APPLICATION OF AIR TO WATER HEAT PUMP IN SERBIAN CLIMATE CONDITIONS

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ABSTRACT

According to Article 20 of the Treaty establishing the Energy Community, the Republic of Serbia has accepted the obligation to implement European Directives in the field of energy efficiency and use of renewable energy sources (hereinafter RES). The introduction of the Directives into National legislation has resulted in numerous changes and amendments to the laws and bylaws, followed by national action plans and strategies.

The paper gives an overview of National Action Plan for Renewable Energy Sources developed by Ministry of Energy, Development and Environmental Protection of the Republic of Serbia, analyzing available potential of RES use. The major goal is to decrease energy consumption in the field of heating and cooling by combining energy-efficient techiques and application of RES. In this paper, special emphasis is placed on the application of heat pumps using outdoor air as a heat source. Analyzed are operating conditions of the heat pump during heating seasone, using weather data for Belgrade. The estimated energy savings and reduced heating costs are presented in comparison with the measurement results. The results are discussed in terms of reduction of energy consumption and cost effectivness of heat pump application.

Keywords: energy efficiency, heat pump, renewable energy, energy consumption, COP, energy savings, cost effectiveness

INTRODUCTION

Based on all conducted analyses, studies and projects in the last decade, it is evident that the final energy consumption in the building sector is dominant and growing, as indicated in the energy balance of the Republic of Serbia [1]. Recognizing the importance of this problem, the Ministries in charge of energy and construction of the Republic of Serbia began a systematic campaign to approach solving the problem of uncontrolled, disorganized, irrational and unsustainable use of energy and fuels in all sectors. Adopted are numerous documents, which provide a route to organized and sustainable treatment of energy issues, including: Energy Law, the Law on Planning and Construction, the Law of Efficient Use of Energy, Energy Development Strategy of the Republic of Serbia, the Regulation on the Implementation Program of the Energy Development Strategy, the First and the Second National Action Plan for Energy Efficiency, Regulation on Energy Efficiency in Buildings, Regulation on conditions, content and manner of issuing certificates on the energy performance of buildings, etc. Institute for Standardization of Serbia, through the involvement of several Commissions for Standards, introduced in the national framework a large number of European and International standards in this area, which, to a large extent, facilitated the process of implementation of relevant legal documents. Formed is the Central Register of Energy Passports (CREP), connected to databases of Serbian Chamber of Engineers and Cadastre, a software platform that provides numerous options for all users, starting from a licensed engineers, through legal authorities and persons who need information about the process of energy certification, to Ministry of construction and urban planning, which oversees the entire process. Thus, it is possible to conclude that the barriers for implementing energy efficiency improvements in the area of legislative framework are almost obsolete.

According to Article 20 of the Treaty establishing the Energy Community, the Republic of Serbia has accepted the obligation to implement European Directives in the field of use of Renewable Energy Sources (hereinafter RES) - Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. In accordance with Directive 2009/28/EC binding targets for Member States of the European Union are set to ensure that the RES, in 2020, accounted for 20% of the gross final consumption at the level of the European Union [2]. The same methodology of the Directive, which was used to calculate the targets in the field of RES for EU member states, is applied to the other members of the Energy Community, with the difference that the base year for calculating the specific targets is set to 2009. instead of 2005. In accordance with Directive 2009/28/EC and the Decision of the Ministerial Council of the Energy Community of October 18, 2012 determined is an ambitious binding target for the Republic of Serbia, which is 27% renewable energy in its Gross Final Energy Consumption (hereinafter GFEC) in 2020.

RENEWABLE ENERGY SOURCES

Renewable energy sources, with an estimated technically exploitable potential of about 5.6 Mtoe per year (Figure 1) can significantly contribute to the reduced use of fossil fuels and to the improved environmental conditions. Of the total of available technical potential of RES Republic of Serbia is already using 35% (0.9 Mtoe of used hydro potential and 1.06 Mtoe of the potential biomass and geothermal energy) [3].

