THE DIFFERENT ENERGY SOURCE TYPE INFLUENCE ON BUILDING PRIMARY ENERGY NEEDS

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Abstract: The paper deals with the influence of different energy sources types on primary energy needs of a residential-business building with a total usable area of 1300m^2, which is located in Belgrade. The annual final energy consumption of the building, including energy for heating, cooling, ventilation, lighting and domestic hot water preparation, is calculated. The total energy needs of the building are calculated and compared for different energy sources. The impact of the applied energy source on primary energy needs is valuated. Different energy sources types, which are compared are as follows: district heating system that generates heat from fossil fuels, individual gas boiler for the building, local air conditioning units, heat pump, and solar heating systems for domestic hot water preparation, and furthermore their influence on primary energy needs of the building. The final energy consumption is calculated in accordance with International and European standards EN ISO 13790, EN 15316 and EN 15193. The energy savings that can be achieved by appropriate selection of energy source and the optimal energy solution are analyzed.

Key words: primary energy needs, annual energy consumption, energy source type, energy savings, optimal energy solution

1. INTRODUCTION

Improving energy efficiency in buildings is one of the most important goals in the Development Strategy of the Republic of Serbia, included in the National Energy Efficiency Action Plan. This question is crucial given the fact that approximately 40% of produced energy is consumed in buildings.[1] This paper deals with the influence of different energy sources types on primary energy needs on the example of one residential-business building with a total usable area of 1300m^2, which is located in Belgrade. Different energy sources types, which are compared are as follows: district heating system that generates heat from fossil fuels, individual gas boiler for the building, local air conditioning units, heat pump, and solar heating systems for domestic hot water preparation, and furthermore their influence on primary energy needs of the building. The energy savings that can be achieved by appropriate selection of energy source and the optimal energy solution are analyzed.

2. BUILDING DESCRIPTION

The building that is considered is located in the center of the Belgrade. It's designed as a residential-business building with a total usable area of $1300m^2$. Building thermal envelop is designed with good thermal insulation (0.37 $[W/m^2K]$ for external walls, and with average quality windows (1.8 $[W/m^2K]$, a=0.4 $[m^3/mhPa^{2/3}]$). The building consists of basement with garage, ground floor and five floors. There are 16 apartments (two of them are luxury penthouses), and 2 commercial properties on the ground floor, (Fig.1.)

Figure 1. 3D model of a building, [2]

3. CALCULATION RESULTS

3.1. Basic equations

The calculation is done in accordance with The International Standard EN ISO 13790:2008, a fully prescribed monthly quasi-steady-state calculation method, EN 15316 and EN 15193, for Belgrade weather conditions. The applied method for calculation of the required heat is a fully prescribed monthly method in accordance with EN ISO 13790, using weather data on the typical meteorological year (TMY) for Belgrade. For whole building and each calculation step (one month), the building energy need for space heating, $Q_{H,nd}$, for conditions of continuous heating, is calculated as given by equation:

$$Q_{H,nd} = Q_{H,ht} - \eta_{H,gn} \cdot Q_{H,gn} \tag{1}$$

where (for whole building, and for each month):

$Q_{H,nd}$, is the building energy need for continuous heating;

$Q_{H,ht}$ is the total heat transfer for the heating mode;

$Q_{H,gn}$ gives the total heat gains for the heating mode;

$\eta_{H,gn}$ is the dimensionless gain utilization factor.

The energy need for cooling, $Q_{C,nd}$, is calculated by equation:

$$Q_{C,nd} = Q_{C,gn} - \eta_{C,ls} \cdot Q_{C,ls} \qquad (2)$$

where (for each building zone, and for each month):

$Q_{C,nd}$ is the building energy need for cooling;

$Q_{C,gn}$ gives the total heat gains for the cooling mode;

$Q_{C,ls}$ gives the total heat losses for the cooling mode;

$\eta_{C,ls}$ is the dimensionless losses utilization factor.

3.2. Calculation results

The simulation for Belgrade weather data, for summer conditions, showed that (as a function of different schedule), the total heat loads for building, including business properties are 122.619 [kW]. For winter design conditions, the total heat losses are 92.942 [kW], [3].

