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Renewable Energy Sources for smart sustainable health Centers, University Education and other public buildings

# A study on energy demand, energy efficiency, available renewable energy sources and recommendation for optimal configuration of smart building energy management systems

- Case 2: Clinical Center of Vojvodina public building -

Novi Sad
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**Title page**

**A study on energy demand, energy efficiency, available renewable energy sources and recommendation for optimal configuration of smart building energy management systems**
- Case 1: Faculty of Technical Sciences public building -

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| **Supported by:** | IPA Cross-border Cooperation Programme Croatia - Serbia 2014-2020 |
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| **Abstract:** | This document presents a comprehensive study on energy demand and energy efficiency for the Faculty of Technical Sciences public building. Furthermore, the study describes the available renewable energy sources that could be used for energy generation in the near vicinity of the public building. After exploring the demand and the potential, the study proposes the optimal configuration of the renewable energy and the smart building energy management systems that would significantly increase the public building efficiency while reducing the energy demand, bringing the public building one step closer to near zero-energy building. This document also gives a short overview of the most important directives and national legislative supporting energy efficiency and renewable sources. |
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# Table of Contents

# List of figures

# List of tables

# 1. Introduction

Energy consumption is constantly increasing as the global population rises and due to the development of the industrial sectors, leaving fossil fuel reserves depleted and causing serious impact on climate change. Fossil fuels are still dominantly employed as a reliable energy source, but the finite supply and numerous problems with energy exploitation imply that the new solutions must be incorporated in the energy production process.

Not only are the fossil fuels reserves limited, harder to locate and expensive to transport, but their negative influence on the environment requires active participation in increasing the energy efficiency, finding and exploiting alternative energy sources. The prediction of the finite energy reserves for coal, gas and oil, the most exploited fossil fuels [1], is given in Figure 1.1.

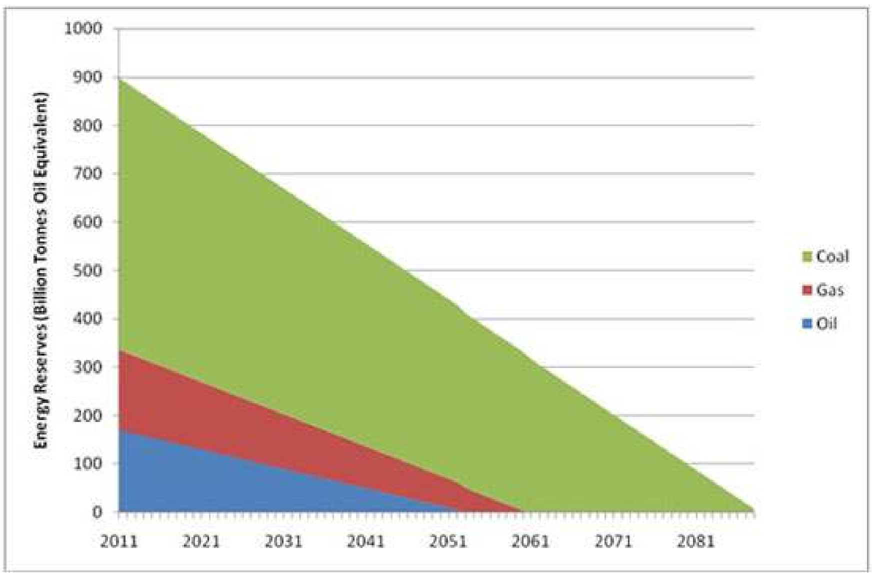


Figure 1.1 *The prediction of fossil fuel energy reserves [1].*

One of the biggest issues associated with the combustion of fossil fuels is the carbon emission. In Figure 1.2 carbon dioxide (CO2) emission by a specific type of fossil fuel is given [2]. It can be seen that industrial and economic growth in the last century has contributed to a significant increase in CO2 concentration.

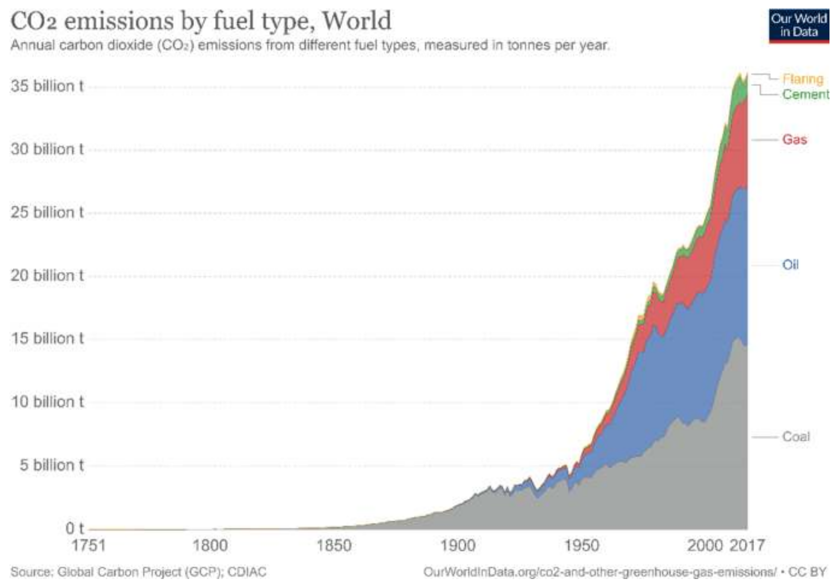


Figure 1.2 *Carbon dioxide (CO2) emission by a specific type of fossil fuel [2].*

Carbon dioxide is a major greenhouse gas and thus extremely contributes to the global warming, climate change and ocean acidification. Carbon dioxide concentration in the atmosphere has risen about 43% since the beginning of the industrial revolution in the mid-eighteenth century – half of that since 1980 [3]. In the high economic growth case, world CO2 emissions increase at an average rate of 1.8% annually from 2006 to 2030, as compared with 1.4% in the reference case. For the OECD countries, the projected average increase in the high growth case is 0.6% per year, for the non-OECD countries, the average is 2.6% per year. In the low growth case, world CO2 emissions increase by 1.0% per year from 2006 to 2030, with averages of 0.1% per year for the OECD countries and 1.8% per year for the non-OECD countries. In 2030, total energy-related CO2 emissions worldwide range from a projected 36,930 Mt in the low growth case to 44,108 Mt in the high growth case, which is 19.4% higher than projected in the low growth case [4]. Figure 1.3 predicts CO2 emission based on different scenarios [2]:

- No climate policies: projected future emissions if no climate policies were implemented; this would result in an estimated 4.1-4.8°C warming by 2100 (relative to pre-industrial temperatures);
- Current climate policies: projected warming of 3.1-3.7°C by 2100 based on currently implemented climate policies;
- National pledges: if all countries achieve their current targets/pledges set within the Paris climate agreement, it is estimated that the average warming by 2100 will be 2.6-3.2°C. This will go well beyond the overall target of the Paris Agreement to keep warming "well below 2°C";

- 2°C consistent: there is a range of the emissions pathways that would be compatible with limiting average warming to 2°C by 2100. This would require a significant increase in the ambition of the current pledges within the Paris Agreement;
- 1.5°C consistent: there is a range of the emissions pathways that would be compatible with limiting average warming to 1.5°C by 2100. However, all would require a very urgent and rapid reduction in global greenhouse gas emissions.

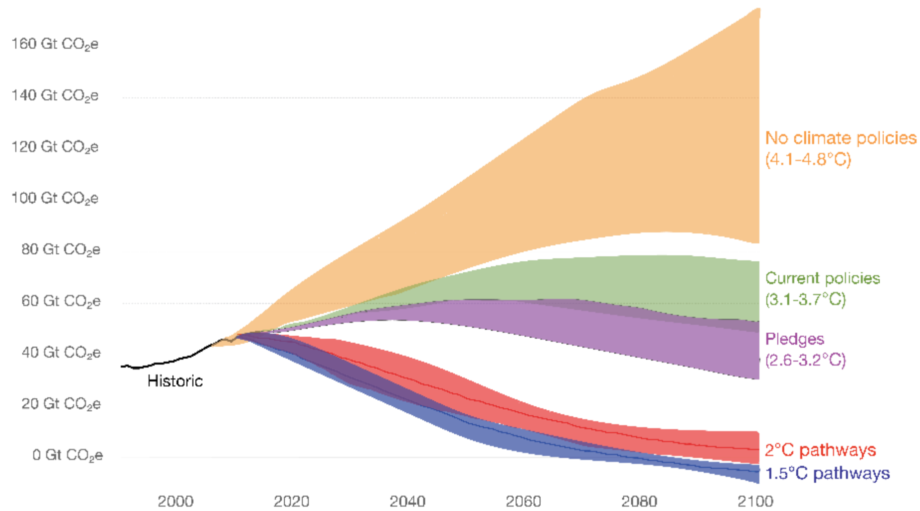


Figure 1.3 *The prediction of the CO2 emission based on different scenarios [2].*

According to the HCWH (Health Care Without Harm) Europe climate report published in Dec 2016 [5], the health sector is a major emitter of the greenhouse gasses. For example, in 2012, the total carbon footprint of England's public healthcare sector was 32 million tons of carbon dioxide equivalents ($CO_2$ equivalent refers to a combination of harmful greenhouse gases, not just carbon dioxide), accounting for 38% of the public sector emissions in England. This serves to illustrate how the healthcare sector is contributing an enormous amount of harmful emissions, which in turn undermines the health of the same population the sector is meant to heal.

Based on these prognoses, it is clear that is absolutely necessary to implement a number of $CO_2$ restriction measures in order to achieve a decrease in the $CO_2$ concentration. One of the measures that can be taken is to increase the reduction of the used energy, for example, with the investment in new equipment that is more energy-efficient. Another one is to use alternative energy sources that contribute less to greenhouse gas emissions.

Nowadays, higher energy efficiency is obtained using power electronics. Power electronic devices are present in almost every part of the power system since they enable the conversion of the electric power and are used to control power flow and voltage. Power electronic devices are fast and reliable, can provide better power quality and add new functionalities and flexibility to the grid. Without them, the integration of the renewable energy sources into the traditional power network could not be possible. Renewables use

technologies that are safe, reliable, affordable and widely available. In order to utilize the best resource locations, many renewable generators have to be located far from existing load centers which leads towards the expansion and decentralization of the power system.

In the last decade, the investment in renewables has drastically increased, which is depicted in Figure 1.4 (large hydropower is not included) [6]. These trends suggest that investors see solar and wind energy as the dominant renewable technologies of the future. The share of renewable energy in the power sector would increase from 25% in 2017 to 85% by 2050, mostly through growth in solar and wind power generation [7].

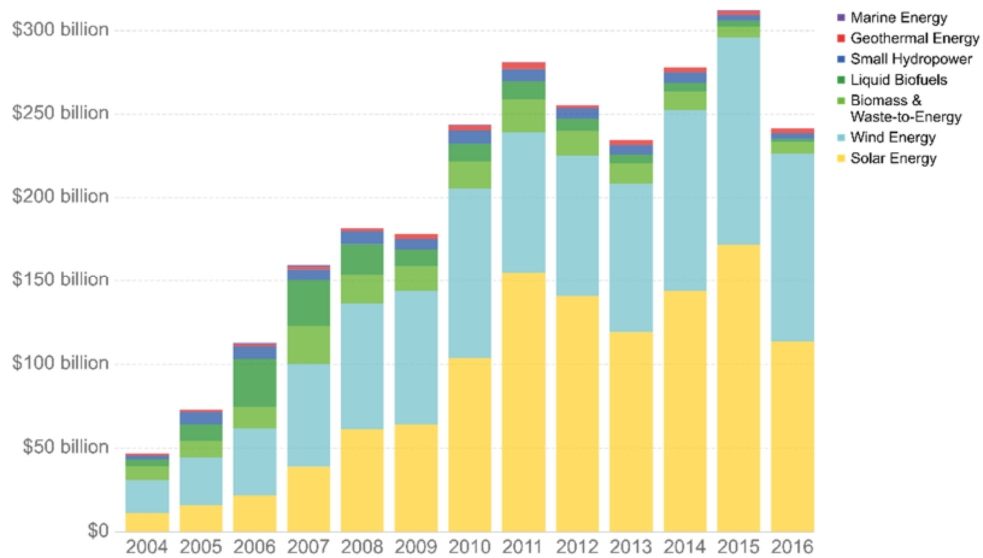


Figure 1.4 *Investment in different renewable energy technologies [6].*

Renewable energy technology should result in less global warming, improved public health through a reduction of air and water pollution, stable electricity price and contribute to the reliability and resilience of the power grid. In addition, unlike fossil fuels, energy sources used by renewables are inexhaustible. Therefore, EIA (U.S. Energy Information Administration) projects that renewables will provide nearly half of the world electricity by 2050, which is depicted in Figure 1.5 [8].

