APPLICABILITY ASSESSMENT OF CENTRAL AND SOLAR HOT WATER SYSTEMS INTEGRATION IN SERBIA

by

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Energy systems for consumers' supply with sanitary hot water can be considered as a separate category of the system with many similar functions, performances and integral elements. This similarity of energy systems for sanitary hot water supply and the way in which they are used enable systemic planning, proposing and undertaking measures for improvements and advancements. This is possible not only by the reconstruction and modernization of existing technological solutions but also by their replacement with new, modern and more efficient solutions.
The basic idea and the aim of this paper is the development of a concept for integrated and upgraded system of sanitary hot water supply for different types of buildings from residential to more complex buildings intended for different purposes. The analysis is based on the application of a systemic approach adapted to the conditions in urban communities and includes only modern but commercial technologies.
This paper presents the results of a net energy analysis of integrated central and solar hot water supply system and compares it with the conventional sanitary hot water system in the City of Novi Sad, Serbia.
The proposed methodology is demonstrated through a simulation example. It is shown that 23% reduction in the total system's costs can be achieved as compared to the existing solution. Also, the methodology is applied to a residential block as a unit and obtained results indicate that investments in the development and construction of integrated systems are justified.

Key words: *hot water supply, solar systems, integration*

Introduction

Energy consumption in Serbia is steadily increasing as a result of population growth and increasing standard of living. This trend is producing an increasing demand on our dwindling resources, and on the environment, with the use of mainly coal fired electricity, natural gas/heavy fuel oil based district heating systems and natural gas fired local boilers in buildings [1]. Hot water supply system in the City of Novi Sad is a central type system and it is realized within the district heating system and associated infrastructure.

Space heating and hot water production consume more than one third of the primary energy in industrialized countries. In Serbia, this share is higher. Therefore, the conservation of fossil fuels and emission reduction may be enhanced significantly and one approach is by solar thermal technology [2, 3].

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This paper presents the results of a net energy analysis of integrated solar and central hot water supply system and compares it with the conventional hot water system in Novi Sad. This analysis is performed for a 20 year period as this is the usual economic lifetime period of solar hot water systems. It is also expected that hot water system will be paid back in energy terms at the beginning of the second decade.

In recent years, the depletion of conventional energy sources and their likely adverse impact on the environment have created growing interest in the application of renewable energy sources [4]. In Serbia, there is also a growing trend of applying renewable energy and one area of interest lies in the wider use of solar thermal energy for hot water supply. Till now, a number of solar thermal systems using sunlight to heat water directly or indirectly have been installed but not as a connected subsystem in the district hot water supply system.

The economic comparison results show that solar thermal systems have greater economic benefits than traditional water heating systems [5]. The solar hot water systems provide net energy saving compared to the conventional systems after 0.5-2 years, for electric and gas boosted systems, respectively [6].

According to [7], the building sector accounts for about 40% of the final global energy consumption and carbon dioxide (CO_2) emissions and must achieve greater energy efficiency through the combination of public policies, technological innovation, informed customer choices, and smart business decisions. In response to mentioned and other relevant findings, the International Energy Agency (IEA) has made some recommendations such as changes of building envelopes, application of heat pumps, solar heating/cooling and the use of renewables as means of reducing energy consumption and emission levels [8].

When developing the integration concept, the paper treats equally technical, economic, social and environmental aspects. The Author [9] considers that such systems may be designed from an economic perspective or from a techno-operational perspective; but within these two pillars, several subdivisions can be found. Economic optimization criteria include *e. g.* total energy system costs, capacity costs and social costs. From a techno-operational perspective, optimization criteria include fuel savings, CO_2 emissions, reserve/back-up capacity, required condensing mode of power generation, minimization of import/export, and elimination of excess power generation. All of these criteria can be applied to assess how well the system has integrated renewable energy.

By using solar energy, considerable amounts of greenhouse polluting gasses can be avoided. The saving, compared to a conventional system, is about 70% for electricity or diesel backup. It can therefore be concluded that solar water heating systems offer significant protection of the environment and should be employed whenever possible in order to achieve a sustainable future [10].

Oil and gas remain the primary energy source and supplied 70% of Serbian energy demand 40 years ago and still supply 70% today. In the future mix of Serbian energy sector alternative forms of energy, such as biofuels, wind, and solar power, will play a growing role in satisfying higher demand. Indeed, all forms of energy, as well as greater efficiency, will be needed to support Serbia's developing economy [11].

The approach and objectives of the proposed concept of supply

Energy systems for consumers supply with sanitary hot water (SHW) can be considered as a separate category of the system with many similar functions, performances and integral elements. This similarity of energy systems for SHW supply and the way in which they are used enable systemic planning, proposing and undertaking measures for improvements and advancements. This is possible not only by the reconstruction and modernization of existing technological solutions but also by their replacement with new, modern and more efficient solutions.

This is why the analysis of typical user groups of buildings and proven technologies is a good starting point for the systemic improvement of the existing situation which can be characterized as unsatisfactory.

