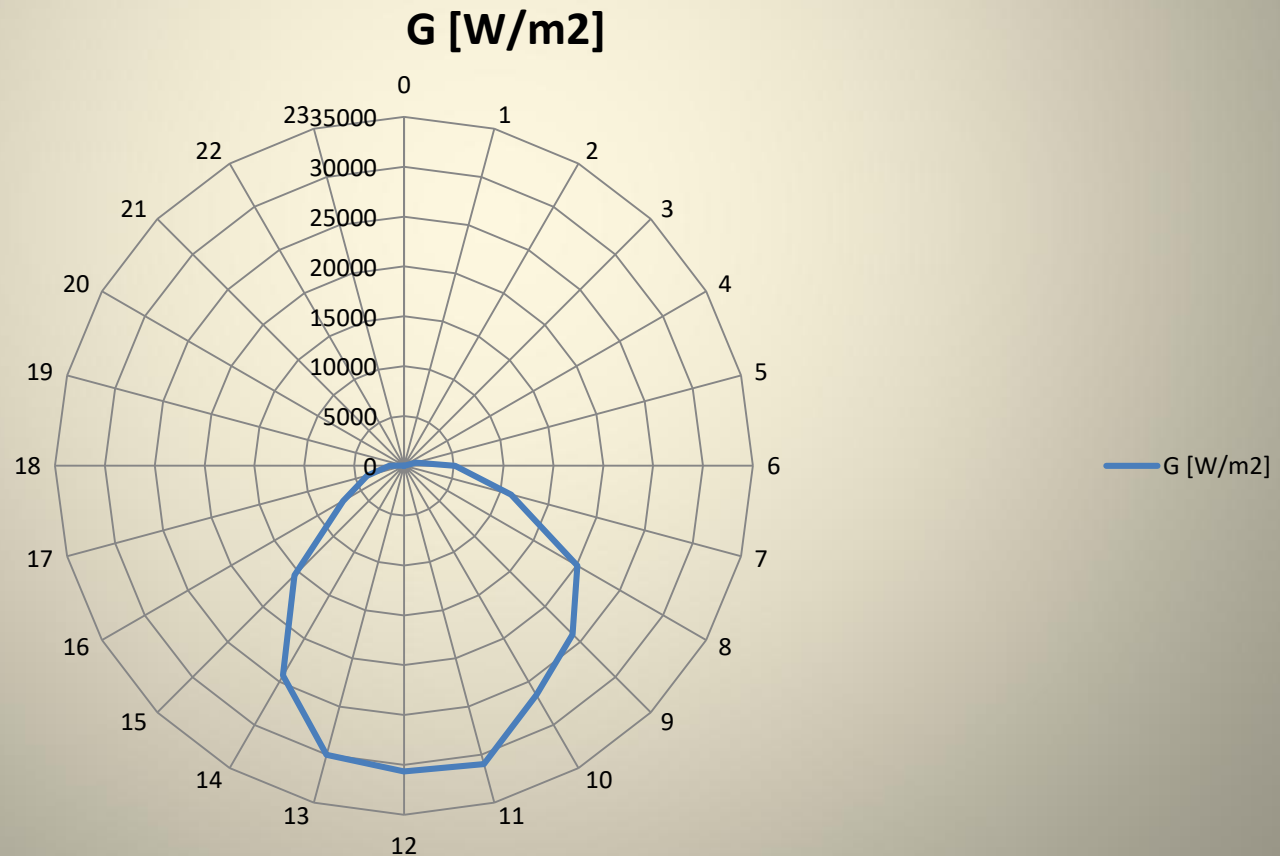
Winter time – reduction of conduction and ventilation heat loads

- **Conduction losses were reduced by compact envelope, drying of walls and improvement of thermal insulation properties of materials used for walls by application of solar radiation, which is why favorable orientation was used.**
- **Ventilation losses were minimized by the favorable aerodynamic shape, orientation, and digging, and possibly also by vegetal surroundings and the steep hinterland on the west.**