Figure 2. shows specific monthly final energy needs for heating and cooling. It is shown that annual final energy needs for heating are 55kWh/m^2 and final energy needs for cooling are 88kWh/m^2. Annual energy needs for lighting and DHW are calculated in accordance with EN ISO 13790, using appropriate recommendation and software for energy needs for DHW preparation calculation [4].

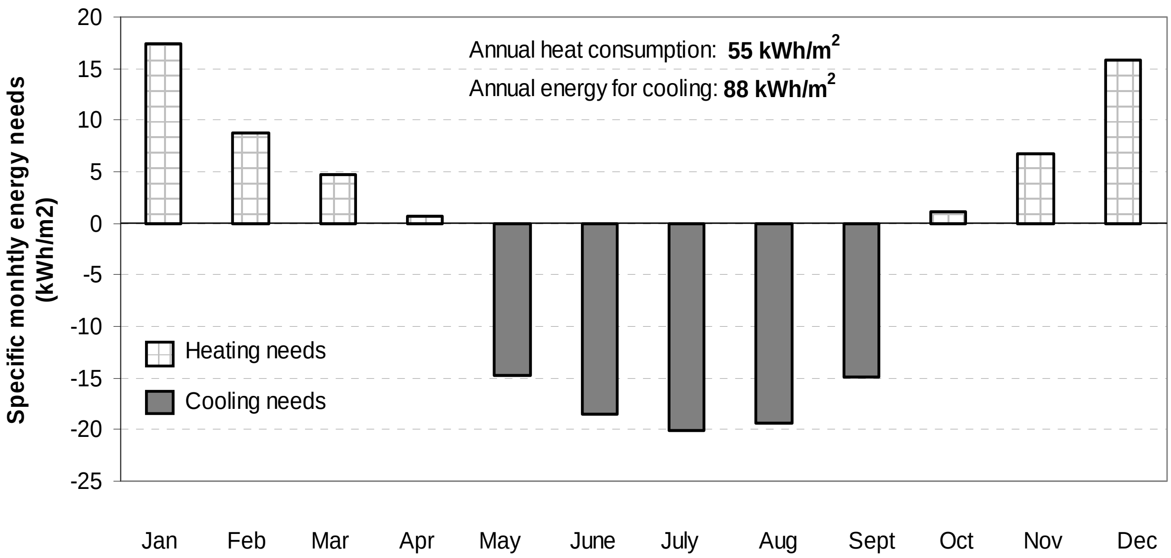

Figure 2. Heating and cooling needs – final energy

There are three models of a different types of energy sources, for the same building, that are compared: basic model (M0) that is considering district heating system that generates heat from fossil fuels for heating, local air conditioning units (split systems) in every apartment and business property, and individual DHW preparation in each apartment and business property, using electrical boilers; Model M1 is considering individual gas boiler for the heating for whole building, local air conditioning units (multi split systems) for each apartment and business property, and individual DHW preparation in each apartment and business property, using electrical boilers; and Model M2 is considering heat pump as a energy source for heating and cooling and solar heating systems for domestic hot water preparation for whole building.

The energy needs for ventilation are calculated through the energy needs for heating, within the calculation of ventilation losses. There isn't mechanical ventilation system, and required air quality can be achieved by natural ventilation (by opening the windows). Total energy needs of the building, for basic model M0 are shown on Figure 3. Annul final energy needs, for basic model M0 are 172kWh/m^2. Annual delivered energy needs are 179kWh/m^2 and annual primary energy needs are 264kWh/m^2.