The concept of integration of central and solar energy systems for SHW supply in different categories of buildings represents logical and rational solution. At that, the focus is on safety and reliability aspects of heat energy supply while economic, environmental and health aspects are conditional criteria which are implied.

In the essence, the integration concept provides the improvement of existing technological solutions and introduces new and modern technologies in full compliance with the existing energy, functional, health, environmental and economic and financial conditions for the use of buildings, which is the primary objective.

However, there are further, higher goals which the improved concept of SHW supply can provide and implement. This refers to the following goals and ways of their implementation:

(1) Increasing safety of SHW supply:
   - by diversifying energy sources where solar energy represents an additional energy source available at the place of production and consumption,
   - by implementing proven, reliable and flexible technologies integrated into existing installations and subsystems, and
   - by increasing possibilities for planning and managing energy systems in case of different types of buildings in urban areas.

(2) Realization of a rational SHW supply:
   - by developing and modernizing energy infrastructure in buildings which, as a rule, contributes to increased energy efficiency in subsystems for the production, distribution and utilization of heat energy,
   - on the basis of improved possibilities for fine regulation, monitoring and control, and
   - by combined exploitation with classical energy sources, already built plants and installations.

(3) Realization of economic sustainability,
   - by reducing operating costs for the supply of users which in turn relieves the budget of providers reserved for the purchase of imported energy carriers,
   - by creating conditions for the decrease of SHW purchase unit price for end users,
   - by opening new opprurtunities for the production, installation and maintenance of the technology at the level of local community, as well as by employing technologies which have the potential and prospects for local development, and
   - by eliminating undesirable consequences on business operations as a result of raised prices of fossil fuels at the market (growing trend of natural gas price rise is obvious and confirmed) and, at the same time, the growth of prices of fossil fuels has favorable effect on the shorter payback period of the investment in a solar plant.

(4) Reduction of negative environmental impacts:
   - by using clean energy sources with the lowest possible emissions of harmful gases which is of particular importance in urban settlements. Solar energy is the cleanest form of energy – ecologically clean or green energy (no exhaust gases: CO_2, SOx, NOx ...), and
   - by using the source of energy which is available and free of charge at the place of production, distribution and consumption (transport and conversion losses are minimum).

Explanation of integration needs

Average specific consumptions of energy in Serbia are several times higher than in EU member countries (data include also SHW consumption). With respect to the present energy, economic and environmental moment, this is unacceptable. On the other hand, already scarce budget funds are pointlessly wasted, the costs of building users are higher than they should be and at the same time the satisfaction of energy needs causes increased green house gas emissions. Moreover, energy systems in buildings are becoming unreliable and obsolete. They do not fulfill prescribed conditions in the proper way and they can also have negative effects on the health of building users.

The policies in developed countries are oriented towards the stimulation of increased use of solar energy. Until 2010, the EU countries installed 100 million m^2 of solar collectors or around 250 m^2 per 1000 inhabitants. In Serbia, there is considerable but not sufficiently used potential for solar energy utilization although it can meet the part of sanitary hot water demand. According to data provide by the Republic Hydrometeorological Service, the number of sunny hours varies from 1,500 to 2,200 hours per year. The actual average solar radiation which reaches the surfaces in Serbia is estimated to around 3.8 kWh/m^2 per day and moves within the range from 3.6 to 4.2 kWh/m^2 per day, depending on the geographic position. The commercial type of collectors can generate from 1.2 to 3 kWh/m^2 per day, during heating seasons. This means that the collector can transfer heat from 36 to 90 kWh per one square meter of collector surface [1-3] to the heating system. The practice has shown that solar collectors can save even more than 750 kWh of energy per 1 m^2.

In the summer period, the solar system can meet SHW the demand for in the amount of 90-100%, in the interim period of 50-70% and in the winter period of 10-25%. The typical solar system for the preparation of sanitary hot water for a flat with 3-4 family members can save up as much as 50-60% of total annual hot water requirements. The solar system, if properly estimated according to actual needs of consumers and if properly installed, can be repaid in the period of 7 to 10 years an the service lifetime of the solar system is around 30 years [12-14].

Possibilities for the use of solar energy in the district heating system

The development of the SHW supply system in cities has been carried out and it is still carried out according to old standards and nothing much has been done to improve their energy efficiency in general and to apply modern energy technologies. However, energy efficiency and diversification of energy sources are economically the most effective way for the improvement of all aspects of energy supply in case of district heating systems. The use of energy efficient technologies based on utilization and integration of solar energy can slow down the growth of natural gas and fuel oil consumption and eliminate the need for the construction of new energy capacities in spite of the growth of population and the standard of living.

Mediterranean countries such as Greece, Spain and Israel have been applying thermal receivers of solar energy a lot, especially on single houses. However, these countries have not developed the system of district heating and this application is certainly justified. In Scandinavian counties (Denmark and Sweden), there has been successful application of large solar systems within municipal heating systems and these are experiences which can be very useful for us. There are two reasons for that. Serbia, including Novi Sad, has a developed network for district heating and favorable climatic conditions when it concerns specific irradiated solar energy per square meter of collector surface (this is some 30% more solar radiation in relation to northern parts of Europe where the concept has been implemented successfully).