Needs for heating by hours at Negotin



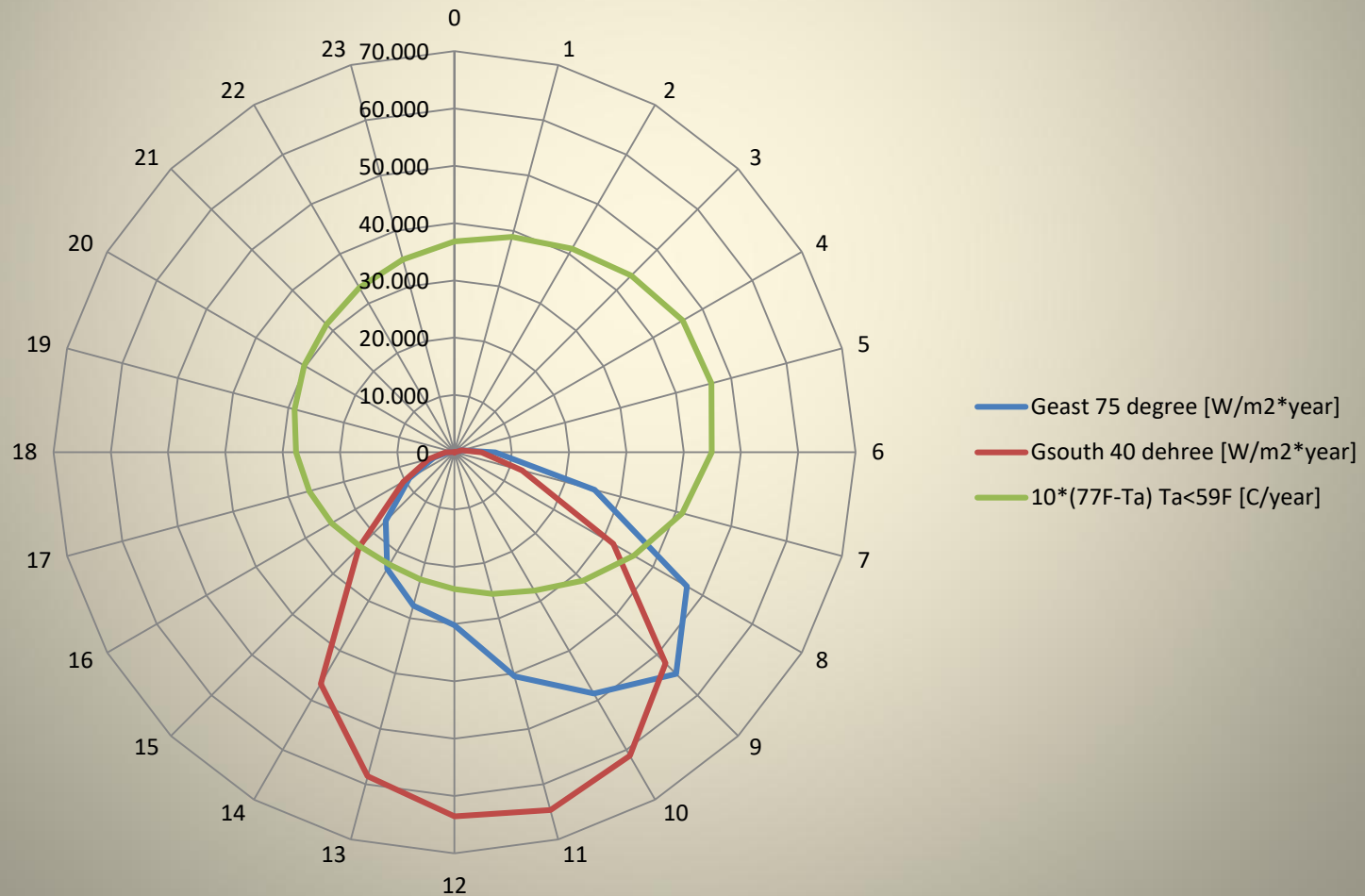
Solar radiation of TMY for Negotin and horizon angles at Lepenski Vir



ORIENTATION

- When applying solar energy, it is necessary to **harmonize generation and consumption of energy**.
- Morning temperatures are lower than outside temperatures in daytime, which is why the need for heating is the greatest in the morning
- Outside daily temperatures are the lowest before sunrise
- This alignment is mostly due to the predominantly eastward orientation of houses, towards the river.