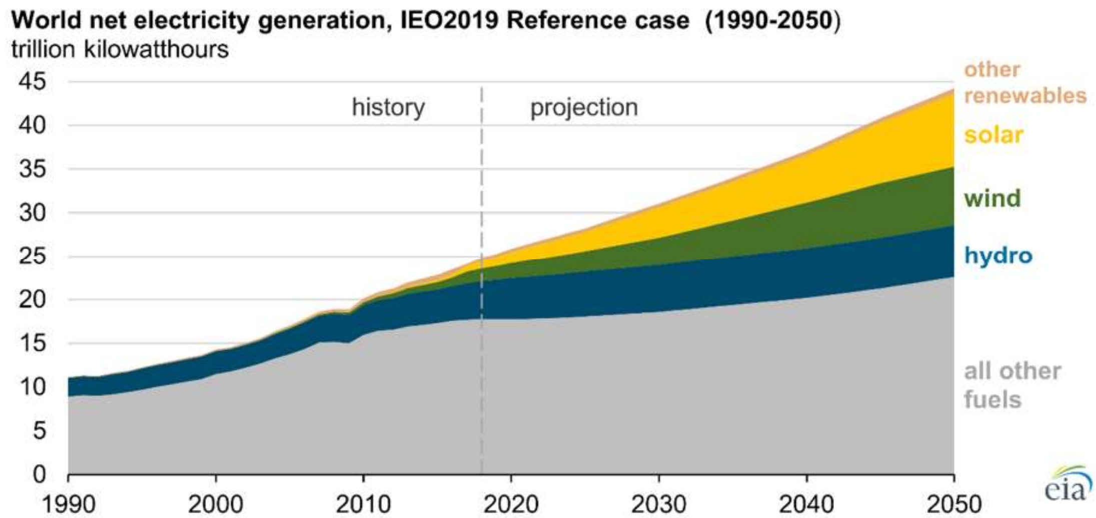


Figure 1.5 *World net electricity generation [8]*.

Energy storage systems, such as batteries, supercapacitors, flywheels, thermal storages, etc., play a critical role in the transition of the global energy system toward 100% renewables. As the shares of the solar and wind energy are going to increase significantly beyond 2030, the role of the storage is crucial in providing an uninterrupted energy supply.

Following the CO2 reduction tendency, vehicles that run on fossil fuels should be replaced with all-electric vehicles. Although currently electric vehicles are more expensive than gasoline vehicles, with time, the running or operating costs of an electric vehicle may be lower than a traditional car (as a result of efficiency gains and lower cost of electricity relative to liquid fuel), so it will be possible to get some economic return on the initial investment.

The reduction of the greenhouse gasses would help to decrease the environmental pollution that has become a severe problem. Another measure that could be undertaken is the waste management system – a series of actions that aim to reduce the generation and promote the reuse and recycling of the solid and hazardous waste. Another benefit that could be achieved is the energy recovery from the waste, which is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel.

Energy efficiency can be increased by reducing the energy consumption of the public buildings. This results in the substantial energy savings and therefore less usage of the fossil fuels, whereby this strategy is already recognized and adopted by a number of countries worldwide given that a zero-energy building would be a preeminent goal. Of course, this is not possible without the renewables which should cover a part of the required energy. In order to supervise and control the energy consumption of buildings, Building Energy Management Systems (BEMS) are crucial, since they provide not only a real-time remote monitoring and integrated control of a wide range of the connected systems, but also they allow easy system operation mode change, optimal energy usage, and environmental impact to be monitored. To function correctly and give expected results these systems must be

properly designed, installed, commissioned and must have a user interface that is intuitive, graphically appealing and easy to operate with.

These issues are addressed in various laws and directives in both Croatia and Serbia.

Regarding the abovementioned data the importance of investment and implementation of the new technologies that enable higher energy efficiency, thus reducing the impact on the climate change and providing energy savings, is clear. In order to achieve this, it is necessary to analyze the energy performance and determine which aspects are critical. This document provides a study of the energy demand and energy efficiency for the exemplary facility, it also considers the possibility for the integration of renewables in order to reduce the energy consumption. Also, this study proposes a configuration of the optimal smart building energy systems.

This document compromises the following sections:

- the second section describes the most important directives and national legislative supporting energy efficiency and renewable sources;
- the third section offers insight into the main geographical, meteorological and other features for the public building;
- the fourth section examines current energy demand for the exemplary facility;
- the fifth section investigates the potential for utilization of renewable energy;
- the sixth section deals with optimal energy system topology and configuration for the building energy management system.

## 2. Energy efficiency directives and national legislative for public buildings

According to Global Status Report 2018 published by UN Environment and the International Energy Agency, buildings and construction together account for 36% of global final energy consumption and 39% of carbon dioxide emissions in 2017. In the period from 2010 to 2017, the final consumption of buildings increased by more than 6 EJ [9]. This sector has the highest share of energy and at the same time has the highest potential for energy savings. Looking at the European Union (EU) alone, buildings represent 40% of total energy consumption, as shown in Figure 2.1, and account for 36% of carbon dioxide emissions affecting the overall climate. Statistics show that over 35% of EU buildings are over 50 years old, and over 75% of the building stock is energy inefficient. Renovation of buildings could reduce total energy consumption and reduce $CO_2$ gases by around 5% creating multiple benefits, such as economic, social and environmental in the process [10].

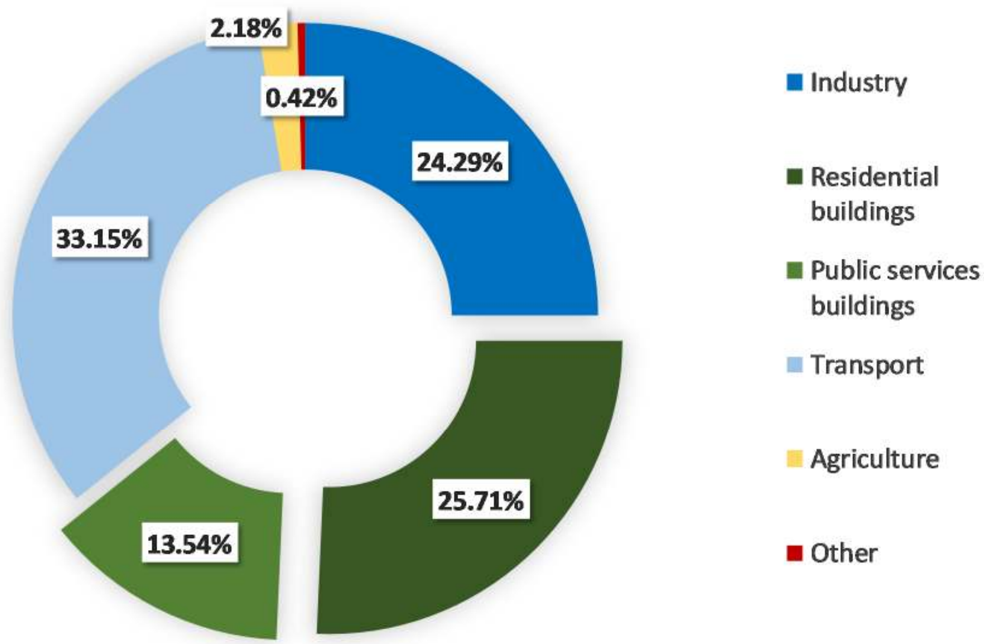


Figure 2.1 *Energy consumption by sector in the EU [11].*

One of the public sectors with the highest energy demand is the healthcare sector. According to the World Bank Group, the healthcare sector generates around 5% of global CO2 emissions annually. Furthermore, it is estimated that around 15,000 hospitals in the EU have high energy demand, not only for electricity, but also for heat. Considering the fact that several million deaths are related to air pollution each year, it can be concluded that the health sector, as one of the largest contributors to air pollution, is affecting human and environmental health in both senses [12].

Referring to the above, the EU has established new guidelines for energy efficiency, in the form of stimulus, financial support and directives, especially for public buildings, which represent large energy consumers.

In order to reduce greenhouse gas emissions and meet the obligations of the Kyoto Protocol, a new directive was issued by the European Parliament on April 23, 2009. Renewable energy directive (2009/28/EC) seeks to increase the control of energy use in Europe and increase the use of energy from renewable sources [13]. Besides, the directive also states that energy savings and increased efficiency must be closely linked to the development of renewable energy. The directive clearly states the mandatory targets for the total share of energy from renewable sources in final gross energy consumption. Article 3 of the Directive sets out mandatory national targets and measures for the use of energy from renewable sources.

*Renewable energy directive (2009/28/EC) Article 3 paragraph 1. states: "Each Member State shall ensure that the share of energy from renewable sources, calculated in accordance with Articles 5 to 11, in gross final consumption of energy in 2020 is at least its national overall target for the share of energy from renewable sources in that year, as set out in the third column of the table in part A of Annex I. Such mandatory national overall targets are consistent with a target of at least 20 % share of energy from renewable sources in the Community's gross final consumption of energy in 2020. In order to achieve the targets laid down in this Article more easily, each Member State shall promote and encourage energy efficiency and energy saving."*

That is, every member of the EU, by the end of 2020, must have a share of 20% from renewable sources in final gross consumption, while promoting energy efficiency and savings. In order to meet the set goals, it is necessary to introduce the required measures.

The EU has agreed to update these regulations in order to meet the obligations under the Paris Agreement on greenhouse gas emissions. The new energy rulebook, called the Clean energy for all Europeans package, is the basis for achieving the goals of the EU. Therefore, Renewable energy directive (2009/28/EC) is revised in December 2018, as part of the Clean energy for all Europeans package [14]. Article 3 of the revised Directive sets out mandatory national targets and measures for the use of energy from renewable sources for 2030.

*Renewable energy directive (2018/2001/EU) Article 3 paragraph 1. states: "Member States shall collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32 %. The Commission shall assess that target with a view to submitting a legislative proposal by 2023 to increase it where there are further substantial costs reductions in the production of renewable energy, where needed to meet the Union's international commitments for decarbonisation, or where a significant decrease in energy consumption in the Union justifies such an increase."*

Renewable energy directive (2018/2001/EU) has established a target for the EU to achieve at least 32% of the total energy produced by renewable sources for 2030. Besides, each EU

member is obligated to achieve new energy savings, which is 0,8% of final energy consumption in the period from 2021 to 2013, each year.

Under the Energy Efficiency Directive (2012/27/EU), a set of measures was established to help EU meet the set efficiency targets by 2020 [10]. Increasing energy efficiency can reduce greenhouse gas emissions and mitigate climate changes. Additionally, it can also reduce primary energy consumption, as well as energy imports. More efficiency should also accelerate the spread of innovative technological solutions. The directive stressed that the public sector should be a model for energy efficiency. In addition, public funds for other purposes can be released, due to their high consumption.

*Energy Efficiency Directive (2012/27/EU) paragraph (15) states: "The total volume of public spending is equivalent to 19 % of the Union's gross domestic product. For this reason the public sector constitutes an important driver to stimulate market transformation towards more efficient products, buildings and services, as well as to trigger behavioural changes in energy consumption by citizens and enterprises. Furthermore, decreasing energy consumption through energy efficiency improvement measures can free up public resources for other purposes. Public bodies at national, regional and local level should fulfil an exemplary role as regards energy efficiency."*

Buildings represent a large share of the final consumption of the EU. Therefore, the renovation of residential and commercial buildings, with the aim of increasing their energy efficiency, would help to achieve the efficiency targets set for 2020, by setting long-term strategies.

*Energy Efficiency Directive (2012/27/EU) paragraph (16) states: "Bearing in mind that the Council conclusions of 10 June 2011 on the Energy Efficiency Plan 2011 stressed that buildings represent 40 % of the Union's final energy consumption, and in order to capture the growth and employment opportunities in the skilled trades and construction sectors, as well as in the production of construction products and in professional activities such as architecture, consultancy and engineering, Member States should establish a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock. That strategy should address cost-effective deep renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance. Such deep renovations could also be carried out in stages."*

As buildings represent the sector with the highest potential for energy savings, they can also help to achieve reduced greenhouse gas emissions by 80-95% by 2050, compared to 1990, as highlighted in the directive.

*Energy Efficiency Directive (2012/27/EU) paragraph (17) states: "The rate of building renovation needs to be increased, as the existing building stock represents the single biggest potential sector for energy savings. Moreover, buildings are crucial to achieving the Union objective of reducing greenhouse gas emissions by 80-95 % by 2050 compared to 1990.*

*Buildings owned by public bodies account for a considerable share of the building stock and have high visibility in public life. It is therefore appropriate to set an annual rate of renovation of buildings owned and occupied by central government on the territory of a Member State to upgrade their energy performance. This renovation rate should be without prejudice to the obligations with regard to nearly-zero energy buildings set in Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (2). The obligation to renovate central government buildings in this Directive complements that Directive, which requires Member States to ensure that when existing buildings undergo major renovation their energy performance is upgraded so that they meet minimum energy performance requirements. It should be possible for Member States to take alternative cost-efficient measures to achieve an equivalent improvement of the energy performance of the buildings within their central government estate. The obligation to renovate floor area of central government buildings should apply to the administrative departments whose competence extends over the whole territory of a Member State. When in a given Member State and for a given competence no such relevant administrative department exists that covers the whole territory, the obligation should apply to those administrative departments whose competences cover collectively the whole territory."*

Intelligent metering systems for measuring energy consumption, which can transmit and receive data, monitor and control the system, can optimize the use of electricity. Furthermore, the use of intelligent metering systems equipped with energy-saving features develops the market for energy services, while the final customers can control individual consumption. The Energy Efficiency Directive points out that at least 80% of consumers must be equipped with intelligent measurements by the end of 2020.

*Energy Efficiency Directive (2012/27/EU) paragraph (27) states: "In relation to electricity, and in accordance with Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity (1), where the roll-out of smart meters is assessed positively, at least 80 % of consumers should be equipped with intelligent metering systems by 2020. In relation to gas, and in accordance with Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas (2), where the roll-out of intelligent metering systems is assessed positively, Member States or any competent authority they designate, should prepare a timetable for the implementation of intelligent metering systems."*

Referring to the above, the Energy Efficiency Directive establishes several important measures, in order to increase energy efficiency in the Union, in order to achieve the 2020 targets. Besides, the directive establishes rules in order to remove obstacles in the energy market, which limits the efficiency of energy supply and its use. One of the goals is that EU energy consumption by 2020 should not exceed 1474 Mtoe of the primary energy or 1078 Mtoe of the final energy consumption.