The use of RES in the previous period was based on the production of electricity from large river flows, and the use of biomass, mainly for heating purposes in households, to a lesser extent in the industry. According to the data from the energy balance of the Republic of

Serbia for 2009, the share of electricity from hydropower in GFEC amounted to 9.6% (28.7% in the electricity sector), while the share of thermal energy from biomass in GFEC amounted to 11.5% (27.5% in the sector of heating and cooling) [3].

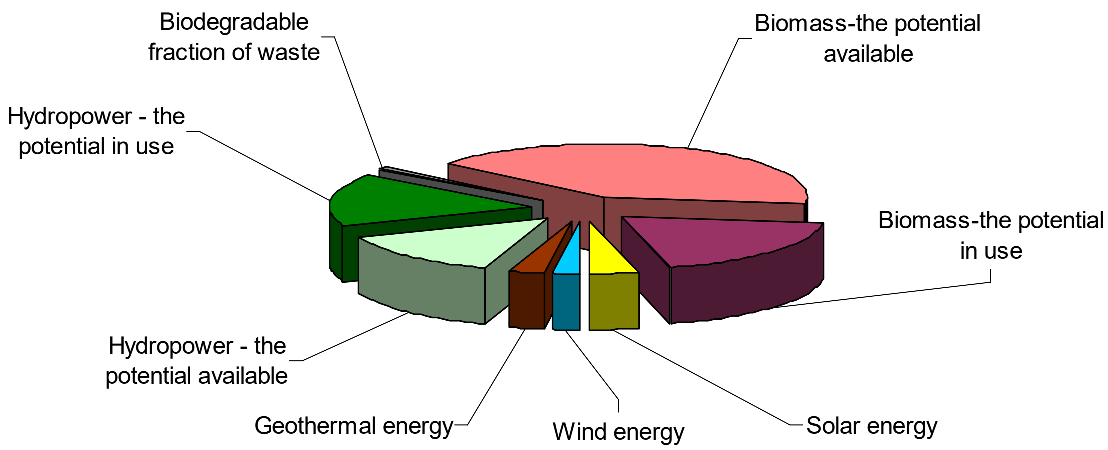

Figure 1 RES structure in the Republic of Serbia [3]

According to the Directive 2009/28/EC, energy from renewable sources' means energy from renewable non-fossil sources, namely: wind, solar, ***aerothermal***, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases [2]. Of the three sectors of energy consumption, the bulk of energy consumption is in the heating and cooling sector. Predicted changes of gross final energy consumption according to the scenario with measures for energy efficiency, for the period from 2010 to 2020, is shown in Figure 2. It can be seen clearly, with the diagram shown in Figure 2, that the biggest savings are projected in the heating and cooling sector [3].