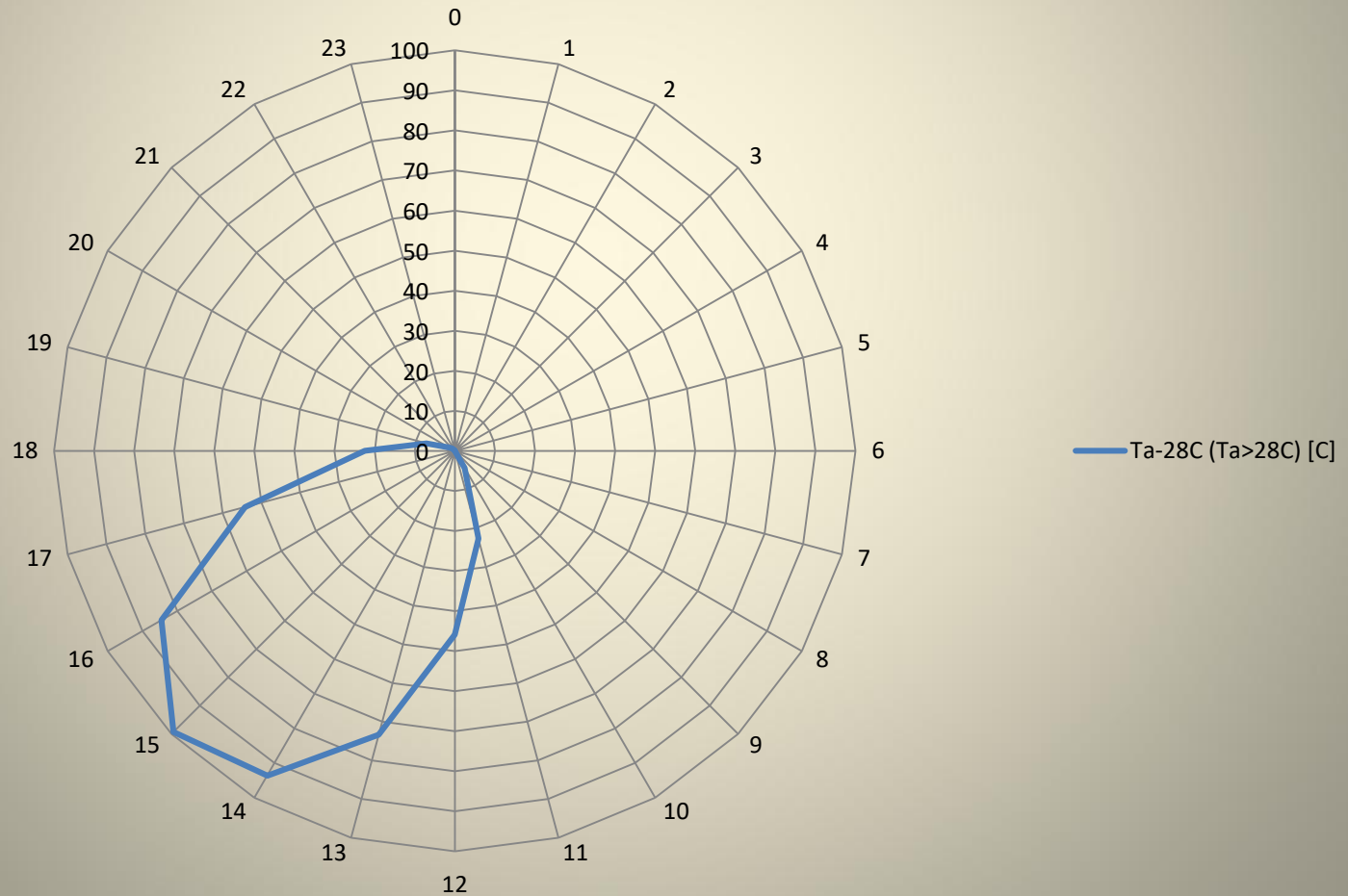
Thermal needs for heating and solar radiation G for East and South wall



Summer needs for cooling

- The compact shape of houses, choice of the location, steep hinterland, vicinity of the river, orientation, and vegetal surroundings also enable pleasant living conditions in summer.
- Heat load is the largest in the afternoon because of joint action of high outside temperature and solar radiation.
- Due to the need for cooling, the optimum orientation is predominantly to the north-east – against the greatest heat load.