*Energy Efficiency Directive (2012/27/EU) Article 1 Paragraph 1. states: "This Directive establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on*

*energy efficiency and to pave the way for further energy efficiency improvements beyond that date. It lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020."*

The directive set out a long-term strategy to encourage the investment in the buildings' renovation, as highlighted in Article 4.

*Energy Efficiency Directive (2012/27/EU) Article 4 states: "Member States shall establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private."*

Among others, Energy Efficiency Directive measures include long-term renovation strategy for the buildings in each country of EU and improvement of energy efficiency of central governments owned buildings by at least 3% each year, as indicated in Article 5. In addition, Article 7 states that is necessary to make an annual reduction of 1.5% in national energy sales by 2020.

*Energy Efficiency Directive (2012/27/EU) Article 5 Paragraph 1. states: "Without prejudice to Article 7 of Directive 2010/31/EU, each Member State shall ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements that it has set in application of Article 4 of Directive 2010/31/EU."*

*Article 7. Paragraph 1. States: "Each Member State shall set up an energy efficiency obligation scheme. That scheme shall ensure that energy distributors and/or retail energy sales companies that are designated as obligated parties under paragraph 4 operating in each Member State's territory achieve a cumulative end-use energy savings target by 31 December 2020, without prejudice to paragraph 2. That target shall be at least equivalent to achieving new savings each year from 1 January 2014 to 31 December 2020 of 1,5 % of the annual energy sales to final customers of all energy distributors or all retail energy sales companies by volume, averaged over the most recent three-year period prior to 1 January 2013. The sales of energy, by volume, used in transport may be partially or fully excluded from this calculation."*

Energy efficiency is recognized as a crucial and element of highest priority, therefore the Energy Efficiency Directive (EED) (2012/27/EU) is revised in 2018, and has set a new efficiency target for 2030 of at least 32.5% [17].

*The Energy Efficiency Directive (2018/2002) states: "Directive 2012/27/EU is amended as follows: (1) in Article 1, paragraph 1 is replaced by the following: '1. This Directive establishes a common framework of measures to promote energy efficiency within the Union in order to ensure that the Union's 2020 headline targets on energy efficiency of 20 % and its 2030 headline targets on energy efficiency of at least 32,5 % are met and paves the way for further energy efficiency improvements beyond those dates. This Directive lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national*

*energy efficiency targets and contributions for 2020 and 2030. This Directive contributes to the implementation of the energy efficiency first principle."*

New target for 2030 is that EU energy consumption by 2030 should not exceed 1273 Mtoe, which is more than 200 Mtoe less than target for 2020. Besides, the Waste Framework Directive (2008/98/EC) has defined a framework for waste management and set two new goals for 2020. Those state that 50% of certain waste materials from households should be prepared for re-use and recycling, and 70% construction and demolition waste should be prepared for re-use, recycling and other recovery. Among others, the Waste Framework Directive governs the waste oils. During 2006 the EU has spent around 5,8 million tons of lubricant oil. Around 50% of used oil becomes waste oil, which is approximately 3 million tons of waste oil each year. Annex II of the Waste Framework Directive, promotes energy production from waste in case that waste recycling is not the environmentally preferable, in order to improve energy efficiency.

The main goal of the EU's long-term strategy is to achieve zero-carbon emission by 2050, as it represents part of the Clean energy for all Europeans packages. Considering that public buildings are one of the largest consumers of energy and, therefore, highly contribute to air pollution, improvement in energy efficiency in buildings can contribute to achieving carbon neutrality.

The European Commission offers a number of Directives on energy efficiency, the Energy Performance Building Directive (2010/31/EU) [15], along with Energy Efficiency Directive, is the legislative for promoting the energy performance of buildings. EPBD proposed a series of measures in order to improve the energy performance of buildings, in form of long-term renovation strategies. The Directive also provides that national authorities must establish a financing plan for programs aimed at increasing the energy efficiency of buildings.

The directive emphasizes that all members must set energy efficiency requirements in order to optimize energy consumption in existing buildings, which can be applied to new buildings. Article 8 highlights the systems that must be found in the requirements.

*Energy Performance Building Directive (2010/31/EU) Article 8 Paragraph 1. states: "Member States shall, for the purpose of optimising the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings. System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible. The system requirements shall cover at least the following:*

*(a) heating systems;*

*(b) hot water systems;*

*(c) air-conditioning systems;*

*(d) large ventilation systems; or a combination of such systems."*

The directive requires the use of intelligent metering systems in the renovation of buildings and in each newly constructed building. In addition, it is proposed to encourage the use of the monitoring and control systems, all with the aim of saving energy, as indicated in article 8.

*Energy Performance Building Directive (2010/31/EU) Article 8 Paragraph 2. states: "Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation, whilst ensuring that this encouragement is in line with point 2 of Annex I to Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity. Member States may furthermore encourage, where appropriate, the installation of active control systems such as automation, control and monitoring systems that aim to save energy."*

Directive proposed an ambitious plan for all new buildings must be nearly zero-energy by December 31, 2020, and all new public facilities, constructed after December 31, 2020, must be nearly zero-energy buildings (NZEB), as indicated in article 9.

*Energy Performance Building Directive (2010/31/EU) Article 9 Paragraph 1. states: "Member States shall ensure that:*

*(a) by 31 December 2020, all new buildings are nearly zero energy buildings; and*

*(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.*

*Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building."*

The directive mandates that the public sector should be a role model for other buildings and all members should take measures and set targets to encourage the renovation of buildings in order to achieve zero-energy.

*Energy Performance Building Directive (2010/31/EU) Article 9 Paragraph 2. states: "Member States shall furthermore, following the leading example of the public sector, develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings, and inform the Commission thereof in their national plans referred to in paragraph 1."*

Energy Performance Building Directive (2010/31/EU) is amended on May 30, 2018 with new directive, as a part of Clean energy for all Europeans' package [15]. Among others, directive statest that the monitoring and automation of buildings have proben to be efficient, especially in large systems, and that there lie a huge potential for significant energy savings.

*Energy Performance Building Directive (2018/844/EU) Paragraph 37. states: "Building automation and electronic monitoring of technical building systems have proven to be an effective replacement for inspections, in particular for large systems, and hold great potential to provide cost-effective and significant energy savings for both consumers and businesses. The installation of such equipment should be considered to be the most cost-effective alternative to inspections in large non-residential and multi-apartment buildings of a sufficient size that allow a payback of less than three years, as it enables action to be taken on the information provided, thereby securing energy savings over time. For small-scale installations, the documentation of the system performance by installers should support the verification of compliance with the minimum requirements laid down for all technical building systems."*

The directive added an article on a long-term renovation strategy, which mandates that all buildings, both public and private, must be renovated in order to increase energy energy efficiency by 2050.

*Energy Performance Building Directive (2018/844/EU) Article 1 Paragraph 2. states: "Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings. Each long-term renovation strategy shall be submitted in accordance with the applicable planning and reporting obligations and shall encompass:*

*(a) an overview of the national building stock, based, as appropriate, on statistical sampling and expected share of renovated buildings in 2020;*

*(b) the identification of cost-effective approaches to renovation relevant to the building type and climatic zone, considering potential relevant trigger points, where applicable, in the life-cycle of the building;*

*(c) policies and actions to stimulate cost-effective deep renovation of buildings, including staged deep renovation, and to support targeted cost-effective measures and renovation for example by introducing an optional scheme for building renovation passports;*

*(d) an overview of policies and actions to target the worst performing segments of the national building stock, splitincentive dilemmas and market failures, and an outline of relevant national actions that contribute to the alleviation of energy poverty;*

*(e) policies and actions to target all public buildings;*

*(f) an overview of national initiatives to promote smart technologies and well-connected buildings and communities, as well as skills and education in the construction and energy efficiency sectors; and*

*(g) an evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality."*

***National and EU legislation on energy efficiency in public buildings in Serbia***

Adopting the Law on ratifying the Treaty establishing the Energy Community between the European Community and the Republic of Serbia, the Republic of Serbia became an Energy Community member in 2006. The Law on energy efficiency, published in the Official Gazette of RS, No. 25/13 of 15 March 2013, shall regulate the efficient use of energy and energy sources in the energy generation, transmission, distribution and consumption sectors, the energy efficiency policy and energy management system. One of the basic principles that are underlying the efficient use of energy is energy sustainability. The sustainability of energy use shall include reduced energy consumption, better use of available technologies and eco-design requirements, higher efficiency and effectiveness in the use of energy, as well as sustainability from the aspect of environmental impacts by applying the principles of environmental protection [16]. This Law also proposes the formation of an action plan for the energy efficiency of the Republic of Serbia. Currently, The Third Action Plan for Energy Efficiency of the Republic of Serbia is in force. This action plan sets targets in energy efficiency by the end of 2018 and proposes energy efficiency measures that should be taken in the generation and distribution systems and future plans that are in accordance with the implementation of the EU directives.

As a candidate country to become a member state of the European Union, the Republic of Serbia should harmonize its laws with the EU, i.e. with EU directives on energy efficiency. The Energy Efficiency Directive 2012/27/EU is pursuing the overall objective of the energy efficiency target of saving 20% of the Union’s primary energy consumption by 2020, and of making further energy efficiency improvements after 2020 [17]. The amending directive (2018/2002) [18] was agreed to update the policy framework to 2030 and beyond.

The Republic of Serbia has adopted the Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030 (Official Gazette of the Republic of Serbia, No. 53/2013). Strategic energy development is based on establishing a balance between the production of energy from available sources, energy consumption with a market and socially sustainable character, and more efficient production and the use of a “cleaner” energy from renewable energy sources. This document is in accordance with EU Directives and together with the Law on energy efficiency and the Third Action Plan for Energy Efficiency presents a foundation for different energy efficiency strategies.

As one of the packages of measures under the Stabilization and Association Agreement, the Republic of Serbia has committed itself to the implementation of the European Union directives and, by a decision of the Council of Ministers from October 2015, undertook to comply with the Energy Efficiency Directive 2012/27/EU.

The Energy Efficiency Law (Official Gazette of the Republic of Serbia, No. 25/2013) was adopted by the National Assembly of the Republic of Serbia on March 15, 2013. The law regulates the conditions and means of efficient use of energy, energy efficiency policy, energy management system, etc. The law goals are to make efficient use of energy by:

- Increasing the security of energy supply and its more efficient use,

- Increasing the competitiveness of the economy,
- Reducing the negative environmental impacts of the energy sector and
- Encouraging responsible behavior towards energy, based on the implementation of energy efficiency policies and energy efficiency measures in the sectors of energy production, transmission, distribution and consumption.

The mentioned law prescribes the existence of minimum energy efficiency requirements, as well as an action plan for the energy efficiency of the Republic of Serbia. Currently, the Third Energy Efficiency Action Plan of the Republic of Serbia Official Gazette of the Republic of Serbia, br. 25/2013) for the period until 2018 is available. This action plan defines the goals for total energy savings in the Republic of Serbia for 2018 and proposes basic frameworks for implementing measures to increase energy efficiency. The main target for 2018 was a reduction of 0.7254 Mtoe, which was about 9% of the reference energy consumption in 2008. Given the development of energy efficiency measures to date, and a savings of 0.37 Mtoe in the period 2010-2015, representing 93% of the measures envisaged for the same period, about 50% of the target remains in 2018, which is an achievable scenario if all the envisaged energy efficiency measures are implemented. This also means a significant increase in energy efficiency in the public sector, especially in public buildings and facilities used by various republic, provincial and local institutions.

***National and EU legislation on energy efficiency in public buildings in Croatia***

On October 31st 2019, the Croatian Government adopted and forwarded to Parliament a draft of new Energy Strategy of Croatia in the period until 2030 with an outlook for the period until 2050, which envisages a much higher share of energy from renewable sources, greater energy efficiency and a reduction of greenhouse gas emissions. The Energy Strategy considers three different energy development scenarios:

- S0, a scenario with no further adjustments of measures, or changes to the regulatory framework;
- S1, a scenario of fast energy transition in Croatia and the EU;
- S2, a scenario of energy transition at an average pace in Croatia.

It is expected that Croatian overall energy consumption will reduce partially due to the decreasing population, but also because more efficient technologies are being incorporated in common consumer products, building energy efficiency and industry. In the next ten years, the overall consumption of energy is expected to reduce by 1% in S2, and by 5% in S1. The overall consumption of energy is expected to be drastically reduced by 2050, by 17% in S2, and by 26% in S1. Renewable energy sources are expected to increase their share of the overall consumption by 10% by 2030 in S2 (from 21.8% in 2017 to 31.5% in 2030), and by a further 15% by 2050 (from 31.5% in 2030 to 46.3% in 2050). The S1 midterm predictions remain the same (31.5% in 2030), but in long term, it predicts a far greater share of renewable energy sources in overall consumption – rising to 56.2% in 2050.