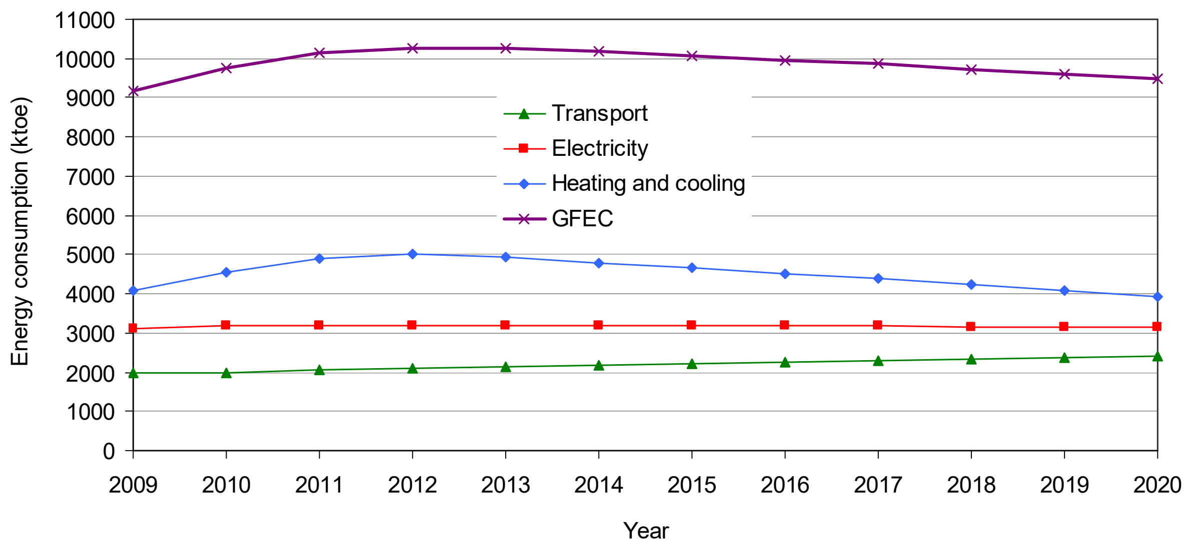

Figure 2 GFEC in total and by sectors – according to the scenario with measures for energy efficiency [3]

In order to contribute in sustainability and energy savings for heating and cooling, it is necessary to take into account all possible application of RES. Since the majority of building stock in Serbia are single family houses, both in urban and rural environment (approximately 50%) [5], it is evident that this subsector is dominant potential for energy savings. It is shown that around 40% savings are possible with application of cost effective energy retrofit measures concerning single family houses, with average investment of 35 euro/m^2 and payback period up to 8 years [6].

AIR TO WATER HEAT PUMP APPLICATION

Although the outdoor air is not considered as RES potential in the National Action Plan for Renewable Energy Sources, it shouldn't be ignored when it comes to single family houses. To this end, this paper analyzes the potential of outdoor air as a heat source for heating, for the Serbian climate conditions. Diagram on figure 3 is showing outdoor air temperature variation during the heating season, in accordance with the data of Typical Meteorological Year (hereinafter TMY) for Belgrade [4]. It can be seen that the heating season lasts approximately 180 days, and that the emergence of low temperatures is typical for several periods in December and January.

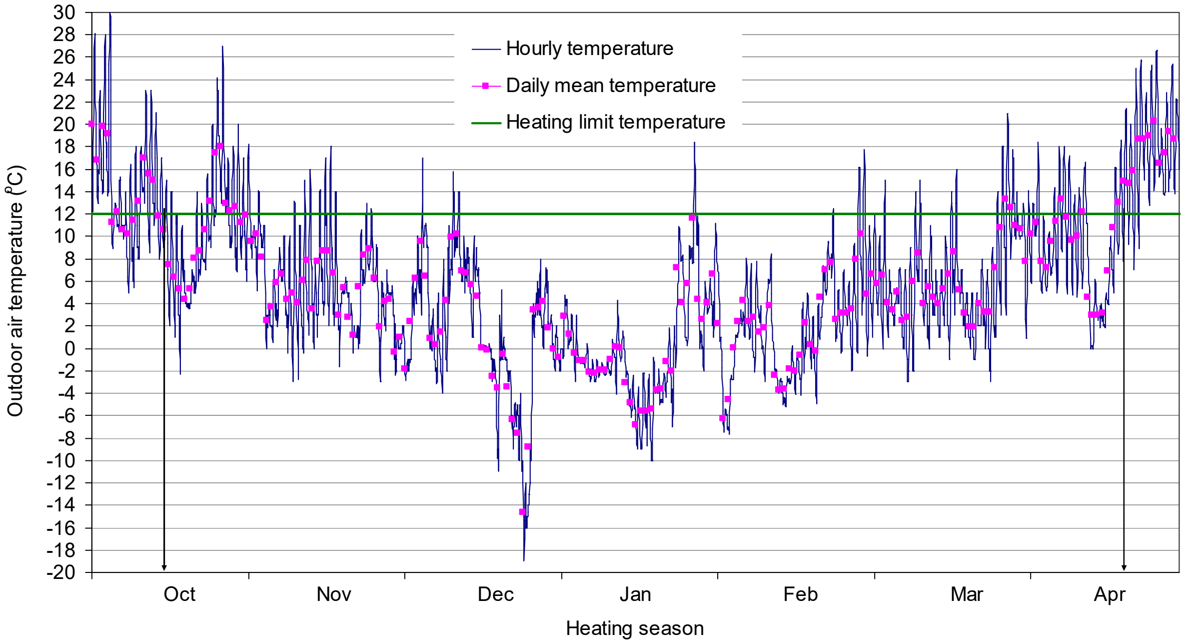

Figure 3 Outdoor air temperature variations during the heating season [4]