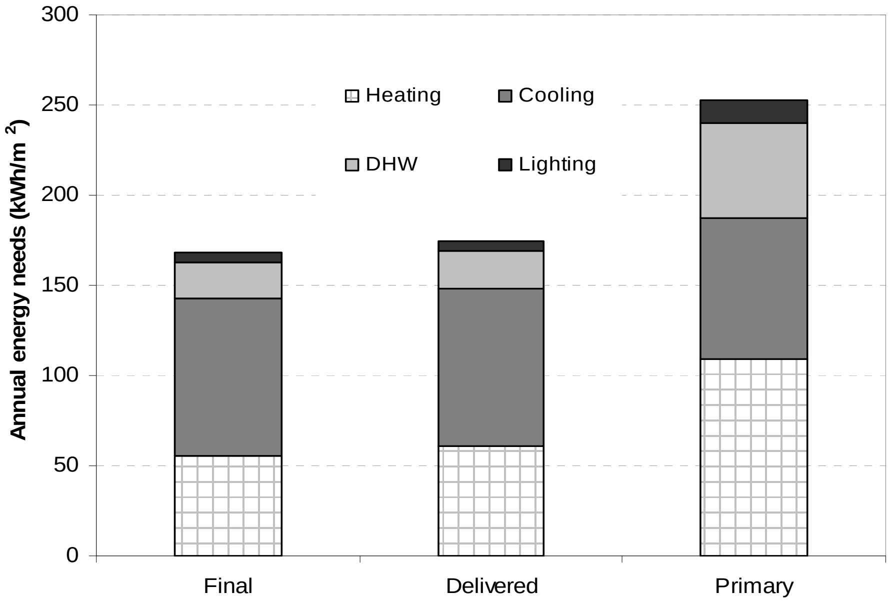

Figure 3. Total energy needs of the building – basic model

The impact of a different heat source types on annual primary energy needs is calculated, and given on a Figure 4. Heat source types that are compared are as follows: district heating system that generates heat from fossil fuels, individual gas boiler for the building, individual oil-fired boiler, individual coal boiler, heat pump and electrical boiler. Figure 4 represents annual primary energy savings that could be achieved by appropriate selection of a heat source type. It is shown that primary energy savings could be up to 68%, using heat pump as a heating source, comparing to the district heating system on a fossil fuel.

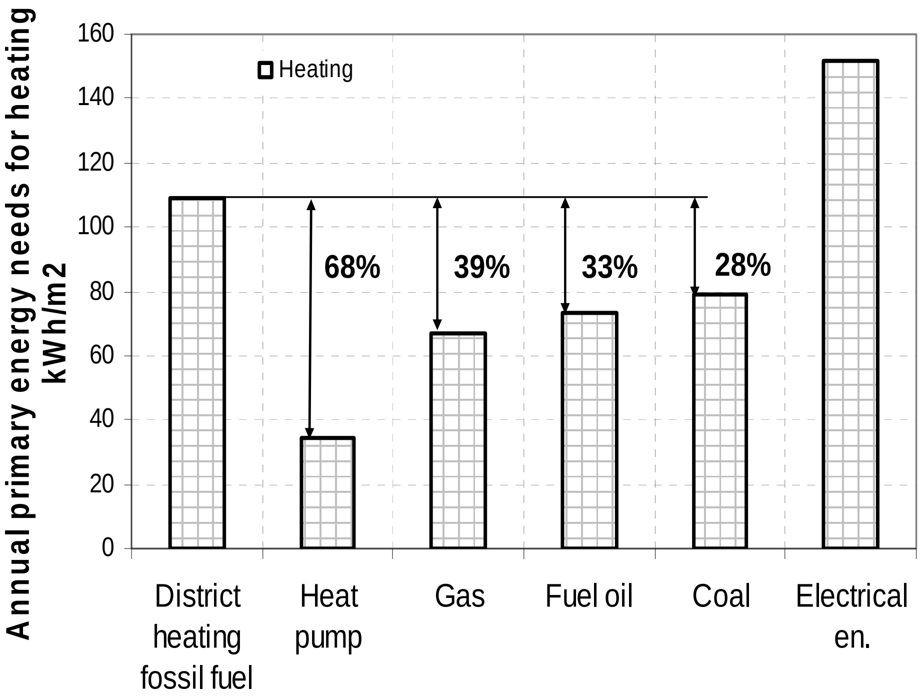

Figure 4. Heating needs depending on the energy source type

Annual primary energy needs for cooling is also calculated, and compared for three energy sources: split system, multi split system and heat pump. Calculation showed that split system, and multi split system has approximately the same primary energy needs for cooling, and with heat pump, approximately 7% energy savings could be achieved in comparing to the split system (Figure 5). The savings that are calculated take into account only energy savings; money savings and techno-economic analysis weren't under consideration in this paper.