Energy Efficiency in Public Buildings in Croatia

Croatia as a member of EU is obliged by all EU legislations regarding the energy efficiency in (public) buildings including:

- Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Official Journal of the European Union, L 156, 19.6.2018, p. 75–91),
- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Official Journal of the European Union, L 315, 14.11.2012, p. 1-56) Special edition in Croatian: Chapter 12 Volume 004 p. 202 - 257

In the Republic of Croatia, Law (Act) on Energy Efficiency has been passed in 2014 (Official Gazette of the Republic of Croatia, No. 127/14). This Law regulates the field of energy efficiency, including:

- adoption of plans at local, regional and national level for improving energy efficiency and their implementation,
- energy efficiency measures,
- energy efficiency obligations: obligations of the energy regulatory authority, transmission system operator, distribution system operator and energy market operators in connection with the transmission, i.e. transport and distribution of energy, obligations of energy distributors, energy suppliers and / or water, in particular activity of energy services
- determination of energy savings
- consumer rights in the application of energy efficiency measures.

Amendments in 2018 (Official Gazette of the Republic of Croatia, No. 116/2018) has been passed to amend discrepancies with the Directive 2012/27/EU on energy efficiency which could call in question the realization of mandatory goals of sustainable development: reduction of negative environmental impact of energy sector, improvement of energy supply security, fulfilling the energy demand and implementation of international obligations of Republic of Croatia in GHG emissions reduction by encouraging energy efficiency measures in all areas of energy consumption and production [Energy in Croatia 2018].

Currently in Croatia, the Fourth National Energy Efficiency Plan of the Republic of Croatia for the Period from 2017 to 2019 is a document that meets the obligations incented in the EPBD Directive (recast) (2010/31/EU), the EED directive (2012/27/EU) and the Directive on the deployment of alternative fuels infrastructure (2014/94/EU). In the 4th NEEAP the main

holders of the increase of energy efficiency in the buildings sector are programmes for energy renovation of multifamily housing and commercial non-residential buildings. The interest for the Programme of energy renovation of multifamily housing has been exceptionally high and has garnered great success. Amendments to the Programme have allowed that all citizens of Croatia apply directly to the EPEEF, and the procedure of submitting an application for an incentive has been simplified by changing the definition of a family house. In 2016 the co-financing programme has been additionally adapted due to the use of resources of European funds within the OPCC. The aim of the Programme is the increase of energy efficiency of existing houses, reduction of energy consumption and emissions of CO2 into the atmosphere and the reduction of monthly costs for energy sources, with an overall improvement of the quality of life.

The national energy renovation target of 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government and amounts to 0.00489 PJ/year. Calls for co-financing of energy refurbishment and use of renewable energy sources in public buildings are being issued in Croatia on regular basis. Furthermore, buildings used by public administration in Croatia built in 2018 onwards, i.e. all buildings for which building permit was requested after 31st December, 2017 have to be constructed as nearly zero energy buildings defined in Technical ordinance on rational energy use and thermal protection in buildings (Official Gazette of the Republic of Croatia, No. 128/15) in order to secure timely implementation of Directive on energy performance of buildings requirements in public buildings. Amendments of former regulation simplify building compliance proof, further enforce integral energy refurbishment of buildings and include additional near zero energy building (nZEB) declaration of buildings.

# 3. The main features of the location and the building for the exemplary facility

Clinical Center of Vojvodina (hereinafter KCV) is located in the city of Novi Sad, South Bačka district of Vojvodina province in Republic of Serbia. More exact location of the KCV facilities is Sajmište, part of the city of Novi Sad, at Hajduk Veljkova No. 1-9 street. Precise geographical coordinates of the KCV facilities are 45°15'05.0" north latitude and 19°49'20.1" east longitude, as shown in Figure 3.1 (source: google.com/maps).

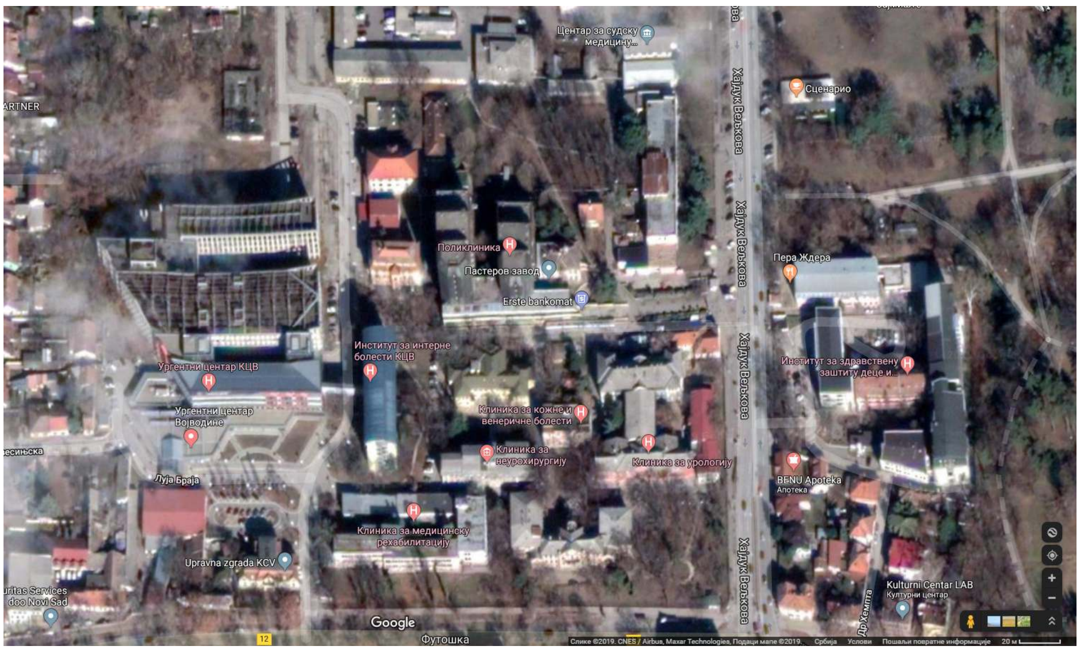


Figure 3.1 *Location of Clinical Center of Vojvodina complex*

The KCV complex is situated at C.P. 7569/1, C.M. Novi Sad I, as shown in Figure 3.2 which represents the segment of the city situation plan (source: a3.geosrbija.rs). The KCV complex includes 26 facilities dedicated to providing tertiary level health care services for the population of Vojvodina as well as specialist trainings for medical graduates given that KCV represents the main medical research and education facility of the University of Novi Sad. The first city hospital was founded in 1859, and with the growing needs of the population, the city government built the Great City Hospital in 1873. Considering the fact that the Great City Hospital, located in the present Futoška street no. 17 (now in that building is the Secondary Electrical Engineering School), it was not enough to take care of all the patients, a new City Hospital was built on the site of today's KCV, according to the Pavilion style. It began operations in 1909 with a 400-bed bedding.

According to the decision to establish the Clinical Center Novi Sad, which begins its work on April 30, 1997, the following health care institutions were included:

1. Institute of Surgery in Novi Sad,
2. Institute for Internal Diseases in Novi Sad,
3. Institute of Neurology, Psychiatry and Mental Health in Novi Sad,
4. Institute of Medical Services in Novi Sad,
5. Clinic for infectious and skin-venereal diseases in Novi Sad,
6. Clinic for Ear, Throat and Nose Diseases in Novi Sad;
7. Eye Clinic in Novi Sad,
8. Gynecology and Obstetrics Clinic in Novi Sad,
9. Medical Rehabilitation Clinic in Novi Sad.

In 2002, the Province of Vojvodina assumed the founding rights over the KCV, and on the basis of the Law on Health Care and at the proposal of the Provincial Government, the Government of the Republic of Serbia adopted the Decree on the plan of the network of health care institutions, which established the Clinical Center of Vojvodina in its present composition. Based on the republican and provincial regulations, in 2006 the Board of Directors of the Clinical Center of Vojvodina adopted the Statute of the Clinical Center of Vojvodina, which established internal organizational units and determined the present activity and bodies of the Clinical Center as a health institution that performs health activity at secondary and tertiary level. Today, the Clinical Center of Vojvodina consists of 26 facilities, whereby administrative building of Clinical Center, clinics for neurology, clinics for abdominal, endocrine and transplantation surgery and emergency center are some of the facilities in the KCV complex, however only a few are of interest for this study.

The KCV class is defined according to SRPS HD 60364-5-51:2012/A12:2017 standard:

Environmental conditions:

| | |
|---|---|
| AA Ambient temperature: | AA5 |
| AB Atmospheric humidity: | AB5 |
| AC Altitude: | AC1 |
| AD Water presence: | AD1 (AD2 or AD4 swimming pool, AD3 toilets) |
| AE Presence of foreign solids: | AE1 |
| AF Presence of corrosive substances or contaminants: | AF3 |
| AG Mechanical stresses - Impact: | AG1 |
| AH Mechanical stresses - Vibrations: | AH1 |
| AK Flora presence and/or mold: | AK1 |
| AL Fauna presence: | AL1 |
| AM Electromagnetic, electrostatic or ionizing effects: | AM1 |

| | |
|---|---|
| AN Solar radiation: | AN1 |
| AP Seismic Impact: | AP1 |
| AQ Atmospheric Discharge: | AQ1 |
| AR Air-movement: | AR1 |
| AS Wind: | AS1 |

- Usage

| | |
|---|---|
| BA Staff competence: | BA3 |
| BC Staff contact with earth potential: | BC2 |
| BD Emergency evacuation conditions: | BD4 |
| BE The nature of the processed or stored materials: | BE4 |

- Building construction

| | |
|---|---|
| CA Construction materials: | CA1 |
| CB Object structure: | CB1 |

The energy efficiency assessment covers the premises in the facility owned by the Clinical Center of Vojvodina, which are in the function of maintaining all activities related to the admission of patients, space for the implementation of rehabilitation exercises, space for the provision of therapy to patients, space for patient accommodation (hospital rooms), communication and stairwells, entry halls, and general and legal clinic facilities.

Most of the time, especially during the performance of general tasks, the clinic staff spends in offices and exam rooms. An example of an exam room is given in Figure 3.2 and the office in 3.3. Exam rooms and offices are most often equipped with computers, computer peripherals, and air conditioning, while they may have other smaller consumers as the case may be. These rooms contain between 1 and 3 workplaces, and in most cases offices have 1 workplace.

Figure 3.2 *Example of an exam room in KCV*

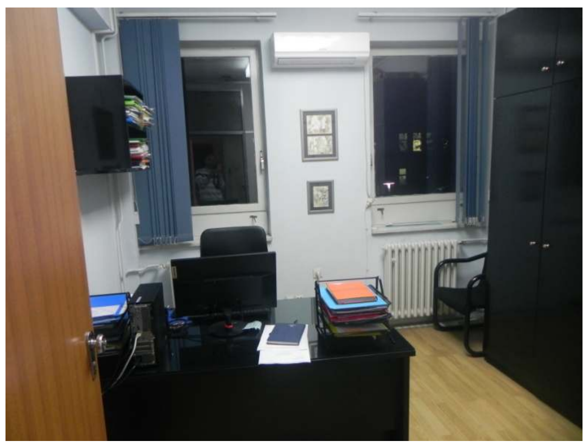

Figure 3.3 *Example of an office*

Facilities in the Clinical center of Vojvodina complex that are of interest in this study are Medical Center for Rehabilitation, Radiology clinic and Emergency center.

The Medical Rehabilitation Clinic shown in Figure 3.4, implements modern methods of evaluation and medical rehabilitation of (physically) disabled persons, regardless of the type and severity of the disability. Prevention of disability and secondary complications of diseases and injuries is carried out through outpatient and inpatient physical treatment in the sick and injured with threatening and temporary disability, as well as with the help of the team for early rehabilitation in patients treated at the Clinical Center of Vojvodina. The Medical Rehabilitation Clinic is an institution of national importance in terms of staff and professional methodologies. The rehab teams at the Clinic consist of all those profiles of professionals that are necessary to deal with the numerous and complex physical, mental and social disability.

Figure 3.4 *Main entrance of the Medical Rehabilitation Clinic in Clinical center of Vojvodina complex*

The KCV Radiology Center shown in Figure 3.5 is one of the largest radiology centers in Serbia and the region. The center performs a secondary and tertiary level of healthcare. With 30 employees of radiology specialists and subspecialists, modern equipment and use of modern methods in the field of diagnostic and interventional radiology, the Center is an irreplaceable link in the functioning of the Clinical Center of Vojvodina.

Figure 3.5 *Main entrance of the Radiology facility in Clinical Center of Vojvodina complex*

The Emergency Center of the Clinical Center of Vojvodina shown in Figure 3.6, area of 9,000 $m^2$ consists of ground floor, three floors and attic, within which there are various facilities: surgical and non-surgical intensive block, as well as offices for examinations of different specialist services, i.e. urgent admission, rapid laboratory, radiological, endoscopic diagnostics as well as on-call neurological services. On the first floor are observation rooms as well as a non-surgical intensive block with 27 beds, of which 10 are intensive care and 17 are semi-intensive. On the second floor is a surgical intensive block with 19 intensive care beds, as well as one operating room. The third floor is designed for 4 operating rooms, with the most modern equipment available on the market.


Figure 3.6 *Main entrance of the Emergency Center facility in Clinical Center of Vojvodina complex*

## 3.2. Climate conditions in the surrounding area

Moderately continental climate characterized by cold winters and warm summers and continental climate with well-distributed rainfall is changing in the territory of Vojvodina. During the autumn and winter, there is a chance of an endemic strong and cold wind ("košava"), which lasts three to ten days and can cause some damage during heavy snowfall.