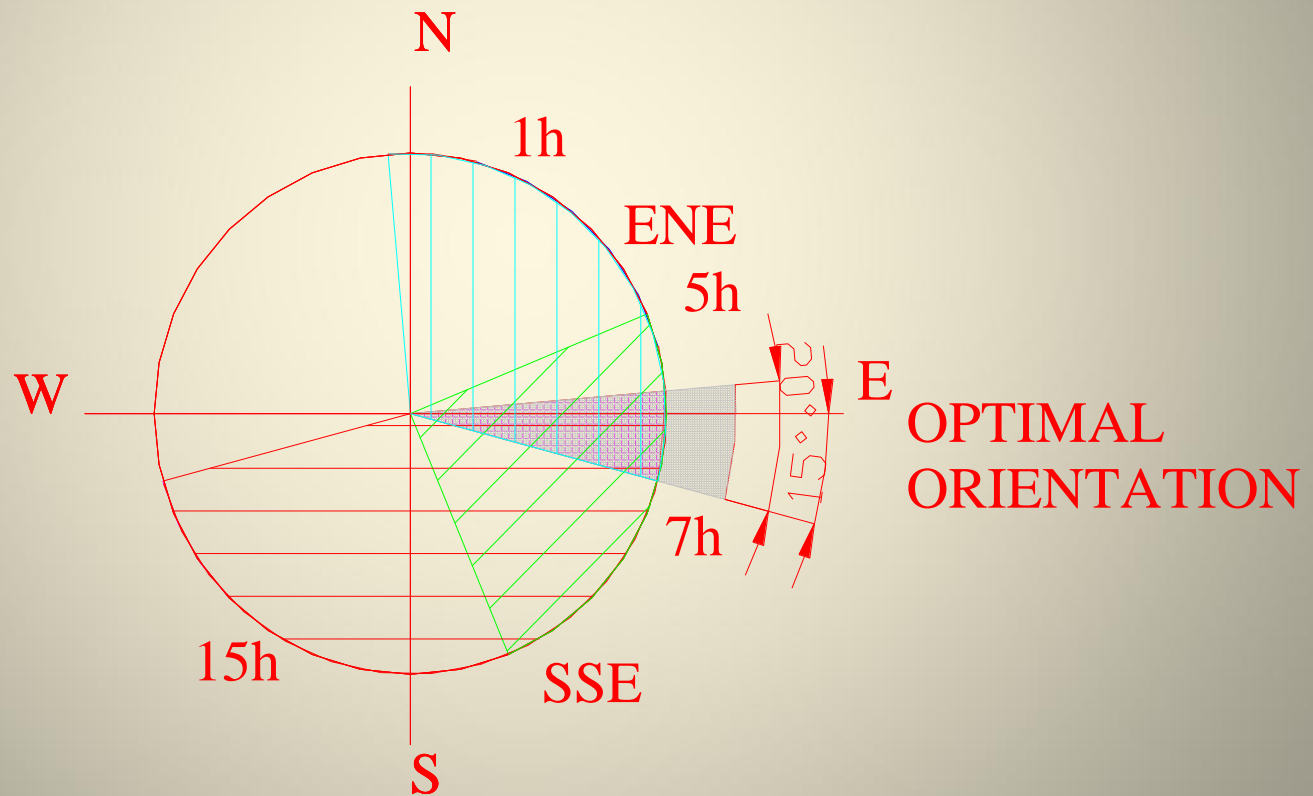
Heat loads for cooling



Optimal orientation

- Next figure shows optimal orientation of structures in LepenskiVir.
- It is predominantly towards the east, with a bias of up to 5° to the north and 15° to the south.
- The figure was obtained by a cross-section of favourable orientations for the purpose of heating (from east to south-west, horizontal red hatch), cooling (from north to east, vertical blue hatch), and elimination of impact of winds (at Lepenski Vir site, ENE and SSE winds are those of impact, as I suppose that the steep hinterland on the west and digging in eliminate the impact of dominant westernly winds; green slanted hatch).