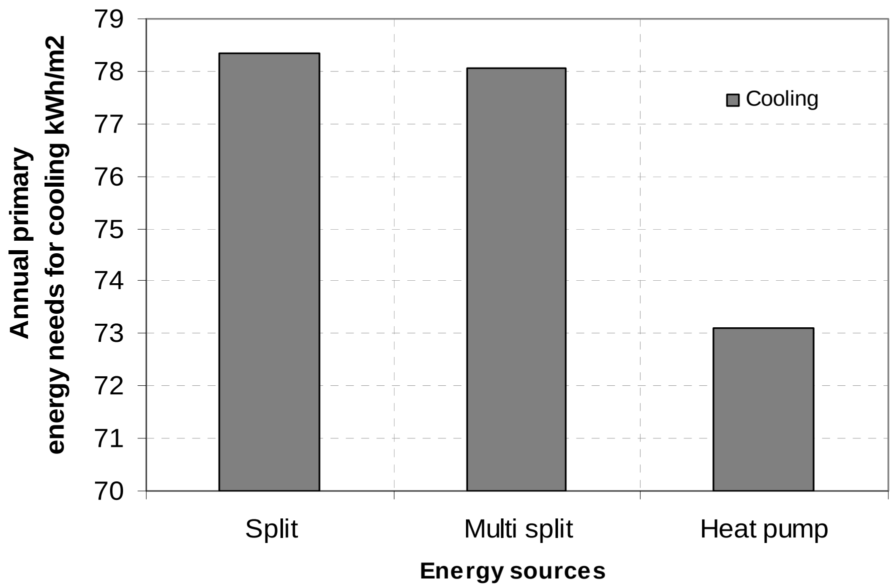

Figure 5. Cooling needs depending on the energy source type

Domestic hot water preparation is compared for two systems: electrical boilers in every apartment and business property and solar heating systems for domestic hot water preparation for whole building. Solar heating collectors are located on the plain roof of the building, and total collector area is 31m^2. Simulation is performed for specific building orientation and for Belgrade weather data, [4]. Annual global irradiance is 1341 kWh/m^2. Total efficiency of collectors is 78,5%, [4].

Fraction of solar energy to the system for DHW preparation for the building is given on the Figure 6, for designed conditions. Figure 6 shows that the fraction of solar energy for DHW preparation is less than 100% even in Jul and August because the simulation is performed for designed conditions.