The application of solar energy is the most cost effective in the systems for the preparation of sanitary hot water as the present ways of supply are confirmed as irrational particularly in summer months. However, the use of solar energy for the purpose of heating has restrictions in the sense of disproportion between availability and requirements during winter period when the heating demand is the greatest.

According to present circumstances, the district heating system in the City of Novi Sad delivers SHW to a limited number of consumers and that mainly in the parts of the city with higher housing density. In these parts of the city, there is developed infrastructure for SHW supply which is an excellent basis for upgrading and integration of solar technologies. Then, this concept can become both technically and economically justified.

When we talk about possibilities for applying solar energy in the district heating system, it is necessary to take into account the following favorable and unfavorable aspects:

(A) *Favorable aspects of centralized SHW supply with the use of solar energy*

- Unit price of solar installation is lower when implementation is on the roofs of residential buildings as the number of SHW consumers in each building and per each installation is larger (high density housing) and the total efficiency of the whole system is also higher.
- Because of the coincidence factor in SHW supply, the total capacity does not necessarily need to be big and the installation robust and complex.
- The range of working temperatures in the district heating system is favorable for the use of solar collectors.
- In case of centralized systems, maintenance, supervision and management are efficient and easier.
- It is possible to construct a large solar plant in the short period of time and also to implement the solar part by means of gradual expansion in stages until full capacity is reached.
- The existing heating plants already have distribution networks, capacities and infrastructure which reduces investment costs for upgrading and integration.
- Hot water pipelines can serve as an enormous reservoir which will equalize consumption and production (surplus energy in summer months can be used to a large extent and also, the problem of stagnation and high temperatures of the collector medium will be significantly reduced).
- Lower unit price of heat accumulation.

(B) *Unfavorable aspects of centralized SHW supply with the use of solar energy*

- The problem occurs in case of tall buildings which often do not have enough space on roofs for installations required for the surface of solar collectors. The problem is to put up adequate capacity which will be harmonized with the housing density which increases with the number of floors.
- In case of majority buildings, roofs are oriented accidentally and not towards south where there are the largest gains of solar radiation.
- The ownership of roofs has not been regulated in the great majority of residential buildings.
- Regulations and design parameters which can enable greater use of solar energy in district heating systems have not been developed.

Integrated system for sanitary hot water preparation

The scheme of a typical – basic solar system consists of: solar collectors, hot water accumulator (tank) with a heat exchanger, solar station with a pump and controls and piping with corresponding working medium. Today, it is possible to find and select at the market various types of solar systems which differ regarding usability of solar energy, service lifetime, installation and price.

However, when integration with the existing situation is concerned, *i. e.*, when it is necessary to retain the existing hot water tank, piping and other, then it is possible to apply special hydraulic scheme which enables rational connection of solar installations (fig. 1).