With the outdoor air temperature decrease, it is necessary to increase supply hot water temperature in heating system, in order to cover heat losses of the building and maintain thermal comfort. On the other hand, this affects lowering of evaporation temperature and increase of condensing temperature of the refrigerant in the heat pump. Since the Coefficient of Performance (hereinafter COP) varies depending on the evaporation and condensing temperature relation, and the efficiency of utilization of outdoor air in the winter months is variable. Refrigerants that are in common use in air to water heat pumps of new generation is R 407c and R 410a, regarding improved environmental features. Figure 4 is showing COP variation depending on the condensing and the evaporation temperature for refrigerant R410a [7], [8].

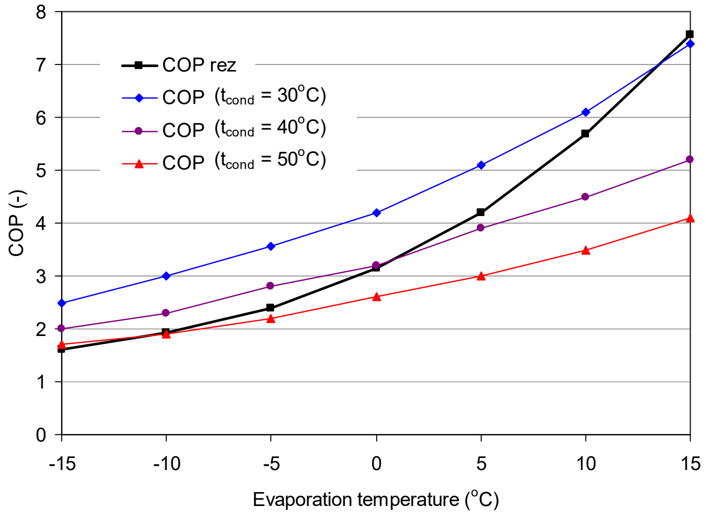

Figure 4 COP variation depending on the condensing and the evaporation temperature for refrigerant R410A [7, 8]

Introducing the assumption that the evaporation temperature of refrigerant is lower by 3°C than the air temperature, as well as the assumption that the condensing temperature is 2°C higher than hot water supply, obtained is a theoretical dependence of COP and the outdoor air temperature. Mentioned assumptions are based on monitored operation of a heat pump during the heating season 2014/15. Diagram on figure 5 is showing the theoretical operating regime of the heat pump: the change of evaporation and condensing temperatures and variation of COP depending on the outdoor air temperature. The established dependence enables calculation of daily electricity consumption for the operation of the heat pump.

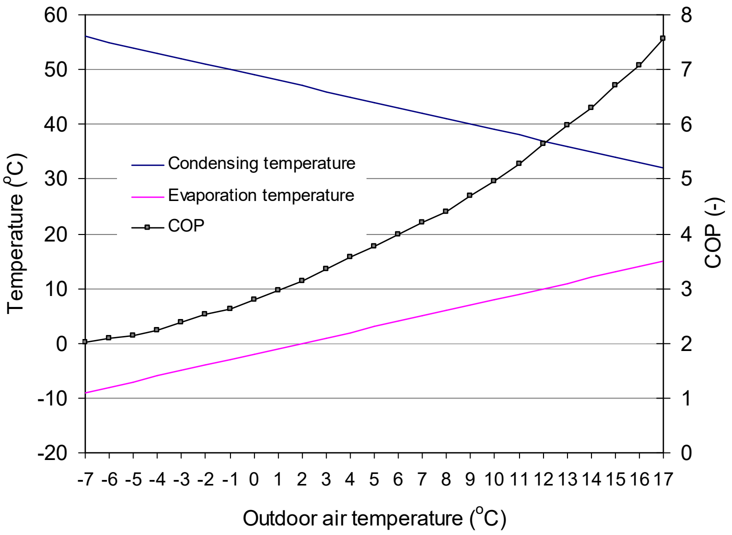

Figure 5 Theoretical operating regime of heat pump depending on the outdoor air temperature

When carrying out analysis of implementation of energy retrofit measures in buildings, as a rule, first applied measures are to improve the building envelope. This process reduces the need for a final overall energy for heating. However, these measures do not necessarily lead to a reduction in energy consumption. Namely, it is necessary to adapt the existing heating system to the new conditions. The existing heating system is then oversized and is usually adjusted using an automatic control. For radiator heating system it is necessary to lower the temperature-mode and adjust the heating curve to the new conditions.