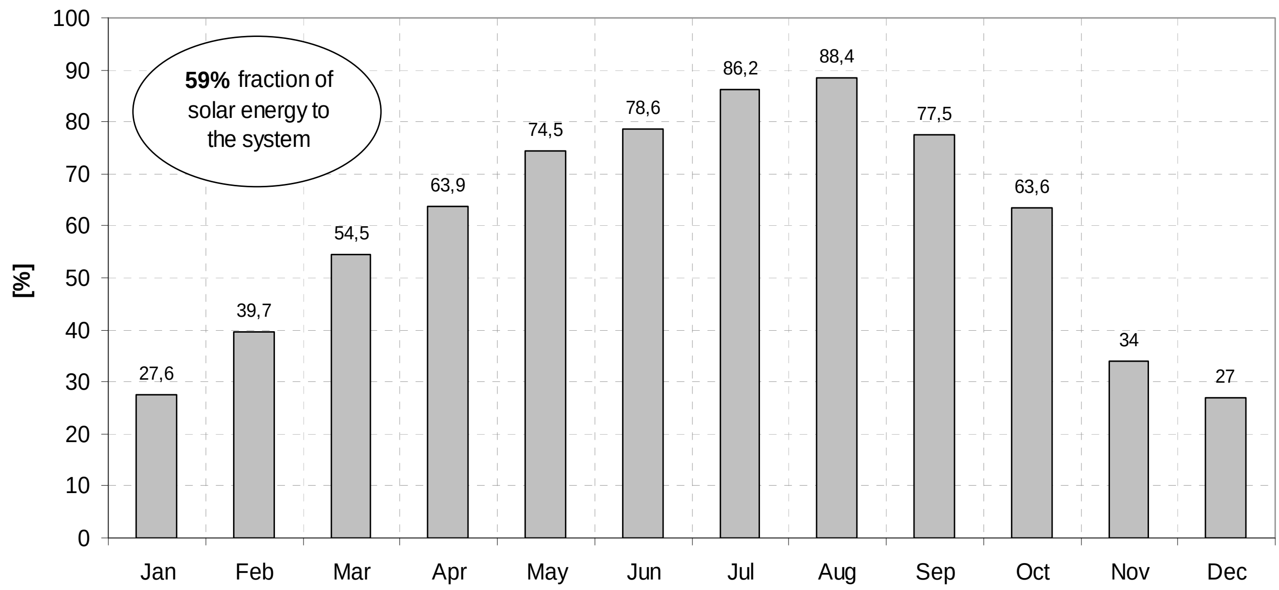

Figure 6. Fraction of solar energy to the system for DHW preparation for the building, [4]

If the solar system is designed to achieve 100% of energy needs in summer months, the system would be oversized and also there would be a possibility of system overheating. So, for system overheating protection and also to avoid oversized system, fraction of a solar energy to the system is up to 88,4% in August, as it is shown on Figure 6. But for weather conditions that are lower than designed conditions, it is possible that solar system can produce enough energy to supply 100% of energy needs for DHW preparation in summer months (July and August), depending on number of sunny hours.

The energy needs for DHW preparation that can't be achieved by solar heating system should be compensate by another system. Figure 7. presents ratio between solar energy that can be used for DHW preparation, and another type of energy (electrical and energy from fossil fuel) that should be used to compensate energy needs.

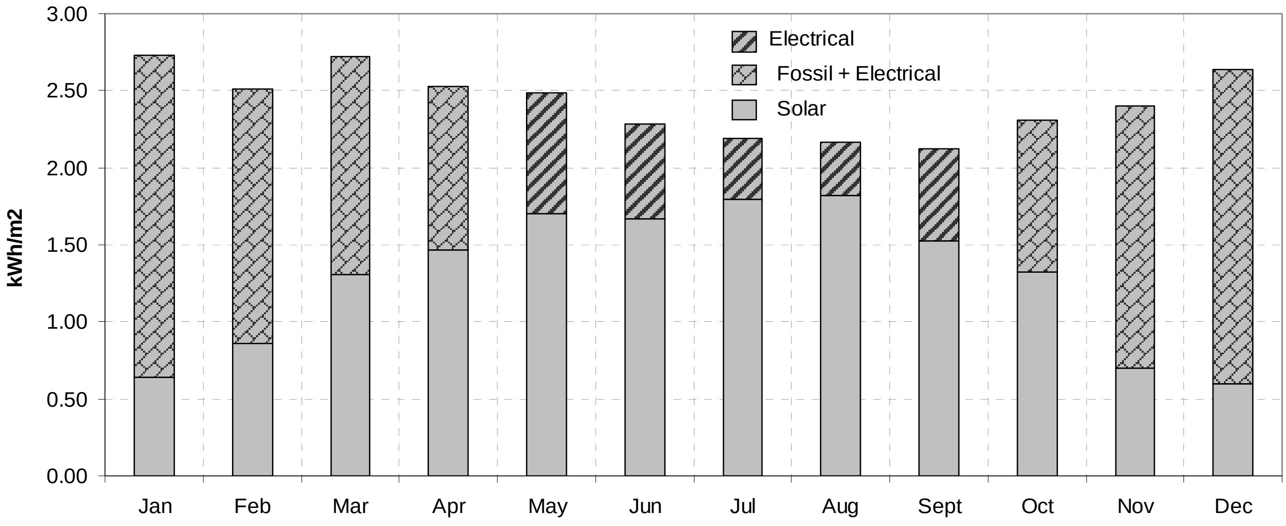

Figure 7. Ratio between solar and fossil and electrical energy needs for DHW preparation

For winter conditions, the fraction of solar and electrical energy and energy from fossil fuel for DHW preparation is given on Figure 8. Final and primary energy needs are considered, depending on the different energy source types. Total final energy needs for DHW preparation in winter conditions are 18kWh/m^2, which consists of 7kWh/m^2 of solar energy and 11kWh/m^2 of electrical and energy from fossil fuel for DHW preparation. Primary energy needs are different depending of the energy source type (Figure 8) and the biggest primary energy needs are for electrical energy for DHW preparation, 27kWh/m^2, and for fossil fuel there are lower primary energy needs, 14 kWh/m^2.

