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The reduction of the energy demand of a hall-type object through vegetative roof constructions

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Abstract. The topic of the energy efficiency of buildings is still relevant, and this article focuses on one form of passively reducing their energy demands, in this case, for a hall-type structure. Hall-type structures are largely horizontal constructions, meaning that their length and width often significantly exceed their height. As a result, a larger cooled surface area of the roof is expected in comparison to the cooled surface area of the facade. While not the sole factor influencing the selection of a structure or balance calculations, it was one of the initial considerations. It is also anticipated that with a larger construction area and its opening structures, there will be a greater area available for covering with a green roof. The coverage of the building's energy facilities occupy a certain percentage of the roof construction area. The work then delves into the energy balances of the given structure under various operational conditions, based on measurements of the thermal-technical improvement of the construction, depending on its composition and coverage with a green structure. The results include balance-based energy savings achieved through the green element, as well as the percentage savings in different operational conditions.

1 Introduction

Heating as well as the factors that affect it can be assessed based on the temperature range. In the article [1], reductions in heat energy demand were demonstrated with regard to temperature areas. Green roofs can contribute to saving energy [2-6].

The object under study was a hall-type building. For the calculation, the volumetric mass of the object was needed to determine the thermal-technical parameters of the constructions of the thermal-exchange envelope of the object. The selected hall with dimensions 100x200x10m (conceptual mass) was input into the DesignBuilder v7 simulation software. Based on the research [7], a reduction value of the heat transfer coefficient (U) by 7.7% was determined. This value was established for the roof conditions closest to our standard as well as to the climatic zone. The reduction using the vegetative layer was from 0.26 W/m^2.K to 0.24 W/m^2.K. This percentage value was also considered in this work.

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2 Reduction of the need for heating energy

The main subject of the article is the case study calculations, which serve as the basis for the further procedure. A total of 6 conditions were demonstrated on the model of the hall object. The first 2 are a basic comparison – an object with a gravel roof U=0.099W/m^2.K and a vegetative roof U=0.1W/m^2.K with a substrate thickness of 240 mm. This comparison is intended to demonstrate the potential of reducing heating energy due to the vegetation layer. Fig. 1 and 2 show Heating energy demand with gravel roof. Fig. 3 and 4 show heating energy demand with vegetative roof.

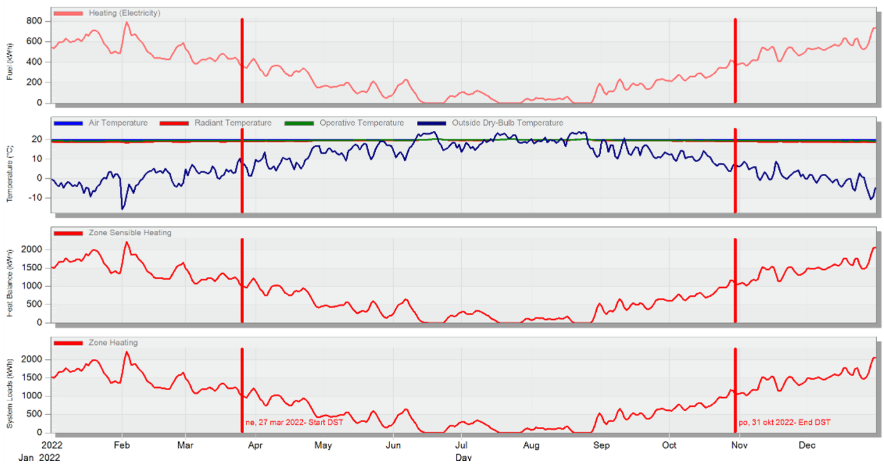

Fig. 1. Thermal balance of an object with a gravel roof.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	313297.65	15.81	15.81
Net Site Energy	313297.65	15.81	15.81