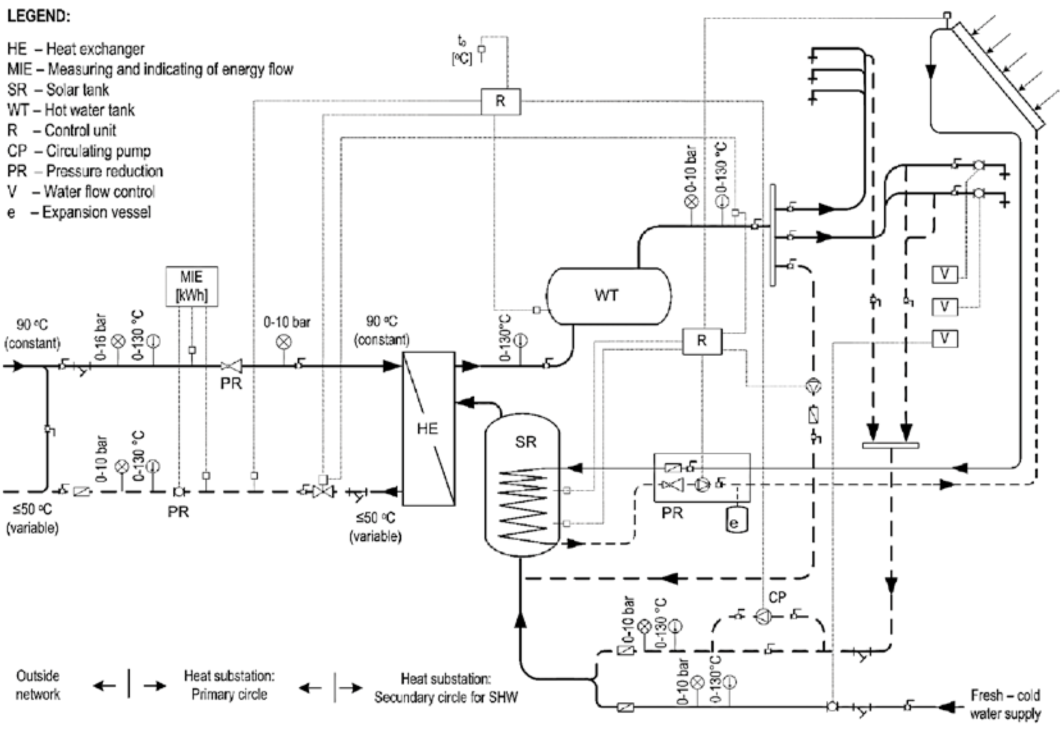

Figure 1. Solar SHW preparation with pre-heating tank and existing tank

The monovalent solar tank for pre-heating must be connected to the existing tank. Solar heating is done over the temperature difference regulation only in pre-heating tanks. With every hot water discharge at the discharge point (shower cabin), pre-heated or sufficiently heated hot water is conducted to the standby tank. In this way, it is possible to save up to 50% of energy since the exchanger does not need to heat up already hot water or this will be done only slightly.

The existing hydraulic installation can be optimized by applying solar regulator and by additional piping. In that case, the regulator will take up heat exchange between both tanks. As soon as higher temperature occurs in the solar tank then, the additional pump for sanitary hot water will pump hotter water into the standby tank. This can further save from 5 to 10%.

Reheating remains the same and it will be done over the existing heat exchanger. In order to enable high inflow of solar energy, it is possible to additionally install mixer of sanitary hot water. It will enable maximum temperature rise in the solar tank at 90 °C and at the same time serve as a reliable protection against overly high temperatures of hot water at discharge points (protection against hot water burns).

Analysis of solar system operations

Solar systems are calculated on the basis of average SHW consumption per person and the number of persons who live in the building. Recommended values of average SHW consumption are given in the tab. 1 [14] and they are stated in liters of water at the temperature of 60 °C per day and per person.

Table 1. Recommendations for average SHW consumption

Type of building: residential building	Lower comfort (minimum consumption)	Medium comfort (standard consumption)	High comfort (maximum consumption)
Social housing construction	25	30	35
General housing construction	30	35	45
Higher rank housing construction	35	40	50

Basic climatic data at the location Rimski Šančevi and necessary parameters for determining daily solar radiation on the collector used in calculations are presented in the tab. 2.

Table 2. Parameters for determining daily solar radiation

Parameter	Value	Unit
Latitude	45.3	°N
Longitude	19.9	°E
Elevation	87	m
Earth temperature amplitudes	20.8	°C
Collector azimuth	13 (Southeast)	°
Collector tilt angle	30 (measured from horizontal)	°
Solar time	4.2	h

Monthly climatic data at the location Rimski Šančevi are presented in the tab. 3. These data are used for the calculation of capacities and the effects of solar systems integration.

Assessment of single building application

The calculation of solar radiation and the choice of required equipment have been done for one high-rise building in the settlement Liman which is connected to the installation for SHW supply from the district heating system. The building is selected according to the criterion of least favorable conditions for the construction of solar collectors which appear on buildings at the territory of the City of Novi Sad and with reference to available space at the roof structure for mounting solar collectors and housing density.

Table 3. Basic climatic data at the location

Month	Air temperature [°C]	Relative humidity [%]	Daily Solar Radiation on a Horizontal Plane [kWh/m²/day]	Atmospheric Pressure [kPa]	Wind Speed at Height of 10 m [m/s]
January	0.1	85.4	1.42	99.9	2.6
February	2.0	78.7	2.18	99.7	2.8
March	6.4	69.5	3.40	99.5	3.2
April	11.7	67.9	4.52	99.1	3.1
May	17.1	66.6	5.52	99.2	2.6
June	20.1	69.1	6.09	99.2	2.3
July	22.0	67.5	6.25	99.2	2.2
August	21.8	67.3	5.40	99.3	2.1
September	16.9	71.6	4.11	99.4	2.3
October	12.0	75.2	3.14	99.7	2.7
November	5.9	83.1	1.49	99.7	2.8
December	1.1	86.2	0.96	99.8	2.7
Year	11.5	74.0	3.72	99.5	2.6

For the calculation, the adopted required daily SHW requirement are estimated on the basis of EU standards and recommendations for medium to higher comfort in the conditions of general housing construction, that is, buildings with average energy characteristics. The calculation of consumer coverage, justification of utilization and the selection of capacities are done for the scenario which takes into account adopted daily consumption of 40 l/day per person. This figure is slightly above recommended consumption for the conditions in Serbia but at the same time, it is in line with the habits of consumers (at the territory of the City of Novi Sad) which get into the zone of higher comfort. The conditions for calculations assume SHW temperature of 45 °C, SHW storage temperature of 60 °C, cold water temperature of 12 °C, adopted factor of consumers' coincidence of 0.75 and planed reserve for cloudy weather of 75%.

The building has 214 tenants, SHW users, the installed SHW capacity is 244 kW and specific installed SHW capacity is 1,140 kW/per tenant. The area of this building is 450 m^2, which is approximately the area of the roof surface. Calculated maximum available surface for the installation of the collectors is 65% or 300 m^2. This area is more than sufficient for the installation of required installed capacity.

The results of calculations regarding required capacities and the choice of required equipment are shown in the tab. 4. This scenario refers to the theoretically needed SHW consumption by users and good condition of installations and measuring equipment. This scenario treats future circumstances after reconstruction and revitalization.