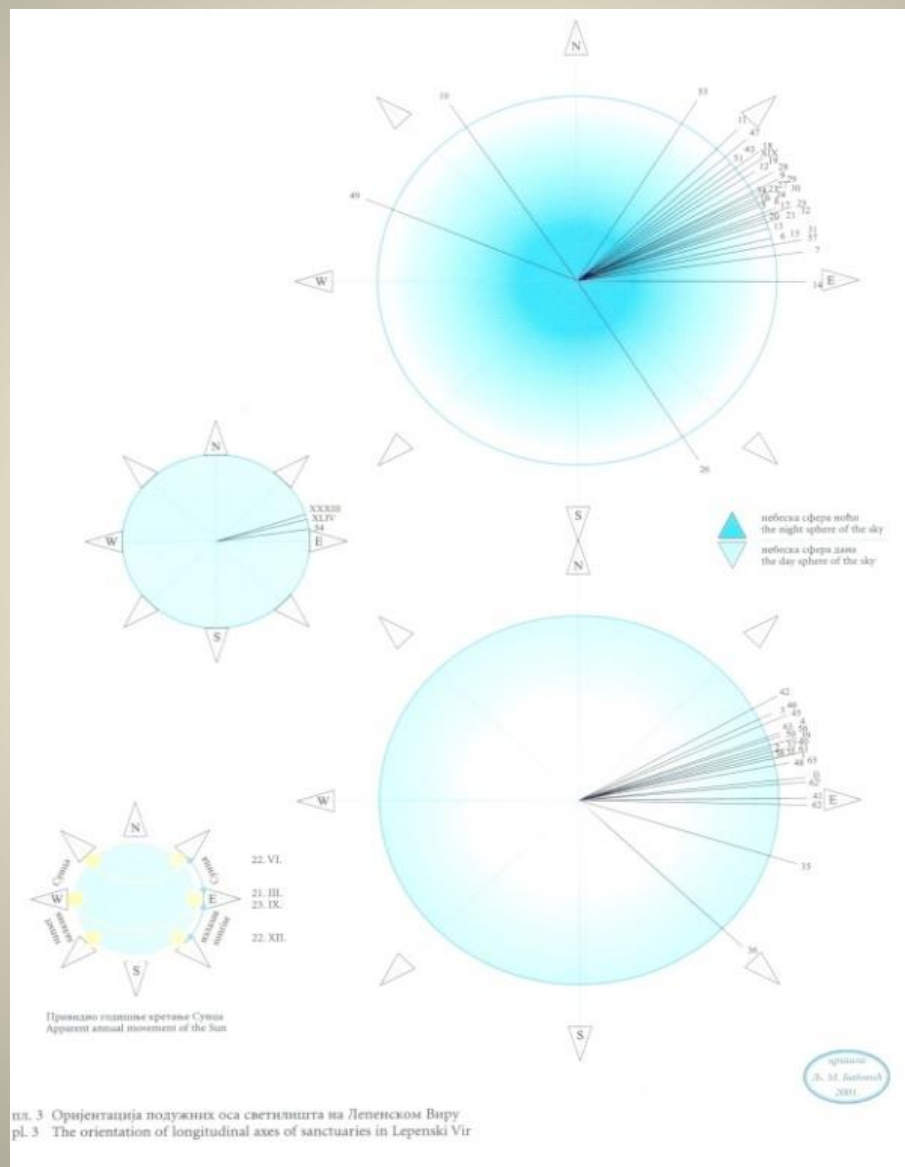
Optimal orientation



Optimal orientation for bioclimatic architecture

- In the beginning it was emphasized that the orientation of a house is the necessary prerequisite it must meet in order to be called bioclimatic or solar.
- In literature of Ljubinka Babović it is possible to find drawings which represent orientations of houses in Lepenski Vir.
- If we have a look at next Figure, it may be concluded that the orientation achieved for these houses is very close to optimal, and that it was applied in the course of construction of houses and settlements in Lepenski Vir.