Fig. 2. Summary numerical balance of an object with a gravel roof

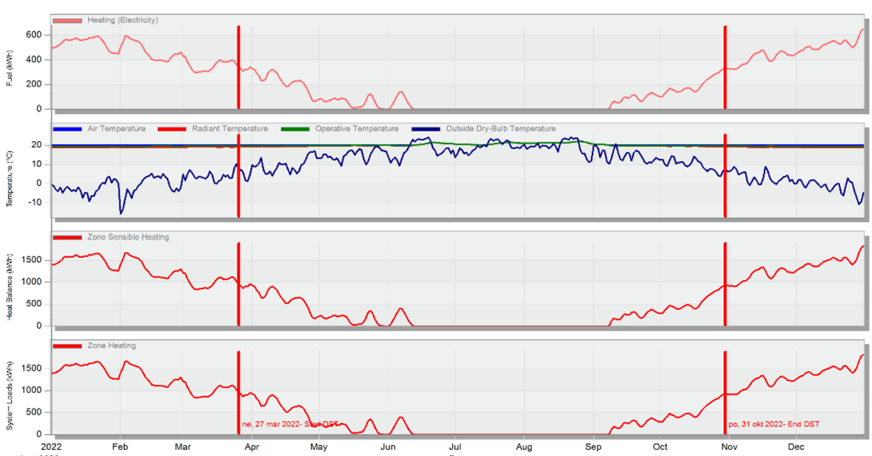

Fig. 3. Thermal balance of an object with a vegetative roof.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	243863.89	12.30	12.30
Net Site Energy	243863.89	12.30	12.30

Fig. 4. Summary numerical balance of an object with a vegetative roof.

Fig. 1,3,5,7,9,11 contain 4 graphs. A. Electricity energy demand, B. Temperatures (Interior and exterior) C and D. Heating energy demand. Subsequently, the effect of temperature attenuation was compared, in which a percentage increase in the reduction of the need for energy for heating with the help of the vegetation layer was expected. Fig. 5 and 6 show heating energy demand with gravel roof with temp. attenuation from 22:00 to 6:00. Fig. 7 and 8 show temp. attenuation in the same time with vegetative roof.

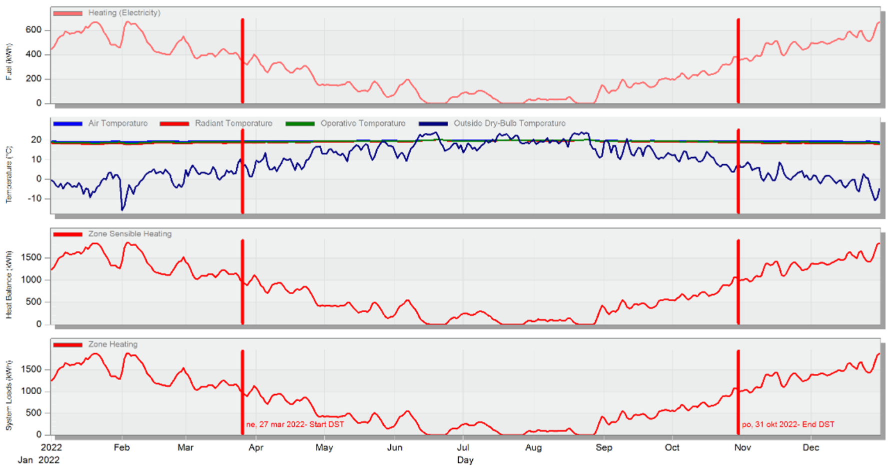

Fig. 5. Thermal balance of an object with a gravel roof with thermal attenuation.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	292526.52	14.76	14.76
Net Site Energy	292526.52	14.76	14.76

Fig. 6. Summary numerical balance of an object with a gravel roof with thermal attenuation.