The calculation shows that it is possible to achieve high degree of coverage regarding annual SHW demand which is not quite usual in case of larger installations. For larger installations, stagnation can cause considerable problems and it restricts the capacity and thus the degree of coverage. However, when the integration of solar systems into district heating systems is concerned, the installation allows surplus heat energy receipt in the hottest summer months and in periods when SHW consumption falls. The reason for such an opportunity is in the fact that temperature regime of existing SHW supply installation is exceptionally suitable for the temperature regime at the moment of surplus heat energy occurrence. Then, it is possible to return surplus heat into the thermal power plant's circle, that is, primary part of the substation.

Table 4. Result of calculations in future circumstances

Parameter	Value	Unit
SHW daily consumption	7,725	l/day
Required heat energy per day	435	kWh/day
Required heat energy per year	157,780	kWh/year
Used irradiated energy[1]	3,773	kWh/day/m^2
Adopted number of collectors	60	Pieces
Adopted total surface of collectors	120	m^2
Possible absorbed energy per m^2 of collector surface	878	kWh/m^{2}year
Output heat power of installations	103	kW
Coverage degree of SHW annual requirements	55	%
Annual energy produced by the solar collector	86,834	kWh/year

[1] Energy delivered from plate collectors for an average summer day without clouds based on collector efficiency

The assessment of payback period for investments into solar installations of single buildings

For the given case of the building with 13 floors 214 tenants (the consumption of 40 l/day per person and 120 m^2 of collector), total calculated consumption of heat energy for SHW is 157,880 kWh per year out of which 86,834 kWh per year can be obtained from solar installations. This indicates that the degree of coverage by solar energy for SHW heating will be 55%.

The payback period is calculated on the basis of current prices of energy and fuels given in the tab. 5 and unit prices of solar collectors of medium quality at the local market.

Table 5. Unit energy and fuel price

Type of Energy	Value	Unit
Electricity	0.055	EUR/kWh
Heat energy based on natural gas	0.053	EUR/kWh
Heat energy based on heavy fuel oil	0.069	EUR/kWh
Solar energy	0.000	EUR/kWh

As these prices are variable, the sensitivity analysis is made regarding the effects of solar systems integration for different scenarios of single price movements. For that purpose, it is adopted that every price can move up and down from 10% to 50%. Of course, it is assumed that certain forms of energy and fuels cannot be substantially cheaper.

In addition, the sensitivity analysis gives opportunities to analyze effects of solar systems integrations for different ways of supply, *i. e.*, for different fuels or forms of energy which are used in the production of heat energy in the district heating systems. Options for the operation of heating plants on natural gas and fuel oil are into considerations, as well as the possibility for the implementation of solar systems in buildings connected to the district heating system but with SHW supply based on electricity.

The adopted unit price for solar installations in relation to the square meter of the collector is 750 EUR/m_c^2 including delivery, installation and accessories, as well as the basic adaptation of the infrastructure. This price, as well as the price of energy and fuels, is the adopted price on the basis of currently valid market prices. The sensitivity analysis considers effects of unit price movements from 450 EUR/m_c^2 (–40%) to as much as 975 EUR/m_c^2 (+30%). For the purpose of comparison, in Germany, the total price of solar installations for SHW preparation per square meter of the collector varies from EUR 800 to 1,100 in case of integrated solar system in the system for remote SHW supply. In the region, the price range is from EUR 625 to 1,125 per square meter of the collector.

The analysis of cumulative (accumulated) costs for the building with 214 tenants and the collector of 120 m^2 are given in the fig. 2 which also shows data for the simple payback period of the investment in case of integration, *i. e.*, expansion of the installation with modules for solar SHW preparation within the specific coverage degree.

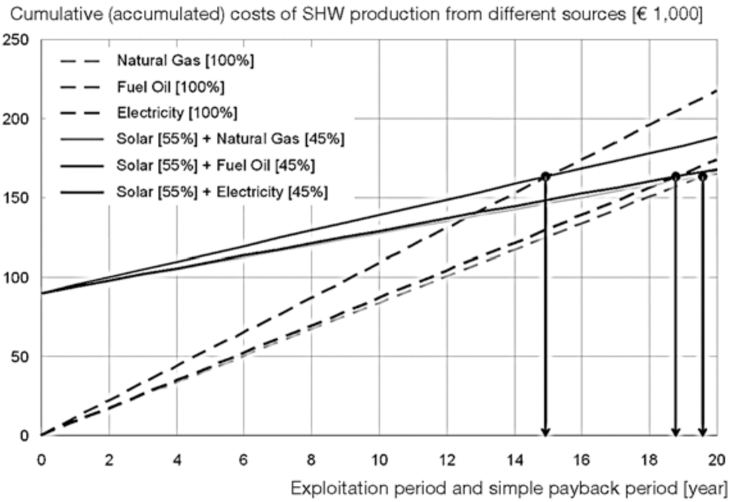

Figure 2. Analysis of cumulative (accumulated) costs of the building with 214 tenants and collector of 120 m^2

If the option with the integration of fuel oil supply system and solar system is observed, the payback period will be around 15 years with current energy and fuel prices and with the equipment price of 750 EUR/m_c^2. In case of natural gas and solar energy integration, the simple payback period of the investment will be even more than 19.5 years. And, in case of the option with electricity and solar energy integration, the simple payback period of the investment will be around 19 years.