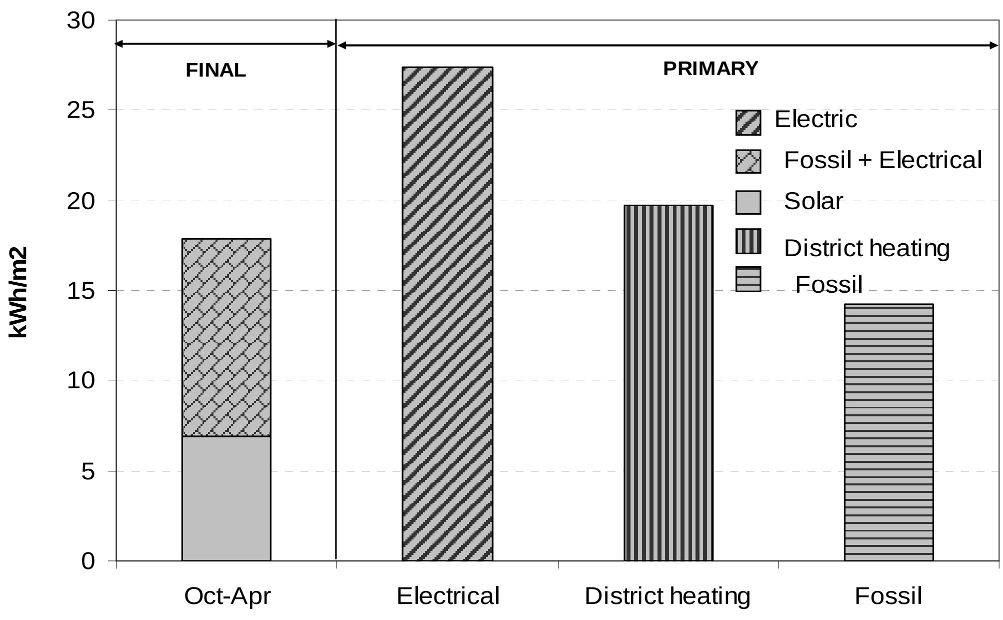

Figure 8. Final and primary energy needs for DHW preparation depending on the energy source type for winter season

For summer conditions, the fraction of solar and electrical energy for DHW preparation is given on Figure 9. It is considered that the energy needs for DHW preparation that can not be supplied by solar heating system, are compensated by electrical heater. Total summer final energy needs for DHW preparation are 11kWh/m^2, which supplies 9kWh/m^2 form solar heating system, and the rest 3kWh/m^2 from electrical energy. Primary energy needs for summer season are 7kWh/m^2.

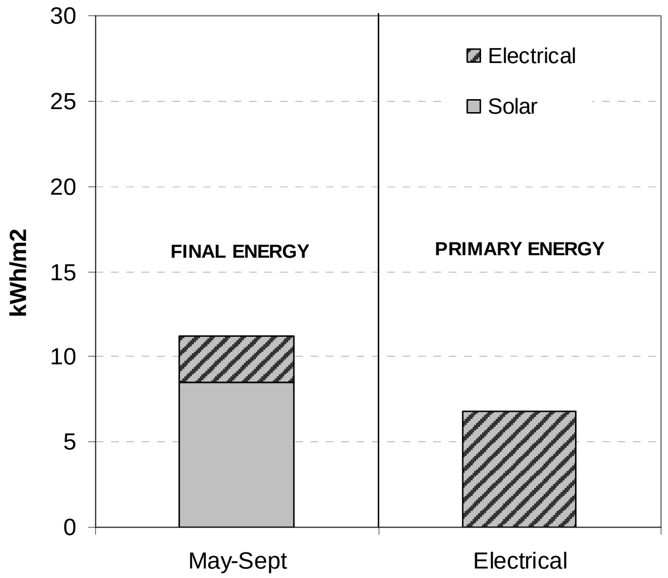

Figure 9. Final and primary energy needs for DHW preparation depending on the energy source type for summer season

The impact of a different source types on annual primary energy needs and energy savings is shown on Figure 10.