Figure 3.7 shows the rose wind for Novi Sad, from which it is possible to recognize that the dominant wind in this area is the Košava, which blows from the east-southeast and west-northwest.

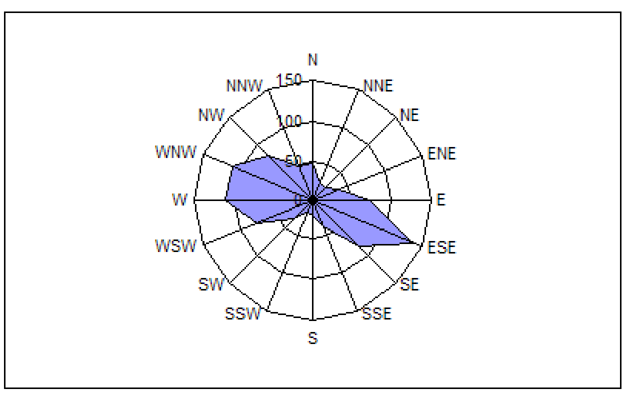


Figure 3.7 *Rose wind for Novi Sad.*

Table 3.1 shows the mean values of monthly, annual and extreme values of climatological values in the period from 1981 to 2010 (according to data of the Republic Hydro-meteorological Institute). Novi Sad is at an average altitude of 80 m, with an average

temperature of 11.4℃ during the year, and with an average temperature of 0.2℃ in January and 21.9 ℃ in July. The lowest measured temperature was -27.6 ℃, while the highest measured temperature was 41.6℃. The annual average rainfall is 647.3 mm and the average number of days with snow cover is 39. The average amount of solar radiation during the year on an area of 1 square meter is 129.2 kWh/m$^2$.

*Table 3.1 The mean values of monthly, annual and extreme values of climatological values for Novi Sad (Rimski Šančevi - 45°20 and 19°51E, n. v. 84 m)*

| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Year** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Temperature [℃]** | | | | | | | | | | | | |
| **Mean maximum value** | 3.7 | 6.1 | 12.0 | 17.7 | 23.0 | 25.8 | 28.1 | 28.3 | 23.6 | 18.0 | 10.5 | 4.8 | 16.8 |
| **Mean minimum value** | -3.1 | -2.4 | 1.5 | 6.2 | 11.3 | 14.1 | 15.5 | 15.3 | 11.4 | 6.9 | 2.2 | -1.5 | 6.5 |
| **Normal value** | 0.2 | 1.6 | 6.4 | 11.8 | 17.3 | 20.1 | 21.9 | 21.6 | 16.9 | 11.8 | 5.9 | 1.5 | 11.4 |
| **Absolute maximum** | 18.7 | 22.3 | 28.3 | 30.8 | 34.0 | 37.6 | 41.6 | 40.0 | 37.4 | 29.2 | 25.0 | 21.0 | 41.6 |
| **Absolute minimum** | -27.6 | -24.2 | -19.9 | -6.2 | 1.8 | 4.8 | 7.5 | 7.0 | 2.5 | -6.2 | -13.8 | -24 | -27.6 |
| | | | | | | | | | | | | | |
| **Mean number of frost days** | 22 | 18 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 18 | 81 |
| **Mean number of tropical days** | 0 | 0 | 0 | 0 | 1 | 6 | 11 | 11 | 2 | 0 | 0 | 0 | 32 |
| **Average relative moisture [%]** | 85 | 79 | 71 | 67 | 66 | 69 | 68 | 68 | 72 | 76 | 82 | 86 | 74 |
| **Hours of daily light** | | | | | | | | | | | | | |
| **Average** | 64.8 | 99.0 | 156.4 | 190.1 | 250.8 | 269.4 | 303.6 | 285.8 | 205.7 | 158.9 | 92.4 | 58.4 | 2135 |
| **Number of clear days** | 3 | 5 | 5 | 5 | 5 | 6 | 11 | 12 | 9 | 8 | 4 | 3 | 75 |
| **Number of cloudy days** | 14 | 10 | 9 | 7 | 5 | 5 | 3 | 3 | 5 | 6 | 11 | 15 | 94 |
| **Radiation [kWh/m$^2$]** | 53.1 | 71.8 | 131 | 161 | 173 | 180 | 201 | 198 | 146 | 113 | 76.3 | 45.9 | 129.2 |
| **Precipitation [mm/m$^2$]** | | | | | | | | | | | | | |
| **Mean monthly sum** | 39.1 | 31.4 | 42.5 | 49.2 | 63.0 | 91.4 | 64.3 | 57.5 | 53.8 | 52.7 | 53.8 | 48.8 | 647.3 |
| **Maximum daily sum** | 31.8 | 23.2 | 32.6 | 40.2 | 91.8 | 67.6 | 68.7 | 68.0 | 48.8 | 59.0 | 54.9 | 37.6 | 91.8 |
| **Mean number of days >=0,1 mm/m$^2$** | 12 | 10 | 11 | 12 | 13 | 12 | 10 | 9 | 10 | 9 | 11 | 13 | 132 |
| **Mean number of days >=10 mm/m$^2$** | 1 | 1 | 1 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 20 |
| **Number of days with snow** | 13 | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 39 |

# 4. Current energy demand overview for the public building

In order to adequately consider the possibility for the implementation of measures to increase the KCV energy efficiency, it is first necessary to consider the state of the electrical infrastructure of the facilities, manner in which the power supply is established and the overall power consumption of each facility.

## 4.1. Connection to the Power Infrastructure - Power Supply of the Medical Rehabilitation Clinic

The facility of the Medical Rehabilitation Clinic is powered by a transformer station located in the courtyard of the Clinical Center of Vojvodina. The transformer station is located in a separate facility, shown in Figure 4.1, near the Technical Services Department. The transformer station is called "TS Klinička Bolnica". The power supply of the facility in the transformer station was achieved by the use of two three-phase oil transformers with a power of 10/0.4 kV / kV 630 kVA, and one three-phase oil transformer with a power of 10/0.4 kV / kV. Figure 4.1 shows the transform building of the transformer station.

Figure 4.1 *Overview of the transformation station "TS Klinička Bolnica"*

The high voltage side consists of 7 fields, divided into two segments. The first segment consists of three fields, namely: "Trafo polje 1", "Merna ćelija" and "Trafo polje 2", Figure 4.2. The transformer boxes 1 and 2 have switchgear and protective equipment for the protection and manipulation of the on / off switch of the 630 kVA transformer. In the measuring cell the equipment for measuring consumption of all facilities connected to the low voltage side of "TS Klinička Bolnica" is located.

Figure 4.2 *Overview of the first segment in the high voltage part of "TS Klinička Bolnica"*

The second segment of the high voltage section consists of 4 fields (or cells), Figure 4.3. The first field (viewed from right to left, Figure 4.3) represents the junction cell, and this cell represents the connection between the first and second segments of the high voltage section. It is equipped with appropriate switching and protection equipment. The second and third cells are identical and represent excerpts to the substations "TS Zagrebačka" and "TS Medicinski fakultet". They are also equipped with appropriate switching and protection equipment. The last, fourth cell is a classic transformer cell equipped with switchgear and protective equipment to protect and manipulate the on / off switch of a third 250 kVA transformer. It is important to note that the third transformer is not used. The high voltage side cable is 3x150 mm2 aluminum. In Figure 4.4 a single-pole diagram of the high-voltage segment of the substation is shown.


Figure 4.3 *Overview of the second segment in the high voltage part of "TS Klinička Bolnica"*

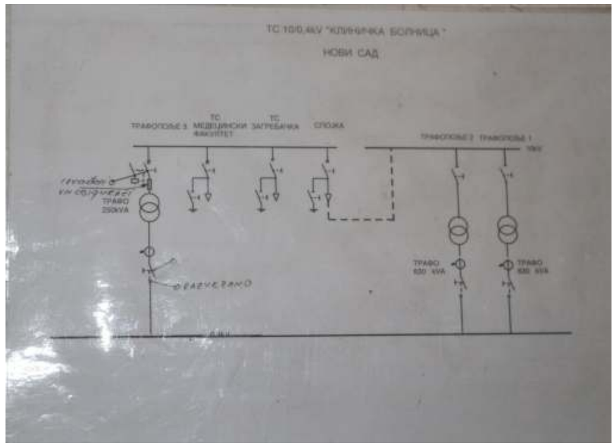


Figure 4.4 *Single-pole diagram of the high-voltage segment of the substation*

The low voltage side of the substation consists of 5 fields (or cells), shown in Figure 4.5, interconnected by copper bus bars. Table 4.1 gives an overview of the low-voltage side of the transformer station "TS Klinička Bolnica", as well as cross sections of the used low-voltage cable lines that supply certain objects.

The first, third and fifth fields, Figure 4.5 (viewed from left to right) are identical and are made up of a group of main switches for the statements given in Table 4.1. The second and fourth fields represent transformers 1 and transformers 2. The fields are equipped with main switches and measuring instruments.

*Table 4.1 Overview of the low voltage side of the transformer station "TS Klinička Bolnica"*

| **Tap No.** | **Clinics** | **Cable type** | **Current limiters** |
|---|---|---|---|
| 1 | Psychiatry Clinic | PP00 4x120 mm$^2$ | 3x200 A |
| 2 | Clinic of Neurology | | |
| 3 | Clinic for Nephrology | PP00 4x150 mm$^2$ | 3x250 A |
| 4 | Gastroenterology Clinic | | |
| 5 | Endocrinology Clinic | | |
| 6 | Hematology Clinic | | |
| 7 | Infectious Diseases Clinic | PP00-A 4x(1x240) mm$^2$ | 3x200 A |
| 8 | Rehabilitation Clinic | PP00 4x150 mm$^2$ | 3x200 A |
| 9 | Technical service | 2xPP00 5x16 mm$^2$ | 3x80 A |
| 10 | Procurement + Garage Workshops | PP00 4x150 mm$^2$ | 3x250 A |
| 11 | Department of Pathology | PP00 4x35 mm$^2$ | 3x100 A |
| 12 | Boiler room | PP00 4x120 mm$^2$ | 3x160 A |
| 13 | Part of outdoor lighting | PP00 4x16 mm$^2$ | 3x25 A |
| 14 | CT on radiology | PP00 4x150 mm$^2$ | 3x250 A |


Figure 4.5 *Overview of the low voltage segment in the transformer station "TS Klinička Bolnica"*

In the event of a power failure by the electricity distribution system, the transformer station "TS Klinička Bolnica" is also connected to the diesel power unit, which assumes the role of electricity supply to the facilities connected to the said substation. The layout of the aggregate with the nameplate is shown in Figure 4.6.


Figure 4.6 *Overview of the diesel generator with its nameplate*

The Medical Rehabilitation Clinic is powered by a PP00 4x150 mm2 cable protected by three fuses rated at 200 A. There are two main distribution cabinets in the clinic facility, shown in Figure 4.7. From these cabinets, smaller distribution cabinets are distributed within the facility.

Figure 4.7 *Overview of the main switchboards inside the Medical Rehabilitation Clinic facility*

The connection of the facility to the electricity infrastructure was made during the construction of the facility (1960). The facility was connected to the TS "Klinička Bolnica" substation, whose approved installed capacity was 660 kW at that time. With the increase in the number of connected facilities to the aforementioned substation, there was a need to increase the installed capacity. Which was done in 1971. when the installed power was increased by 330 kW. According to the 1971 electricity approval, the total approved installed capacity of the TS "Klinička Bolnica" is 990 kW. The layout of the copy of the Power Consent (Connection Permit) then obtained is attached.

## 4.1.2. Description and classification of the power consumers in the facility

The facility in question has premises for different purposes, containing different types of consumers. In this chapter, some of the most common electricity consumers are described.

One of the most important consumers of electricity, especially in offices and exam rooms, are computers, whereby around 50 units are in the facility. Figure 4.8 shows one representative example of computers. Computers are deployed in 17 offices and 9 examine rooms.

Figure 4.8 *Example of a computer station in one office*

For cooling, ventilation and temperature control purposes, air conditioners are most commonly used in the premises of the facility, which can also be a major consumer of electricity (especially in periods when climatic conditions require longer operation). The object in question contains a total of 38 air conditioners of the latest generation and 8 air conditioners of the older design. The capacity of individual capacity of newer air conditioners is 9000 BTU, while for old air conditioners it was not possible to determine the capacity of capacity. The facility of the medical rehab clinic also has one central climate. Central climate is of special design and is located in the hydrotherapy room, where it is used to regulate the ventilation of the pool. Figure 4.9 shows the appearance of a characteristic newer air conditioning unit used in the facility. Figure 4.10 shows the appearance of an older generation air conditioner, and Figure 4.11 shows the appearance of a central climate in hydrotherapy space.


Figure 4.9 *Overview of a standard new generation air conditioner inside the facility and outdoor unit*

Figure 4.10 *Overview of older generation air conditioners inside the facility and outdoor unit*

Figure 4.11 *Overview of central climate in hydrotherapy space*

In addition to the above-mentioned premises, the Medical Rehabilitation Clinic has 7 kinesiotherapy rooms, 4 electrotherapy rooms and 2 occupational therapy rooms. Occupational therapy is part of a therapeutic-rehabilitation program and includes manual, creative, recreational, social, educational and other activities, with the aim of achieving a specific function, mental attitude or behavior in the patient. Kinesiotherapy is an area of physical therapy that deals with the application of movement for the purpose of healing, with the aim of establishing the optimal functioning of parts and the organism as a whole. Electrotherapy represents the use of numerous modalities of electric current, which are obtained by means of modern electronic devices for therapeutic purposes.