There are no doubts that these figures are not very favorable but it is necessary to take into account the fact that the analysis is made for circumstances without any type of incentives either for equipment or operating costs.

It is realistic to expect that the results will be more favorable by some 20 to 25% due to the inevitable price rise of natural gas and fuel oil and also of electricity. In addition, the price of the equipment can be significantly lower as the purchase of equipment for large capacities (surfaces) belongs to the category of capital investment projects which assume special conveniences given by equipment suppliers. For that reason, the sensitivity of the simple payback period to the unit price of equipment, *i. e.*, square meter of the collector surface is tested as shown in fig. 3.

Based on fig. 3, it is realistic that the simple payback period will vary between 12 and 15 years and that without any subsidies, incentives, own production or other circumstances but exclusively on the basis of reduced investment costs related to the purchase and installation of solar collectors and accessories. This reduction of investment costs is conditioned by a mild trend of price fall at the market (including the average for all manufacturers and distributors both domestic and foreign).

It is estimated that with the organized domestic production which will be specially intended for the requirements of the heating plant and with the involvement of the heating plant in this production (both technically and financially), the specific price of solar installation can be reduced to the level around 500 EUR/m^2 of collector surface. Then, the simple payback period can be between 10 and 12 years. Since there are offers at the market from 500 to 550 EUR/m^2 of collector surface even now, this scenario is quite possible and actually very realistic.

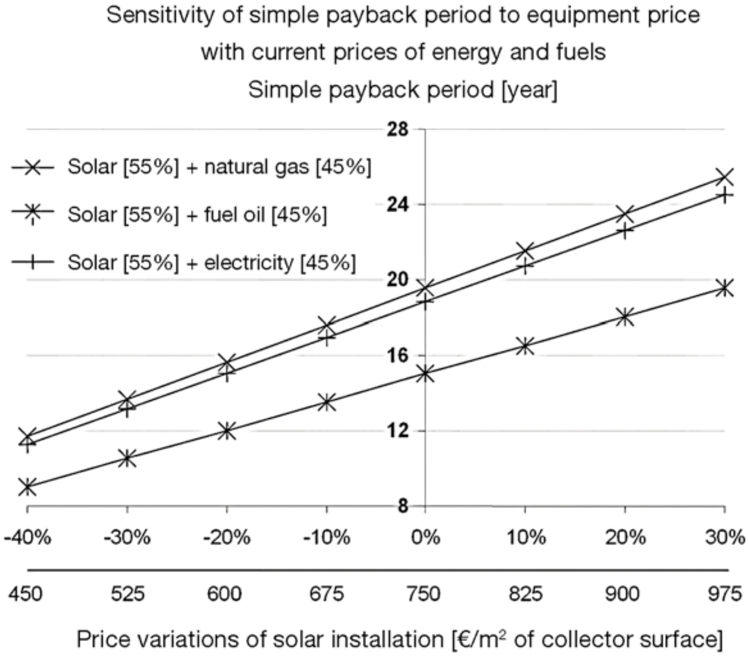

Figure 3. Sensitivity analysis to unit price of equipment

It is also possible to start production and installation of equipment in cooperation with a renowned manufacturer. The unit price of this equipment can be much lower than the existing one at the market. Thus, a systemic solution will be created and enable wide application of the technology in many residential blocks. This will considerably improve performances of the project for the integration of solar systems into the SHW supply system and it will be possible to achieve return on investments in the first third of the service lifetime of equipment and installations. In addition, the concept of local development for the production of equipment will have manifold positive socioeconomic effects for the City of Novi Sad.

Sensitivity analysis of effects of single building reconstruction

Since the effects of reconstruction, the costs of implementation of proposed solutions and expected savings are very much dependent on the price of energy and fuels at the market, as well as on the price of equipment itself, it is necessary to check the sensitivity of the parameter – simple payback period, against every unit price of fuel and forms of energy. The analysis implies the change of the simple payback period depending on the variation of unit prices of certain forms of energy and fuels of 10% each.

The presented analysis includes three options for the combination of resources, *i. e.*, energy sources, and in all of them solar energy participates with 55%. Three scenarios are taken, when heating plants operate on natural gas or fuel oil and the third option is when users are supplied by means of electricity.

First, the parameter's sensitivity is tested to the unit price of natural gas and for three levels of the unit price of solar collectors, which is shown in the fig. 4.

In the similar way, the parameter's sensitivity is tested to the unit price of fuel oil and for three levels of the unit price of solar collectors, which is shown in the fig. 5.