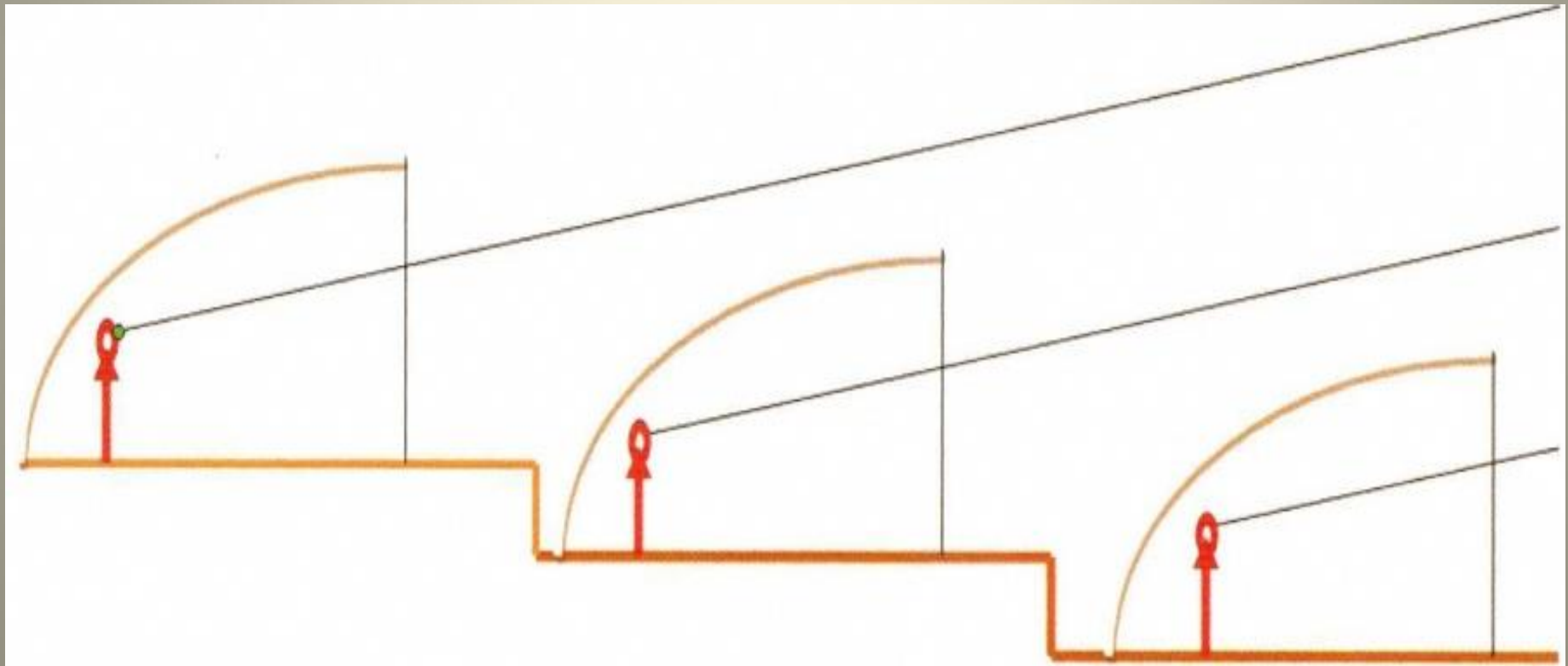
Orientation at Lepenski Vir by Lj. Babović



Urbanism of Lepenski Vir

- Not only individual houses were constructed for the purpose of application of passive solar heating.
- The whole settlement has the form which fits in the natural settings;
- We have already observed that the settlement was terraced.
- In book of Bajić, Pavlović it was stated that the first morning ray of the Sun could be seen from almost all houses.
- Due to the need for heating and drying of dwellings, it was important that houses did not cast shadow on one another.
- The settlement was carefully planned in these terms.

Urbanism of Lepenski Vir (Bajić, Pavlović)



THE CONCLUSION

- The shape of houses is very compact and contributes to saving of heating or cooling energy.
- This compact form reduces heat exchange with the surroundings and conduction losses, which is why favourable orientation was used.
- Conduction losses were also reduced by drying of walls and improvement of thermal insulation properties of materials used for walls by application of solar radiation.

THE CONCLUSION

- Ventilation losses were minimized by the favourable aerodynamic shape, orientation, and digging.
- The compact shape of houses, choice of the location, steep hinterland, orientation and vegetal surroundings also enable pleasant living conditions in summer.

CONCLUSION

- Having in mind geographical and astronomical data on Lepenski Vir and data on a typical meteorological year (TMY) for Negotin, optimal orientation of houses for the purpose of heating and cooling was calculated.
- This orientation is close to the orientation achieved for the constructed houses of the pre-historic settlement, so in this case we may speak about original passive solar and bioclimatic architecture.

CONCLUSION

- These houses were comfortable for the period, which is corroborated by the fact that thermal stability of these dwellings was increased.
- The inhabitants of Lepenski Vir were aware of some principles of bioclimatic architecture.
- This is proved by the remains of architecture (house floors) and natural surroundings of the site, including movement of the Sun along the firmament.
- This is also proved by the fact that numerous generations lived in this settlement and at that site.

CONCLUSION

- The answer to the question of Helmut Krames, engineer, whether people in prehistory cared about EE in building stock is:
- the remains of the architecture of Lepenski Vir which emerged some 8,000 years ago, indicate to recognizable measures aimed at increasing EE in building stock.
- Even though there is no written evidence, bases of the houses speak about the applied measures the sense of which may be grasped only when observed within the natural (geographic, meteorological, vegetal, and astronomic) surroundings.

CONCLUSION

- **The remains of architecture in Lepenski Vir are the remains of an energy efficient and bioclimatic architecture.**
- This architecture shows the way how we can build the passive and low energy architecture in the future, what is important for sustainable living.
- Cooperation between architects and engineers for integral designing is needed.

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THANK YOU FOR ATTENTION

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