In the further analysis considered is a replacement of the existing central electric heating boiler with a heat pump, and transition to low-temperature heating mode (63/48°C). It should be noted that the new temperature regime determines whether the heat pump can be used as monovalent heat source. If this is not a case, it is necessary to include an additional heat source. The selection of the heating capacity of the heat pump is then linked to the limit value of external air temperature, which enables selection of smaller and cheaper unit. Figure 6 is showing heating curve for the low-temperature radiator heating. It can be seen that limit temperature value is -7°C. When the outdoor air temperature reaches values lower than -7°C, additional heat source starts with operation.

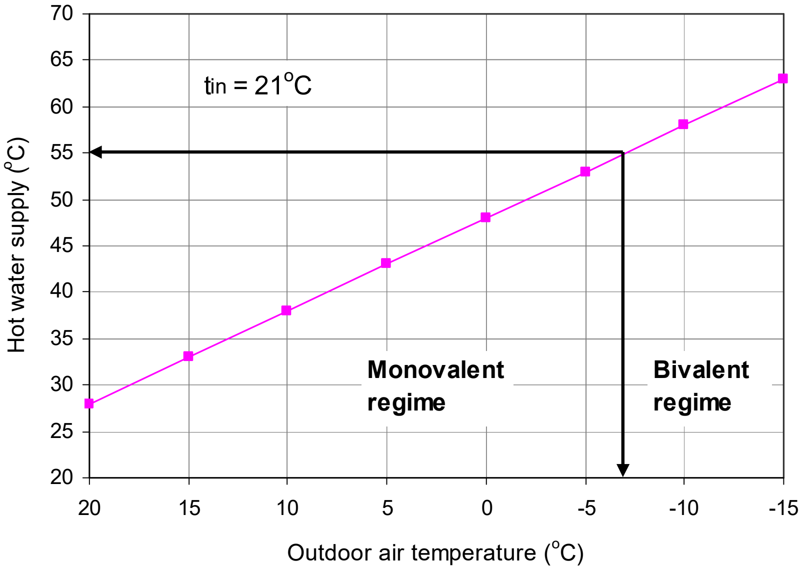

Figure 6 Heating curve for low temperature radiator heating (63/48°C)

In order to gain a better overview of the heat pump operation during the entire heating season, it is necessary to observe frequency of outdoor air temperature values. For this reason, the annual heat load duration curve is constructed, using data of TMY, which is presented at figure 7. One can see that only 8 days during the season external temperature drops under limit value of -7°C, representing less than 5% of the heating season duration. Also, the number of days with outdoor temperature below freezing is rather small, when the heat pump operates in a mode with unfavorable COP values (lower than 3). On the other hand, additional heat source should cover less than 10% of total energy consumption.

During the transitional periods, at the beginning and end of the heating season, the outdoor temperature is high, resulting in a favorable value of the COP. However, during the abovementioned periods (October and April), the consumption of energy for heating is not high, that is, the proportion of energy consumed in those periods is less than 20% in total consumption for heating on an annual basis. Calculation of the energy consumption for each day of the heating season is performed, and compared is the consumption for a system with an electric boiler and the system with a heat pump. Energy savings obtained with the application of the heat pump are shown on monthly bases on figure 8. Although the COP values are lower during the coldest months, the amount of energy used is large, so that the greatest savings are achieved. When a comparison of the total energy consumption on an annual basis is done, the total savings amounts to 47.6%.