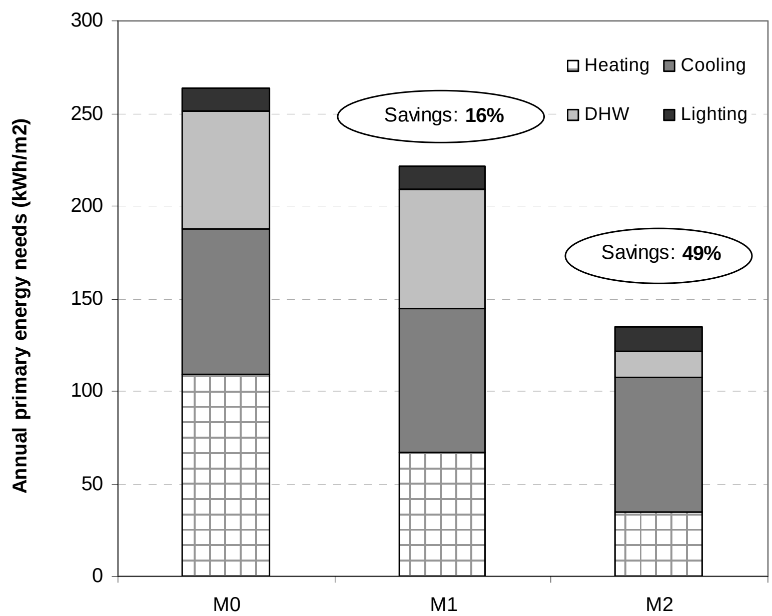

Figure 10. Optimal energy solution and energy savings

Calculations are compared between three models: basic model M0, M1 and M2, as it mentioned above. Basic model M0 has annual primary energy needs of 264kWh/m^2. Model M1 has lower annual primary energy needs than M0, and achieves annual primary energy savings up to 16%. It is shown that, observing only energy savings, the optimal energy solution is model M2, which taking into account energy for heating and cooling from heat pump source, and solar heating system for DHW preparation (Figure 10). With this energy solution, it is possible to achieve annual primary energy savings up to 49%. This analysis does not consider which model is optimal according to financial aspects. It's only energy savings analysis.

4. CONCLUSIONS

Calculation shown that the annual final energy consumption of the building, including energy for heating, cooling, ventilation, lighting and domestic hot water preparation, is 172kWh/m^2, for basic model of a HVAC systems (M0). The selection of energy source has a big impact on a primary energy needs. It is shown that primary energy savings that could be achieved by appropriate selection of a heat source type are going up to 68%, using heat pump as a heating source, comparing to the district heating system on a fossil fuel. Annual primary energy needs for cooling is also calculated, and compared for three energy sources: split system, multi split system and heat pump. Calculation showed that split system, and multi split system has approximately the same primary energy needs for cooling, and with heat pump, approximately 7% energy savings could be achieved in comparing to the split system. The simulation for solar heating system for DHW preparation, for Belgrade weather data shown that the fraction of solar energy to the system for DHW preparation for the building is going up to 88,4% in August, for designed conditions, and on annual basis fraction of solar energy to the system is going up to 59%. Total final energy needs for DHW preparation in winter conditions are 18kWh/m^2, which consists of 7kWh/m^2 of solar energy and 11kWh/m^2 of electrical and energy from fossil fuel for DHW preparation. Primary energy needs are different depending of the energy source type and the biggest primary energy needs are for electrical energy for DHW preparation, 27kWh/m^2, and for fossil fuel there are lower primary energy needs, 14 kWh/m^2. Total summer final energy needs for DHW preparation are 11kWh/m^2, which supplies 9kWh/m^2 form solar heating system, and the rest 3kWh/m^2 from electrical energy. Primary energy needs for summer season are 7kWh/m^2.

The selection of different sources types has a big influence on annual primary energy needs and energy savings. It is shown that, observing only energy savings, the optimal energy solution is model M2, which taking into account energy for heating and cooling from heat pump source, and solar heating system for DHW preparation. With this energy solution, it is possible to achieve annual primary energy savings up to 49%. This analysis does not consider which model is optimal according to financial aspects.

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