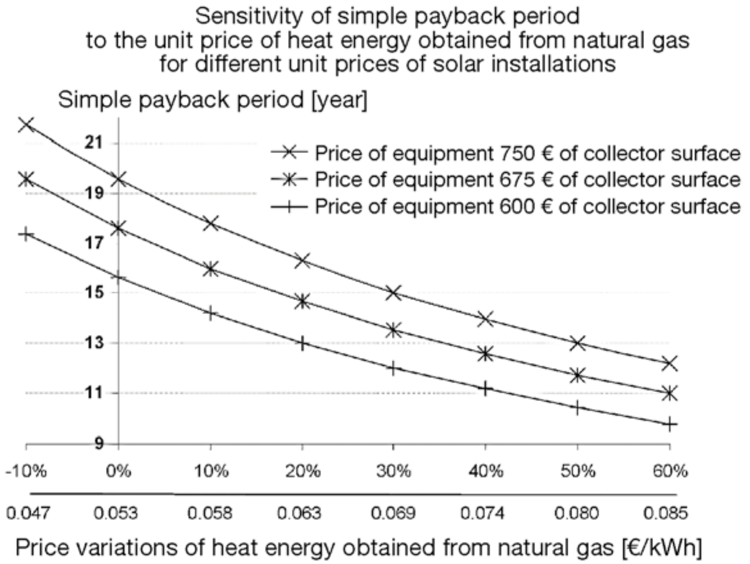

Figure 4. Sensitivity analysis to natural gas unit price

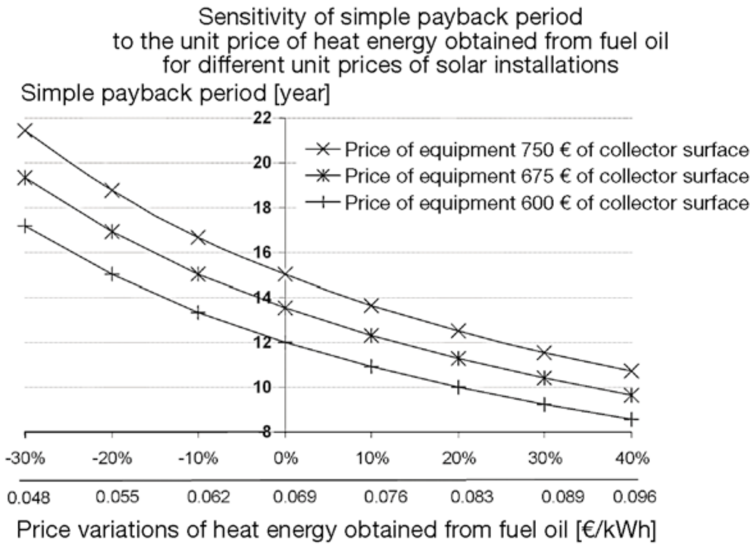

Figure 5. Sensitivity analysis to fuel oil unit price

Finally, the parameter's sensitivity is tested to the unit price of electricity and for three levels of the unit price of solar collectors, which is shown in the fig. 6.

If the trend of growing prices of energy and fuels is taken into account, it can be observed that every fuel or form of energy has different impact on the effects of the implementation of proposed solutions and expected savings. The Figure 3 shows relations for different options. It is noticeable that the growth of energy and fuel prices has considerable influence on expected effects in a favorable way. Thus, it is possible to expect variations in the simple payback period in the direction of its reduction because the trend of rising prices of energy and fuels is a much more realistic scenario.

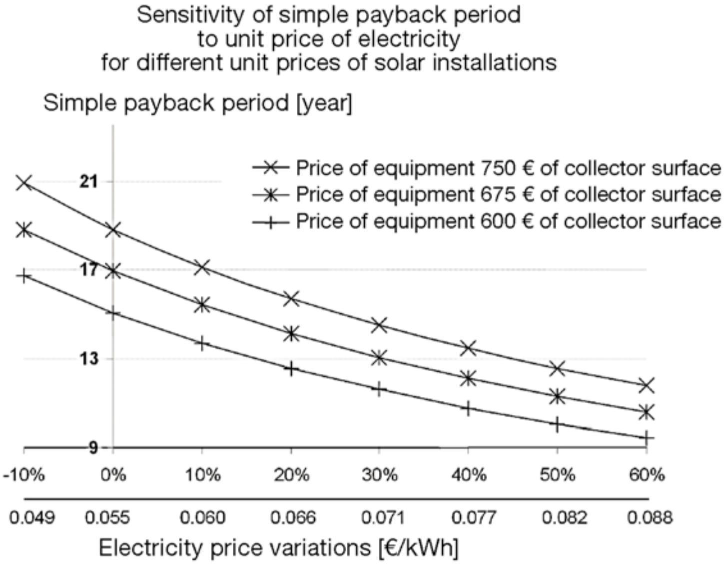

Figure 6. Sensitivity analysis to the unit price of electricity

Assessment of effects of single building reconstruction

According to the heating plant records, the total consumption of heat energy in the relevant building is 373,253 kWh per year. In relation to the calculated price of heat energy obtained from fuel oil and at the place of delivery, the total annual cost of the heating plant for the relevant building is 25,575 EUR. In case, the solar system with the total surface of solar collectors of 120 m^2 is integrated in the building according to the SHW consumption standards per person and per one day, the total annual consumption of heat energy will be reduced for the portion produced by the solar collector in the amount of 86,834 kWh/year or 23% of total SHW demand. This will reduce annual costs of the heating plant by 5,950 EUR.