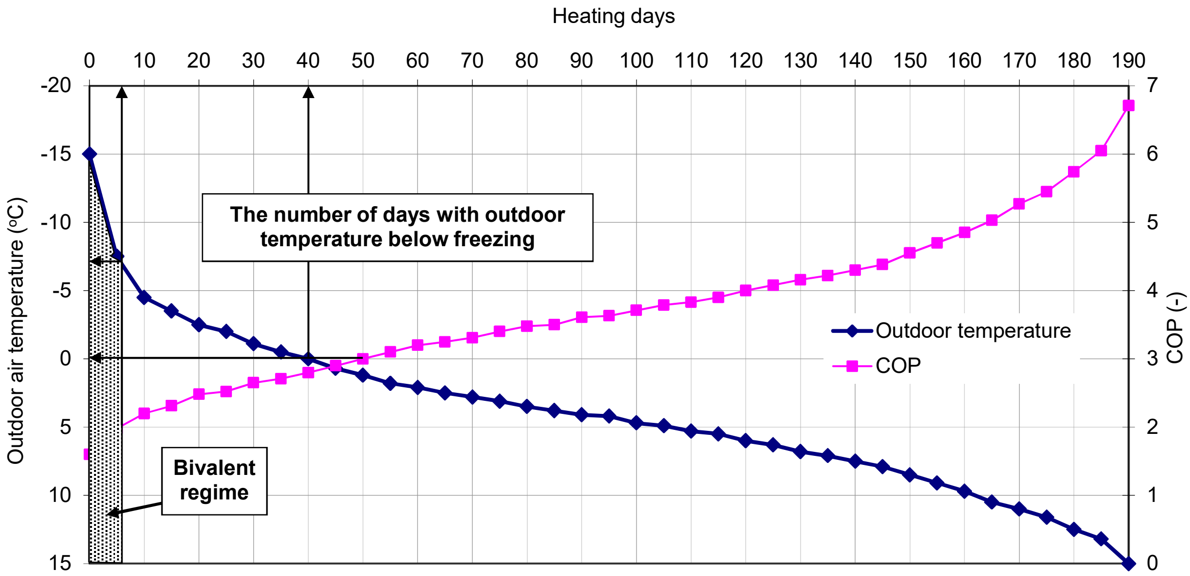

Figure 7 Seasonal heat load duration curve and COP change

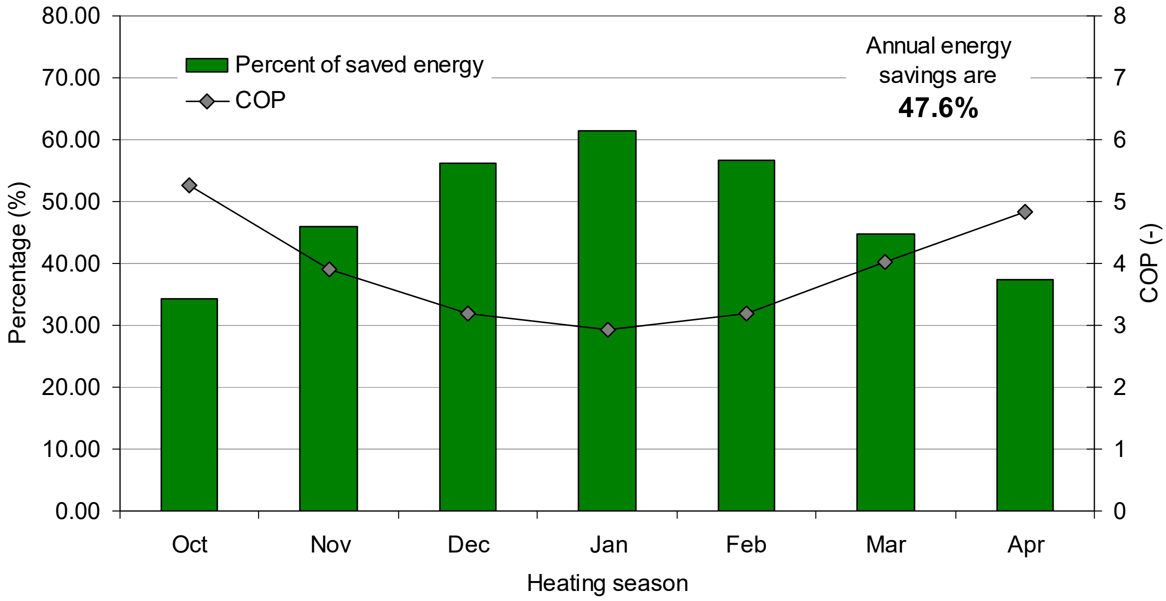

Figure 8 Theoretical energy savings during the heating season

MEASUREMENT RESULTS

Theoretical calculation of possible energy savings by application of air to water heat pump has shown significant potential of use external air as heat source. In order to confirm the results of the theoretical analysis conducted in this paper, monitoring of the heat pump operation was carried out, after reconstruction of heating system in single family house in Belgrade. Net heating area is 120 m^2, with radiator central heating system, with temperature regime of 63/48^{o}C. Final