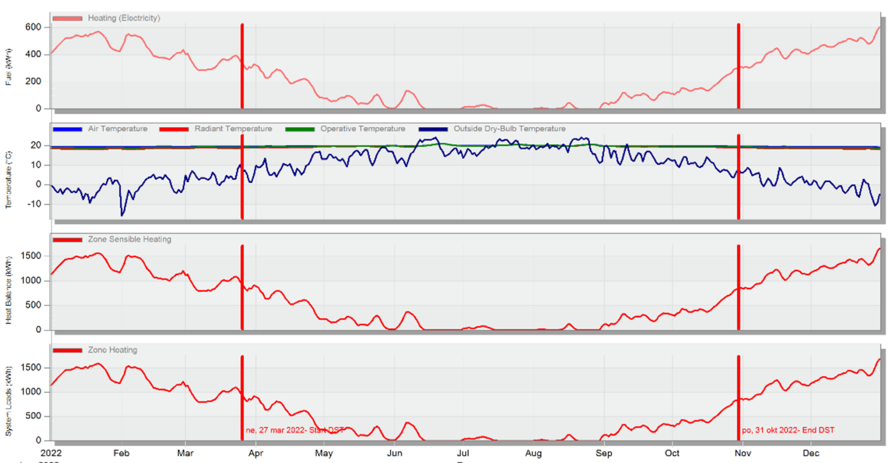

Fig. 7. Thermal balance of an object with a vegetative roof with thermal attenuation.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	234177.13	11.81	11.81
Net Site Energy	234177.13	11.81	11.81

Fig. 8. Summary numerical balance of an object with a vegetative roof with thermal attenuation.

The case study of the hall object did not consider glazing for the primary evaluation of the roof structure. In real object such usually there is glazing. That is why the last calculation took into account another impact on the heat energy demand – 10% glazing in total area of perimeter walls. Fig. 9 and 10 show heating energy demand (gravel roof) with the temp. attenuation and 10% glazing. Fig. 11 and 12 show this aspect with vegetative roof.

Fig. 9. Thermal balance of an object with a gravel roof with thermal attenuation and 10% glazing.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	254091.43	12.82	12.82
Net Site Energy	254091.43	12.82	12.82

Fig. 10. Summary numerical balance of an object with a gravel roof with thermal attenuation and 10% glazing.

Fig. 11. Thermal balance of an object with a vegetative roof with thermal attenuation and 10% glazing.

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	216580.75	10.93	10.93
Net Site Energy	216580.75	10.93	10.93

Fig. 12. Summary numerical balance of an object with a vegetative roof with thermal attenuation and 10% glazing.

The following Tab. 1 shows a comparison of the building with two different roof structures and different operating states.

Table 1. Numerical summary and comparison of the results of 6 operating states.

State	kWh/a	Saving
Gravel roof	313297.65	0.0%
Vegetative roof	243863.89	22.2%
Gravel roof + attenuation	292526.52	6.6%
Vegetative roof + attenuation	234177.13	25.3%
Gravel roof + attenuation + 10% glazing	254091.43	18.9%
Vegetative roof + attenuation + 10% glazing	216580.75	30.9%

3 Conclusion

The given calculations confirmed a certain effect on reductions in the need for energy for heating. Simulation model shows that solar gains is important in real conditions. The simulation confirmed impact of vegetative roof on heating energy demand by 22.2%. This value is influenced by real exterior temperatures. This result will lead to further work steps in determining the influence of vegetation elements on heating and cooling.

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References

1. T. Susca, Green roofs to reduce building energy use? A review on key structural factors of green roofs and their effects on urban climate, Building and Environment **162**, 1, (2019)
2. T. Takakura, S. Kitade, E. Goto, Cooling effect of greenery cover over a building, Energy and Buildings **31,** 1-6, (2000)
3. T.G. Theodosiou, Summer period analysis of the performance of a planted roof as apassive cooling technique, Energy and Buildings **35**, 909–917, (2003)
4. A. Niachou, K. Papakonstantinou, M. Santamouris, A. Tsangrassoulis,G. Mihalakakou, Analysis of the green roof thermal properties and investigation of its energy performance, Energy and Buildings **33**, 719–729, (2001)
5. C.-F. Fang, Evaluating the thermal reduction effect of plant layers on rooftops, Energy and Buildings **40**, 1048–1052, (2008),
6. S. Onmura, M. Matsumoto, S. Hokoi, Study on evaporative cooling effect of roof lawn gardens, Energy and Buildings **33**, 653–666, (2001),
7. A. Niachou, K. Papakostantinou, M. Santamouris, A. Tsangrassoulis, G. Mihalakakou, Analysis of the green roof thermal properties and investigation of its energy performance, Energy and Buildings **33**, 719-729, (2001)