Assessment of application to several buildings – urban block

As it has already been emphasized, the unit price of solar collectors has a considerable impact on the level of investments and their effects. In this regard, more favorable circumstances, as well as better results, can be expected only with the expansion of capacities and by applying the concept to a large number of buildings and blocks.

If the simulation of the concept for solar system integration in the SHW supply system is made for ZONA VI, Urban Block 194 (Liman III, residential block between Boulevard Stefan Despot and Narodnog Fronta Street and Šekspirov a Street and Balzakova Street) with 4,806 inhabitants and 1,743 flats for collective housing, the results shown in the tab. 6 will be obtained.

Table 6. Results of calculations in the residential block

Parameter	Value	Unit
SHW daily consumption	173,250	l/day
Required heat energy per day	9,700	kWh/day
Required heat energy per year	3,540,000	kWh/year
Used irradiated energy[1]	3,773	kWh/day m^2
Adopted number of collectors	1,285	Pieces
Adopted total surface of collectors	2,570	m^2
Possible absorbed energy per m^2 of collector surface	878	kWh/m^{2}year
Output heat power of installations	2,300	kW
Coverage degree of SHW annual requirements	55	%
Annual energy produced by the solar collector	1,950,000	kWh/year

[1] Energy delivered from plate collectors for an average summer day without clouds based on collector efficiency

The result implies SHW consumption per person and per day as recommended in standards and literature [14], *i. e.*, quantity which is considered to be rational and sufficient in every respect.

If annual amount of energy produced by solar collectors is expressed as reduced costs of the heating plant calculated at the price of final energy on the basis of SHW production by using fuel oil as drive fuel, the saving of the heating plant will be 135,000 EUR/year, and if the saving is expressed on the basis of SHW produced by natural gas as drive fuel, the saving of the heating plant will be 105,000 EUR/year. The investment at the level of the whole urban block will be about 1,670,000 EUR which implies that a simple payback period of the investment can be expected in the range from 12 to 16 years.

If we are evaluating the savings of solar installations which are sized according to the standards for SHW consumption per person and per day in relation to the existing and evidenced situation with the SHW consumption at present, it will be approximately 25%. If actual consumption of tenants in buildings is taken into account which is not know with high reliability but only at the level of expert and experience assessment of the heating plant and which can be estimated as 30% increase in relation to recommended values, the saving of the heating plant may even reach the value of as much as 35%.

Possibilities for mounting solar collectors

Solar collectors can be installed in four possible ways out of which two are most suitable for the given case [14]. The first type of installation is on the flat roof and it enables optimum orientation and tilt of the collector. Installation on flat roofs can be done by corresponding supports for vertical and horizontal collectors. The largest annual energy yield is obtained if the surface is facing the south and tilted at the angle of 30 degrees. This orientation and the tilt are optimum for periods March-April and August-September. The other type is installation above the roof which is the simplest and the fastest way of installation. Roof cover remains closed and roof structure retains its function of sealing. Collectors and the roof have the same tilt angle.

By analyzing several buildings in the above mentioned zone which have either flat or sloped roofs, it is determined that the implementation of required capacities is feasible but only in case consumers remain within the range of SHW consumption from 35 to 40 l per day and per person and that coverage degree remains from 50 to 55%. In case of high consumption as is currently the case even with the expected degree of coverage it is not possible to confirm the sufficient amount of available surfaces.

Recommendations and conclusions

Taking into considerations the results of presented analysis, real technical and economic circumstances in the world and in our country, and trends when solar technology is in question, it can be generally concluded that the time of favorable circumstances for the construction of solar capacities is in front of us. Also, the increase of this capacity as proposed in the integration concept, together with the implementation of equipment manufactured by domestic companies, additionally increases justification of the investment in solar technology and makes the investment economically and socially sustainable in the mid term.

However, there are some circumstances which should be improved or put into the function of the development of presented concept. Since this concerns the supply system which is owned by the City of Novi Sad, there are institutions which have the power to significantly contribute to the whole idea. In this regard, it is possible to highlight some recommendations addressed to the following institutions and companies in the City:

- Heating plant should include the concept of solar technology integration into its strategic plans and documents and to actively develop the idea up to the level of its implementation. This will fully respect the fact regarding the justification of the constructions of these systems.
- Urban planners should create and develop conditions for smooth implementation of the concept. This means that urban and technical conditions should be prepared for architect who will design roof structures adjusted to the mass utilization of solar technology.
- The City of Novi Sad should institutionally and administratively enable improved atmosphere in the sense of the development of procedures and instructions for local institutions in order to ensure efficient implementation with lower costs (human, material and temporal).
- Provincial institutions and competent secretariats should develop and promote conditions for implementation a so called public private partnership (PPP Model) which has proved itself as a very good solution in developed countries when public utility companies, new technologies and renewable energy sources are concerned.

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