energy need for heating amounts to 80 kWh/m^2. Monitored are: evaporation temperature, condensing temperature, external temperature, indoor temperature, heat pump operating hours, compressor operating hours in different stages, additional electric heater operating hours, etc. Measured is electricity consumption on monthly basis. Achieved energy savings in heating season 2014/15 are shown on figure 9 in comparison with theoretical calculation. Measured energy savings amounts to 57.1%. Diagram on figure 10 indicates decrease in monthly electricity bills after installing heat pump.

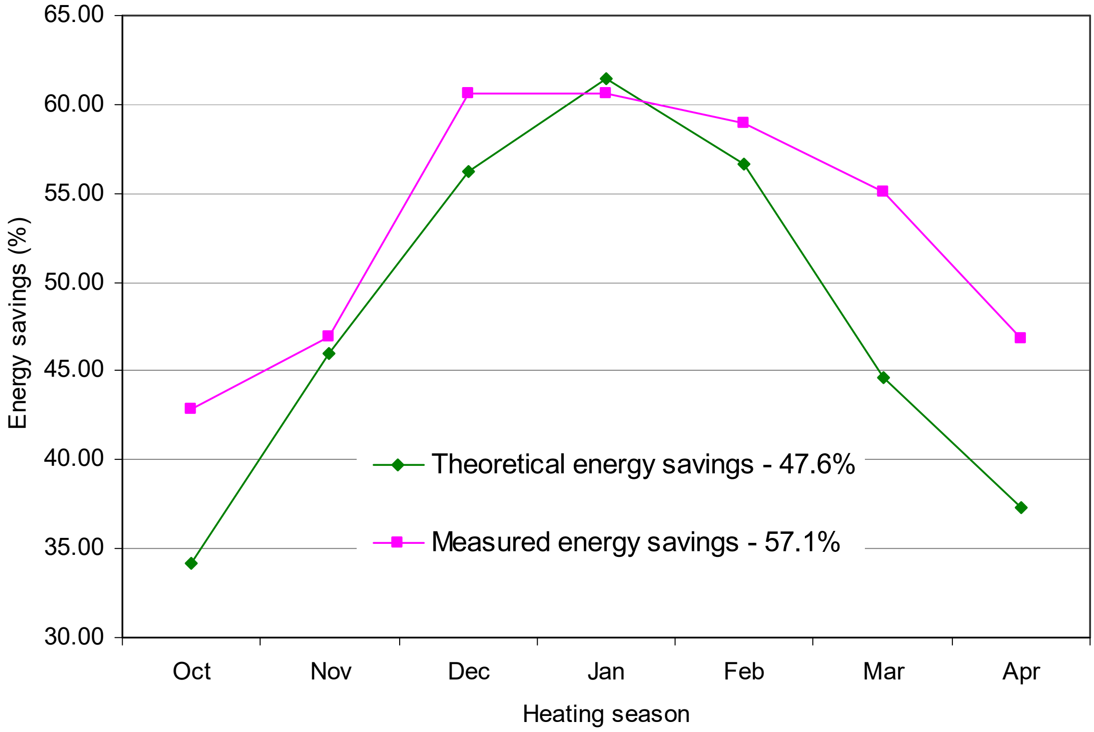

Figure 9 Comparison of theoretical and measured energy savings during the heating season