Kinesiotherapy and occupational therapy rooms, with the exception of air conditioning, are not equipped with significant electricity consumers. While electrotherapy rooms have special electronic devices used for therapeutic purposes. Figure 4.12 and Figure 4.13 shows an example of a nameplate electrotherapy device.

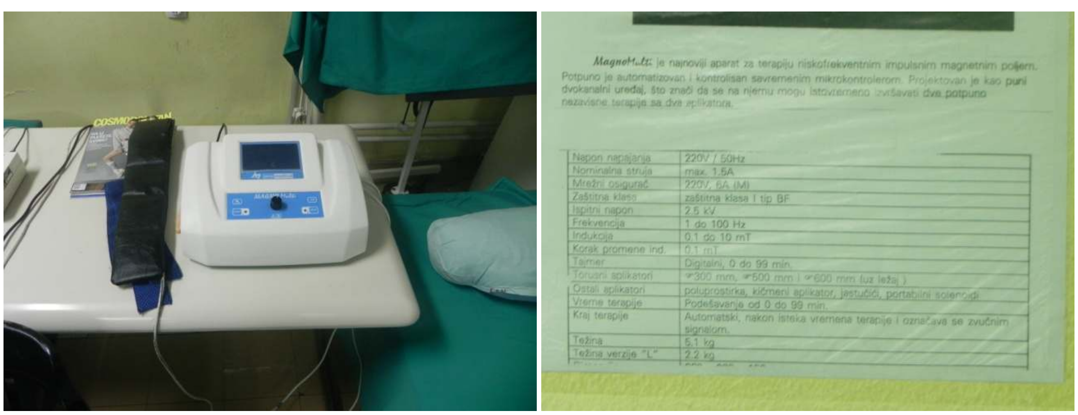


Figure 4.12 *Electrotherapy device with a nameplate*

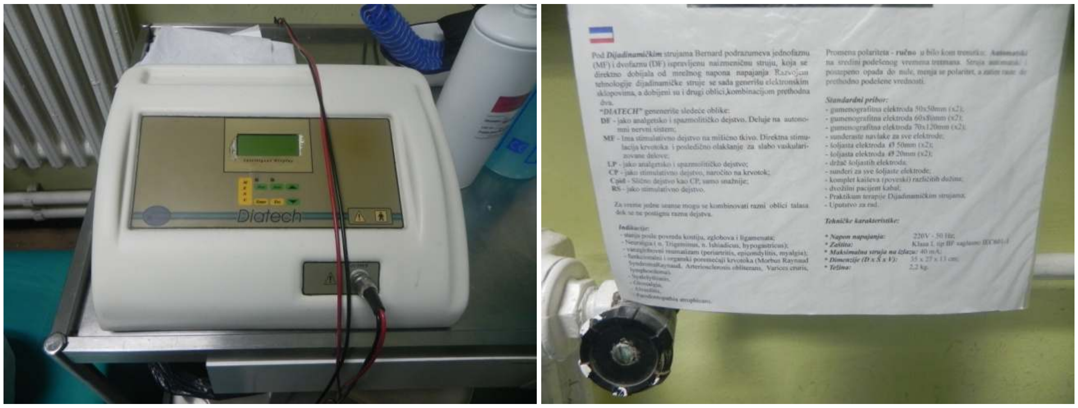


Figure 4.13 *Electrotherapy device with a nameplate*

Significant consumers of electricity in the clinic's facility are water heaters, boilers and elevators for the transportation of persons and materials. The Medical Rehabilitation Clinic has 3 boilers with 80 l capacity of 2 kW, 2 boilers with capacity of 10 l with capacity of 2 kW and 2 lifts for transportation of patients and staff, as well as one small lift for transportation of materials. Figure 4.14 shows an example of a commonly used boiler in an object and Figure 4.15 shows an example of an elevator.


Figure 4.14 *Example of a commonly used water heater in a subject object*

Figure 4.15 *Example of an elevator with accessories*

## 4.1.3. Analysis of the power consumption

One of the basic elements of a preliminary energy audit, which will provide the basis for proposing energy efficiency measures, is the analysis of energy consumption in the facility concerned.

The subject facility of the Medical Rehabilitation Clinic is supplied from the transformer station "TS Klinička Bolnica", from which another 12 facilities and part of the external lighting are supplied. The electricity consumption is measured for all the facilities together, and the electricity bills show the consumption of all the facilities connected to the transformer station "TS Klinička Bolnica". Figure 4.16 shows an example of an electricity bill, for all consumers connected to the substation, with the most important billing parameters.

The picture shows that the account is divided into 5 segments. The first segment represents the read values of the meter, where the difference represents the consumption of electricity over a period of one month. The apparent measurement of active electricity in a facility is two-tariff, while for reactive energy it is calculated in a single tariff. The lower rate is calculated between 00 and 08 o'clock each day, daylight saving time, or from 23 to 07 o'clock in winter time. In the remaining period a higher tariff is charged. Obviously, and given the primary purpose of the facility, the highest spending is in the higher tariff.

ЕЛЕКТРОПРИВРЕДА СРБИЈЕ

ЈП ЕПС Београд
11000 Београд, ул.Балканска 13

ПИБ: 103920327
Матични број: 20053658

**ОБРАЧУН ЗА ЕЛЕКТРИЧНУ ЕНЕРГИЈУ - ЈУЛ 2019**

Обрачун број: 25798541
Место издавања: Београд
Датум издавања: 15.08.2019
Датум промета и акцизе: 01.08.2019
Датум доспећа: 16.09.2019

Број места мерења: 4012730204
Уговор број: 18.01-15259/477-19 01.10.18-30.09.19
Категорија: Потрошња на средњем напону

Врста снабдевања: Комерцијално снабдевање
Одобрена снага (kW): 450
Период обрачуна: 02.07.2019 - 01.08.2019

Место мерења: 1410159364
ZTS "KLINIČKA BOLNICA"
HAJDUK VELJKOVA 1
21101 NOVI SAD

**Приликом уплате на текући рачун 845-484849-65 позвати се на број 14-4012730140-1907 модел 97.**

Република Србија
Аутономна Покрајина Војводина
КЛИНИЧКИ ЦЕНТАР
ВОЈВОДИНЕ
НОВИ САД
Примљено: 19 AUG 2019
Орг. јед. | Број
РТ | 3260/1

ПИБ: 101696893
МБ: 08664161
4010059348
KLINIČKI CENTAR VOJVODINE
HAJDUK VELJKOVA 1
NOVI SAD

21101 NOVI SAD

**1.** ОЧИТАНЕ ВРЕДНОСТИ 1

| Број бројила | Датум очитавања | Обрач. величина | Стање бројила – Претходно стање ВТ | Претходно стање НТ | Ново стање ВТ | Ново стање НТ | Обрач. константа | Коеф. свођења | Енергија за обрачун ВТ | Енергија за обрачун НТ | Стање макс. | Константа максигр. | Коеф. свођења снаге | Снага (kW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10630711 | 01.08.2019 | kWh | 3.449,194 | 1.166,257 | 3.529,368 | 1.190,714 | 1500 | | 120.261 | 36.686 | 0,319 | 1 | | 478,5 |
| | 01.08.2019 | kVArh | 2.361,166 | 828,083 | 2.415,414 | 846,98 | 1500 | | 81.372 | 28.346 | | | | |

**2.** ОБРАЧУН ЗА ИСПОРУЧЕНУ ЕЛЕКТРИЧНУ ЕНЕРГИЈУ 2

| Р.бр. | Назив | Јед. мере | Испоручена количина | Јединична цена (EUR) | Ср.курс НБС на дан промета(РСД) | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7=5*6 | 8=4*7 |
| 1 | Активна електрична енергија у ВТ | kWh | 120.261 | | | 6,760000 | 812.964,36 |
| 2 | Активна електрична енергија у НТ | kWh | 36.686 | | | 6,760000 | 247.997,36 |
| | Укупно за испоручену електричну енергију: | | | | | | **1.060.961,72** |

**3.** ОБРАЧУН ЗА ПРИСТУП СИСТЕМУ ЗА ПРЕНОС/ДИСТРИБУЦИЈУ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ 3 Реактивна енергија за cosФ(0.95) = 51.588

| Р.бр. | Назив тарифе | Обрачунска величина | Количина за обрачун | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6=4*5 |
| 1 | Одобрена снага | kW | 450 | 93,0270 | 41.862,15 |
| 2 | Виша дневна тарифа за активну енергију | kWh | 120.261 | 0,9710 | 116.773,43 |
| 3 | Нижа дневна тарифа за активну енергију | kWh | 36.686 | 0,3240 | 11.886,26 |
| 4 | Реактивна енергија | kVArh | 51.588 | 0,4540 | 23.420,95 |
| 5 | Прекомерна реактивна енергија | kVArh | 58.130 | 0,9070 | 52.723,91 |
| 6 | Прекомерна снага | kW | 28,5 | 372,1100 | 10.605,14 |
| | Укупно за приступ систему за дистрибуцију електричне енергије: | | | | **257.271,84** |

**4.** ОБРАЧУН НАКНАДА ЗА ПОДСТИЦАЈ ПОВЛАШЋЕНИХ ПРОИЗВОЂАЧА ЕЛ. ЕНЕРГИЈЕ И УНАПРЕЂЕЊЕ ЕНЕРГЕТСКЕ ЕФИКАСНОСТИ 4

| Р.бр. | Назив тарифе | Обрачунска величина | Количина за обрачун | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6=4*5 |
| 1 | Накнада за подстицај повлашћених произвођача ел. | kWh | 156.947 | 0,093 | 14.596,07 |
| 2 | Накнада за унапређење енергетске ефикасности | kWh | 156.947 | 0,015 | 2.354,21 |
| | Укупно накнаде за подстицај повлашћених произвођача ел. енергије и унапређење енергетске ефикасности: | | | | **16.950,28** |

**5.** РЕКАПИТУЛАЦИЈА ОБРАЧУНА 5

| | | |
|---|---|---|
| 1 | Испоручена електрична енергија | 1.060.961,72 |
| 2 | Приступ систему за пренос/дистрибуцију електричне енергије | 257.271,84 |
| 3 | Накнада за подстицај повлашћених произвођача ел.енергије | 14.596,07 |
| 4 | Накнада за унапређење енергетске ефикасности | 2.354,21 |
| 5 | Основица за обрачун акцизе (5=1+2+3+4) | 1.335.183,84 |
| 6 | Износ обрачунате акцизе (стопа 7,5%) (6=5*0.075) | 100.138,79 |
| 7 | Основица за ПДВ (7=5+6) | 1.435.322,63 |
| 8 | Порез на додату вредност 20% (8=7*0.20) | 287.064,53 |
| 9 | Такса за јавни медијски сервис | 0,00 |
| 10 | Укупно за обрачун (10=7+8+9) | **1.722.387,16** |

Figure 4.16 *Example of electricity bill for the object in question*

The second segment of the bill is the calculation of consumed active electricity for a period of one month for the higher and lower tariff expressed kWh, as well as the equivalent monetary value (RSD) for the consumed energy. It can be observed here that the contracted price of 1 kWh of electricity is 6.76 RSD for higher and 6.76 RSD for lower tariff.

The third segment is the calculation for access to the electricity transmission / distribution system, which shows the approved power for the facility, consumed active electricity of higher and lower tariffs, spent reactive energy, excessive reactive energy and excessive power. It can be easily seen that the price for spent reactive energy is 0.454 RSD for 1 kVArh, while the price for excessive reactive energy is almost twice higher and is 0.907 RSD. In order to exceed the maximum approved power, an additional 372.11 RSD per 1 kW must be allocated.

In the fourth segment, the calculation of the incentive fee for privileged electricity producers according to the Official Gazette of RS No. 7 from 23.01.2015 is presented, which amounts to 0.093 RSD per kWh of electricity consumed. The fifth segment consists of a recapitulation of the calculation where the previous segments are collected and excise duties and value added tax (VAT) are calculated. An overview of basic data on electricity consumption with debt calculation in the period from September 2018 to August 2019 is shown in Table 4.2.

*Table 4.2 Electric power consumption – "TS Klinička Bolnica"*

| | Consumption High tariff [kWh] | Consumption Low tariff [kWh] | Total consumption [MWh] | Total for electric energy [RSD] | Total tax-free debt [RSD] | Total charges [RSD] |
|---|---|---|---|---|---|---|
| **Sep 2018** | 81.335,00 | 28.850,00 | 110,19 | 618.137,85 | 885.767,85 | 1.062.921,42 |
| **Oct. 2018** | 99.027,00 | 34.065,00 | 133,09 | 899.701,92 | 1.223.160,84 | 1.467.793,00 |
| **Nov 2018** | 105.431,00 | 35.964,00 | 141,40 | 955.830,20 | 1.291.070,88 | 1.549.285,06 |
| **Dec 2018** | 115.656,00 | 39.542,00 | 155,20 | 1.049.138,48 | 1.409.110,98 | 1.690.933,18 |
| **Jan 2019** | 115.794,00 | 39.677,00 | 155,47 | 1.050.983,96 | 1.410.213,94 | 1.692.256,73 |
| **Feb 2019** | 102.819,00 | 34.779,00 | 137,60 | 930.162,48 | 1.254.544,77 | 1.505.453,73 |
| **Mar 2019** | 100.458,00 | 34.578,00 | 135,04 | 912.843,36 | 1.237.928,88 | 1.485.514,65 |
| **Apr 2019** | 94.905,00 | 32.244,00 | 127,15 | 859.527,24 | 1.170.894,30 | 1.405.073,16 |
| **May 2019** | 93.440,00 | 31.040,00 | 124,48 | 841.484,80 | 1.148.516,93 | 1.378.220,32 |
| **Jun 2019** | 120.807,00 | 35.457,00 | 156,26 | 1.056.344,64 | 1.431.300,09 | 1.717.560,11 |
| **July 2019** | 120.261,00 | 36.686,00 | 156,95 | 1.060.961,72 | 1.435.322,63 | 1.722.387,15 |
| **Aug 2019** | 127.797,00 | 38.600,00 | 166,40 | 1.124.843,72 | 1.508.420,75 | 1.810.104,90 |
| **Total** | ***1.277.730,00*** | ***421.482,00*** | ***1.699,212*** | ***11.359.960,37*** | ***15.406.252,84*** | ***18.487.503,41*** |

The table shows that electricity consumption is almost constant throughout the year. Considering the type of work that is done in the facilities supplied from the substation, it is expected that the electricity consumption will be approximately constant. Figure 4.17

shows a graphical representation of electricity consumption by month, expressed in megawatt hours (MWh), from September 2018 to August 2019.