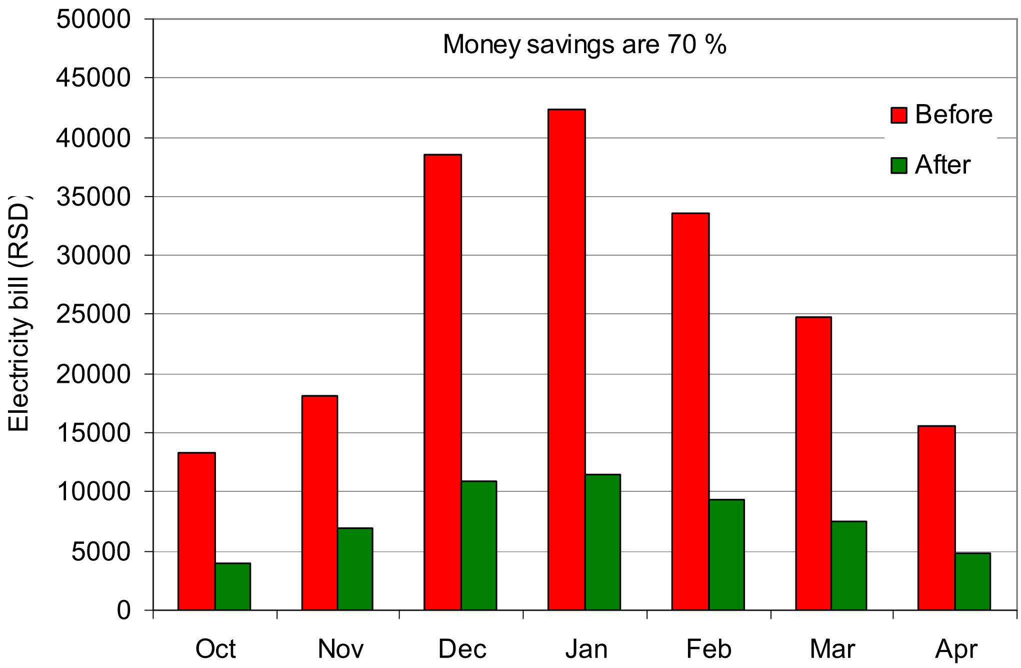

Figure 10 Reduction of electricity bills during the heating season

CONCLUSION

Lack of equal financial incentives for different consumers groups also may be identified as a barrier. Particularly it relates to the buildings sector, both municipal public and residential buildings. Some barriers, preventing the scaling up of EE financing are related to regulatory framework, or institutional setup, but in general, the majority of barriers to EE financing are related to the internal capacity and lending behavior of local financial institutions (LFIs). That is why dedicated EE financing mechanisms, adapted to the local market conditions, may be the key to successful implementation and scaling up of EE investments in Serbia.

REFERNCES

[1] Ministry of Energy, Development and Environmental Protection of Republic of Serbia: Energy Balance for 2015, Official Gazette 147/2014, www.mre.gov.rs

[2] Directive 2009/28/EC of the European Parlament and of the Council, Official Journal of the European Union, 05.06.2009., available at: http://www.buildup.eu/sites/default/files/RES%20Directive%202009-28-EC.pdf

[3] Ministry of Energy, Development and Environmental Protection of Republic of Serbia: National Action Plan for Renewable Energy Sources, Belgrade 2013.

[4] Weather data for Typical Meteorology Year for Belgrade http://www.eere.energy.gov/buildings/energyplus/weather_data.cfm

[5] Todorović M.: Energy efficiency and use of renewable energy sources in Serbia, IEEP 2015, Zlatibor, 24-27. June 2015, Proceedings on CD.

[6] Todorović M., Šumarac D., Galić R.: Survey of potential energy savings in the building sector in Serbia and needed investments, SIMTERM 2013, Soko Banja, Proceedings on CD.

[7] Emerson Climate Technologies: R410A – R407C A Refrigerant Analysis for Air to Water Heat Pump Application, http://www.emersonclimate.com/europe/ProductDocuments/CopelandLiterature/TSC123-EN_ScrollHeating_vs10_0.pdf

[8] Winandy E.: New Compressors Technology Trends For Residential, Commercial and Industrial Heat Pumps, Institute for Refrigeration, December 2012, London