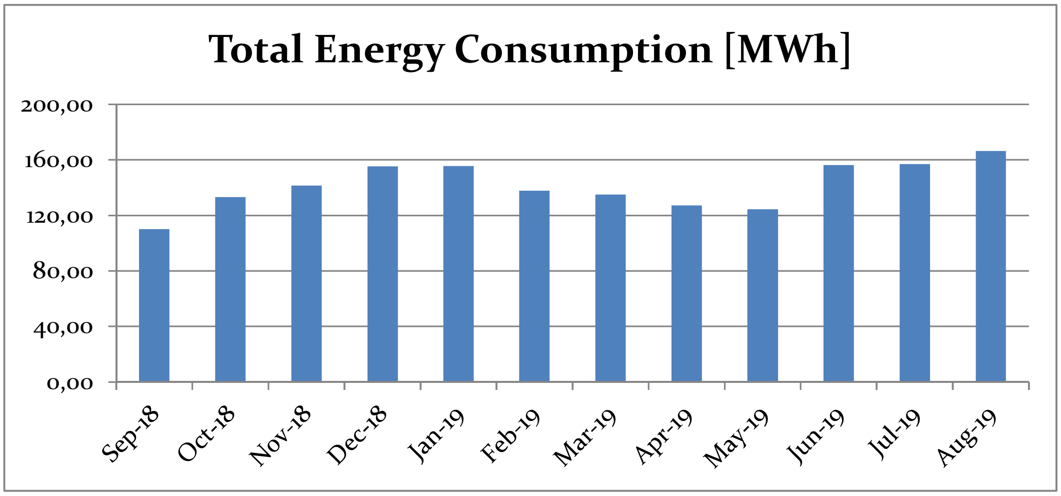


Figure 4.17 – *Overview of the electrical energy consumption for "TS Klinička Bolnica"*

The graphs clearly show that the highest electricity consumption is in July. The reason for this can be found in the fact that during this period the climatic conditions were such that the use of the air conditioners was necessary. In winter, the highest power consumption was in December.

## 4.2. Connection to the Power Infrastructure - Power Supply of the Radiology

The Radiology clinic is powered from two transformer station namely "TS Poliklinika" and "TS Kotlarnica". Both transformer stations are located in the courtyard of the Clinical Center of Vojvodina. The exterior overview of the two transformer stations is shown in Figure 4.18.

Figure 4.18 *Overview of the transformation stations "TS Kotlarnica" (left) and "TS Poliklinika" (right)*

The high voltage side consists of 5 fields, namely: "Trafo", "Merna", "Dovodno polje", "Odvodno polje" and "Rezerva" and these are shown in Figure 4.19. The transformer box has switchgear and protective equipment for the protection and manipulation of the on/off switch of the 1000 kVA transformer. In the measuring cell the equipment for measuring consumption of all facilities connected to the low voltage side of "TS Kotlarnica" is located.

Figure 4.19 *Overview of the high voltage part of "TS Kotlarnica"*

Power transformer in "TS Kotlarnica" is three phase 20/0.4 kV/kV oil transformer with rated power of 1000 kVA. Cooling of the transformer is oil natural air natural (ONAN) which means that windings are cooled with natural flow of the oil while the transformer dish is cooled by natural flow of the air. Winding connection is Dy5 which is standard for

a distribution transformers. This transformer together with its nameplate is shown in Figure 4.20.


Figure 4.20 *Transformer in "TS Kotlarnica" (left) and its nameplate (right)*

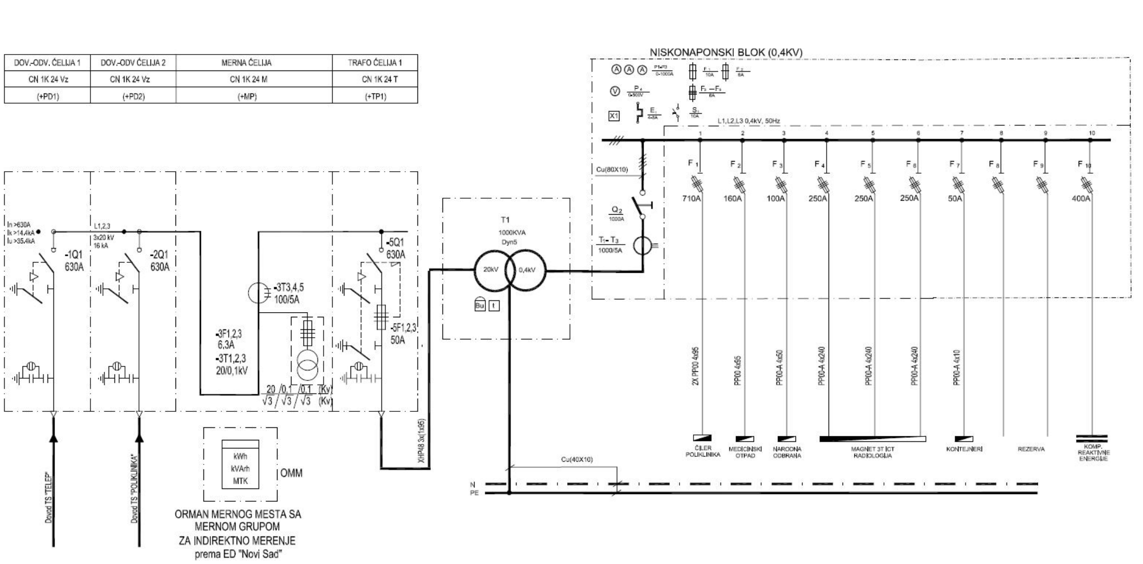


Figure 4.21 *Single-pole diagram of the "TS Kotlarnica"*

The low voltage side of the transformer station consists of 4 fields shown in Figure 4.21, interconnected by copper bus bars. Table 4.3 gives an overview of the low-voltage side of the transformer station "TS Kotlarnica", as well as cross sections of the used low-voltage cable lines that supply certain objects and accompanying current limiters.


Figure 4.22 *Overview of the low voltage segment in the transformer station "TS Kotlarnica"*

*Table 4.3 Overview of the low voltage side of the transformer station "TS Kotlarnica"*

| Tap No. | Facility | Cable type | Current limiters |
|---|---|---|---|
| 1 | Chiller in Policlinic facility | PP00 2x(4x150) $mm^2$ | 3x710 A |
| 2 | Medical waste | PP00 4x95 mm2 | 3x160 A |
| 3 | Population protection | PP00-A 4x50 mm2 | 3x100 A |
| 4 | MRI scanners and CT scanners in Radiology clinic | PP00-A 4x240 mm2 | 3x250 A |
| 5 | | | |
| 6 | | | |
| 7 | Containers | PP00 4x10 mm2 | 3x50 A |
| 8 | Reserve | PP00 4x120 mm2 | 3x160 A |
| 9 | | PP00 4x120 mm2 | 3x160 A |
| 10 | Reactive power compensation | PP00 4x150 mm2 | 3x400 A |

The high voltage side in the "TS Poliklinika" consists of 5 fields, namely: "Tranrsformator 1", "Transformator 2", "Merenje celija", "Dovod 1" and "Dovod 2" and these are shown in Figure 4.23. The transformer boxes 1 and 2 have switchgear and protective equipment for

the protection and manipulation of the on/off switch of the 1000 kVA transformer. In the measuring cell the equipment for measuring consumption of all facilities connected to the low voltage side of "TS Kotlarnica" is located.

Figure 4.23 *Overview of the high voltage part of "TS Kotlarnica"*

Figure 4.24 gives a single-pole diagram of the high-voltage segment of the "TS Poliklinika" where all 5 substation fields can be clearly seen. Second segment of the high-voltage side in the "TS Poliklinika" is shown in Figure 4.25.

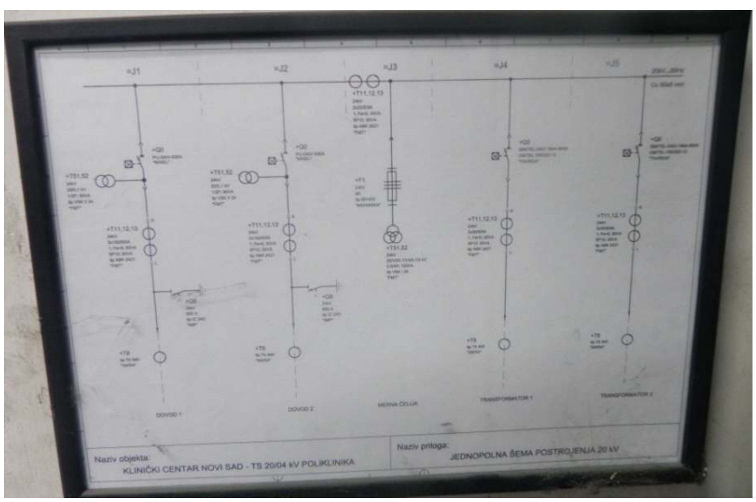


Figure 4.24 *Single-pole diagram of the high-voltage segment of the "TS Poliklinika"*

Figure 4.25 *Second segment of the high-voltage side in the "TS Poliklinika"*

Two power transformers in "TS Poliklinika" are three phase 20/0.4 kV/kV oil transformers with rated power of 1000 kVA. Cooling of the transformer is oil natural air natural (ONAN) which means that windings are cooled with natural flow of the oil while the transformer dish is cooled by natural flow of the air. Winding connection is Dy5 which is standard for a distribution transformers. Due to safety issues entrance in the transformer room was prohibited thus no photographs of the transformers are available.

The low voltage side of the transformer station consists of 12 fields shown in Figure 4.26, and they are interconnected with the copper bus bars. Table 4.4 gives an overview of the low-voltage side of the transformer station "TS Poliklinika", as well as cross sections of the used low-voltage cable lines that supply certain objects and accompanying current limiters.

Figure 4.26 *Overview of the low voltage segment in the transformer station "TS Kotlarnica"*

*Table 4.4 Overview of the low voltage side of the transformer station "TS Poliklinika"*

| Tap No. | Clinics | Cable type | Current limiters |
|---|---|---|---|
| 1 | Policlinic Facility | PP00 3x150 mm$^2$ | 3x400 A |
| 2 | Surgery admission | PP00 3x150 mm$^2$ | 3x400 A |
| 3 | Kitchen | PP00 3x150 mm$^2$ | 3x400 A |
| 4 | Dialysis Department | PP00 3x150 mm$^2$ | 3x400 A |
| 5 | Policlinic Facility | PP00 4x150 mm$^2$ | 3x400 A |
| 6 | | | |
| 7 | | | |
| 8 | MRI Scanner | PP00 4x120 mm$^2$ | 3x400 A |
| 9 | Lighting system | PP00 4x150 mm$^2$ | 3x400 A |
| 10 | Pathology Department | PP00 4x70 mm$^2$ | 3x160 A |
| 11 | Sterilization | PP00 4x185 mm$^2$ | 3x400 A |
| 12 | Infectious diseases clinic | PP00 4x150 mm$^2$ | 3x400 A |

## 4.3. Connection to the Power Infrastructure - Power Supply of the Emergency Center

The facility of the Emergency Center is powered from a transformer station located in the courtyard of the Clinical Center of Vojvodina. The transformer station is located in a separate facility, shown in Figure 4.27 together with the transformer. The transformer station is called "ZTS Urgentni Centar". The power supply of the Emergency Center was achieved with the use of two identical three-phase dry transformer. Two power transformers in “ZTS Urgentni Centar” are three-phase 20/0.4 kV/kV oil transformers with rated power of 1600 kVA working in parallel. Cooling of the transformers is air natural (AN) which means that windings of the dry transformer without enclosure are cooled with natural flow of the air. Winding connection is Dy5 which is standard for a distribution transformers.

Figure 4.27 *Overview of the "ZTS Urgentni Centar" (left) and one of the two dry transformers (right)*

Transformer station "TS Urgentni Centar" as well as transformer room are equipped with modern fire detection and fire extinguishing system as shown in Figure 4.28.


Figure 4.28 *Fire detection and fire extinguishing system in "TS Urgentni Centar"*

The "TS Urgentni Centar" facility is complex and contains a high number of compactly integrated protective, manipulative and measuring equipment. High voltage segment in "ZTS Urgentni Centar" is shown in Figure 4.29, however due to safety issues the cabinets were not opened thus the equipment inside was not photographed. Single-pole circuit diagram of the high voltage side in the "TS Urgentni Centar" is shown in Figure 4.30.

Figure 4.29 *Overview of one segment in the high voltage part of "ZTS Urgentni Centar"*

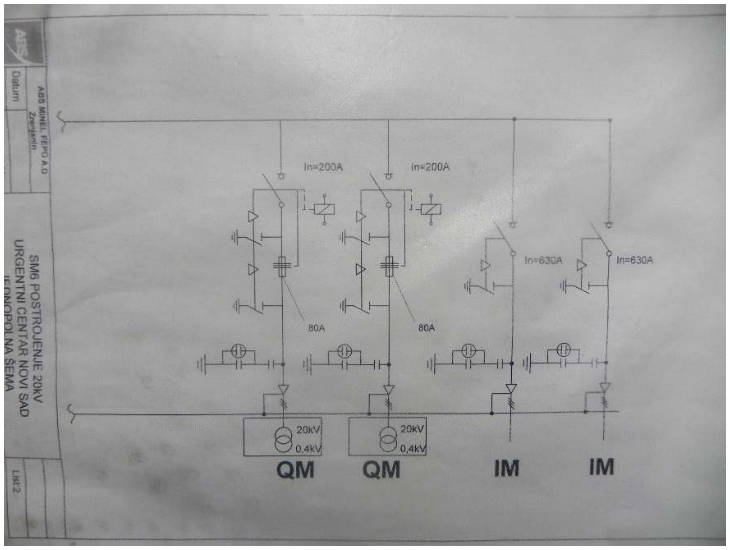


Figure 4.30 *Single-pole diagram of the high-voltage segment in "TS Urgentni Centar"*

In the event of a power failure in the electricity distribution system, the transformer station "ZTS Urgentni Centar" is also connected to the diesel power unit, which assumes the role of electricity supply to the facilities connected to this substation. Diesel generator units are shown in Figure 4.31. All diesel generator stations are accompanied with appropriate ATS units which means that immediately after the power outage occurs the diesel generators are automatically activated.


Figure 4.31 *Diesel generators in "ZTS Urgentni Centar"*

The "ZTS Urgentni Centar" is equipped with the reactive power compensation system as shown in Figure 4.32. Two electrical cabinets designated as "Polje kompenzacije TRAFO 1" and "Polje kompenzacije TRAFO 2" contain all necessary switch, protective and measuring equipment as well as capacitor blocks that are required to achieve power factor

correction. First electrical cabinet is responsible for the first and latter for the second dry transformer reactive power compensation.


Figure 4.32 *Overview of the electrical cabinets with equipment for reactive power compensation*

The low voltage side of the transformer station is very complex and for this reason only one segment is shown in Figure 4.33. Separate electrical cabinet showed in Figure 4.34 is used to supply lighting system in the building as well as for the decorative lighting system on the exterior walls of the Emergency Center. Table 4.5 gives an overview of the low-voltage side of the transformer station "ZTS Emergency Center", as well as cross sections of the used low-voltage cable lines that supply consumers.

Figure 4.33 *Overview of one segment in the low voltage part of "ZTS Urgentni Centar"*

Figure 4.34 *Electrical cabinet for lighting system in the low voltage part of "ZTS Urgentni Centar"*

*Table 4.5 Overview of the available taps at low voltage side of the transformer station "ZTS Urgentni centar"*

| Tap No. | Clinics | Cable type | Current limiters |
|---|---|---|---|
| 1 | Two CT scanners | PP00 4x150 mm$^2$ | 3x400 A |
| 2 | Three X-Ray scanners | | |
| 3 | Lighting system | PP00 4x150 mm$^2$ | 3x400 A |
| 4 | Reserve | PP00 4x95 mm$^2$ | 3x160 A |
| 5 | | | |

## 4.4. Consumption overview in Radiology clinic and Emergency center

The facilities in question have premises for different purposes, containing different types of consumers however some of the biggest consumers that herein are of interest are similar. In this chapter, these common consumers of electric energy are described, with the exception of lighting which in this case was not considered.

One of the most important consumers of electricity, especially in offices and exam rooms, are computers and typical working station equipped with personal computer is shown in Figure 4.35.

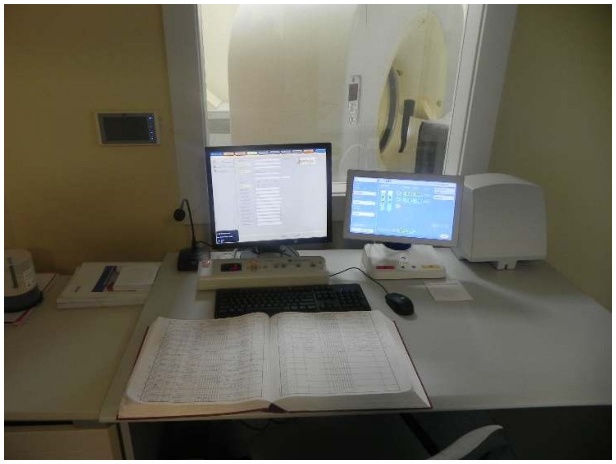

Figure 4.35 *Working station of CT scanner equipped with personal computer*

For cooling, ventilation and temperature control purposes, air conditioners are most commonly used in the premises of both facilities as shown in Figure 4.36. These can be a major consumer of electricity (especially in periods when climatic conditions require longer operation). The capacity of newer air conditioners is 9000 BTU, while for old air conditioners it was not possible to determine the capacity.

Figure 4.36 *Air conditioner used for temperature control*

Most common type of consumer that fall into the category of high power consumers are CT scanners, MRI scanners and X-Ray scanners used for diagnostic purposes in both institutions. In Figure 4.37 one MRI scanner from Radiology clinic is shown while in Figure 4.38 the X-Ray scanner in the same institution is shown. Same equipment is also used in Emergency Center.

Figure 4.37 *MRI scanner used for diagnostic purposes in Radiology clinic*

Figure 4.38 *X-Ray scanner used for diagnostic purposes in Radiology clinic*

Each room that contains said diagnostic equipment is accompanied by a room with oversight and control equipment as shown in figure 4.39.

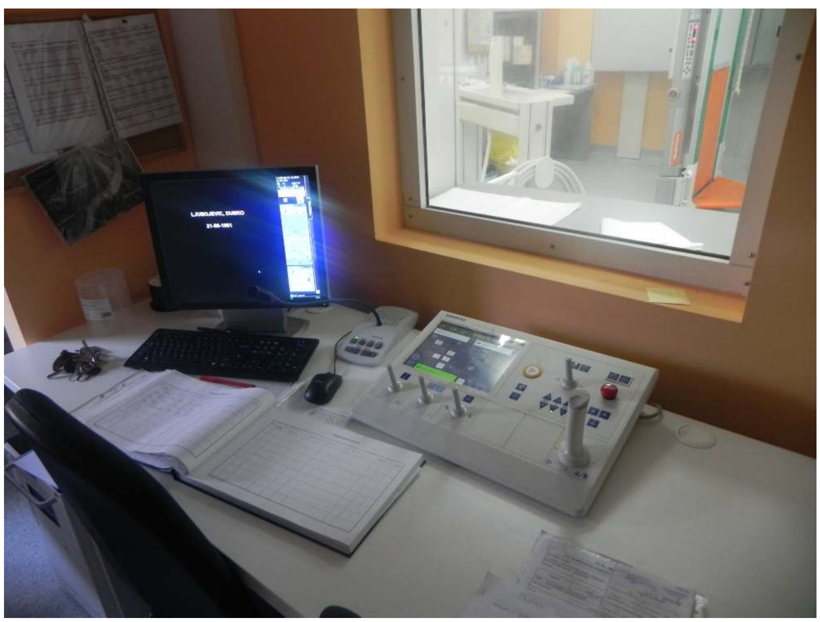

Figure 4.39 *Room with oversight and control equipment for X-Ray scanner*

In figure 4.40 one of the CT scanners used for diagnostic purposes in Emergency Center is shown.

Figure 4.40 *CT scanner used for diagnostic purposes in Emergency Center*

In table 4.6 an overview of the biggest power consumers is shown as well as transformer station from which the particular consumer is supplied.

*Table 4.6 Overview of the biggest consumers in Emergency Center and Radiology clinic*

| Qty. | Consumer type | Power supply | Location | Power rating |
|---|---|---|---|---|
| 2 | CT scanner | ZTS Urgentni Centar | Emergency Center | 65 kVA |
| 3 | X-Ray scanner | | | 100 kVA |
| 1 | CT scanner | TS Kotlarnica | Radiology Clinic | 100 kVA |
| 1 | CT scanner | TS Klinicka bolnica | | 80 kVA |
| 1 | CT scanner | TS Poliklinika | | 100 kVA |
| 1 | MRI scanner | | | 88 kVA |
| 1 | MRI scanner | | | 100 kVA |
| 1 | X-Ray scanner | | | 65 kVA |
| 1 | X-Ray scanner | | | 60 kVA |
| 2 | X-Ray scanner | | | 50 kVA |

Figure 4.41 shows an example of an electricity bill for Emergency Center, for all consumers connected to the substation, with the most important billing parameters. The picture shows that the account is divided into 5 segments. The first segment represents the read values of the meter, where the difference represents the consumption of electricity over a period of one month. The apparent measurement of active electricity in a facility is two-tariff, while for reactive energy it is calculated in a single tariff. The lower

rate is calculated between 00 and 08 o'clock each day, daylight saving time, or from 23 to 07 o'clock in winter time. In the remaining period a higher tariff is charged.

**ЕЛЕКТРОПРИВРЕДА СРБИЈЕ**

ЈП ЕПС Београд
11000 Београд, ул.Балканска 13

ПИБ: 103920327
Матични број: 20053658

**ОБРАЧУН ЗА ЕЛЕКТРИЧНУ ЕНЕРГИЈУ - ЈУН 2018**

Обрачун број: 23436603
Место издавања: Београд
Датум издавања: 17.07.2018
Датум промета и акцизе: 01.07.2018
Датум доспећа: 16.08.2018

Број места мерења: 4012730190
Уговор број: 18.01-334720/205-17 01.10.17-30.09.18

**Приликом уплате на текући рачун 845-484849-65 позвати се на број 26-4012730140-1806 модел 97.**

Категорија: Потрошња на средњем напону
Врста снабдевања: Комерцијално снабдевање
Одобрена снага (kW): 500
Период обрачуна: 02.06.2018 - 01.07.2018

Место мерења: 1410363590
TS "URGENTNI CENTAR"
HAJDUK VELJKOVA 1-9
21101 NOVI SAD

ПИБ: 101696893
МБ: 08664161
4010059348
KLINIČKI CENTAR VOJVODINE
HAJDUK VELJKOVA 1
NOVI SAD

21101 NOVI SAD

1. ОЧИТАНЕ ВРЕДНОСТИ

| Број бројила | Датум очитавања | Обрач. величина | Стање бројила: Претходно стање ВТ | Претходно стање НТ | Ново стање ВТ | Ново стање НТ | Обрач. константа | Коеф. свођења | Енергија за обрачун ВТ | Енергија за обрачун НТ | Стање макс. | Константа максигр. | Коеф. свођења снаге | Снага (kW) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 147348 | 01.07.2018 | kWh | 2.027,48 | 843,588 | 2.089,719 | 867,231 | 2400 | | 149.374 | 56.743 | 0,204 | 1 | | 489,6 |
| | 01.07.2018 | kVArh | 267,377 | 96,334 | 278,538 | 99,567 | 2400 | | 26.786 | 7.759 | | | | |

2. ОБРАЧУН ЗА ИСПОРУЧЕНУ ЕЛЕКТРИЧНУ ЕНЕРГИЈУ

| Р.бр. | Назив | Јед. мере | Испоручена количина | Јединична цена (EUR) | Ср.курс НБС на дан промета(РСД) | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7=5*6 | 8=4*7 |
| 1 | Активна електрична енергија у ВТ | kWh | 149.374 | | | 5,610000 | 837.988,14 |
| 2 | Активна електрична енергија у НТ | kWh | 56.743 | | | 5,610000 | 318.328,23 |
| | Укупно за испоручену електричну енергију: | | | | | | **1.156.316,37** |

3. ОБРАЧУН ЗА ПРИСТУП СИСТЕМУ ЗА ПРЕНОС/ДИСТРИБУЦИЈУ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ    Реактивна енергија за cosΦ(0.95) = 67.751

| Р.бр. | Назив тарифе | Обрачунска величина | Количина за обрачун | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Одобрена снага | kW | 500 | 93,0270 | 46.513,50 |
| 2 | Виша дневна тарифа за активну енергију | kWh | 149.374 | 0,9710 | 145.042,15 |
| 3 | Нижа дневна тарифа за активну енергију | kWh | 56.743 | 0,3240 | 18.384,73 |
| 4 | Реактивна енергија | kVArh | 34.546 | 0,4540 | 15.683,88 |
| 5 | Прекомерна реактивна енергија | kVArh | 0 | 0,9070 | 0,00 |
| 6 | Прекомерна снага | kW | 0 | 372,1100 | 0,00 |
| | Укупно за приступ систему за дистрибуцију електричне енергије: | | | | **225.624,26** |

4. ОБРАЧУН НАКНАДЕ ЗА ПОДСТИЦАЈ ПОВЛАШЋЕНИХ ПРОИЗВОЂАЧА ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ

| Р.бр. | Назив тарифе | Обрачунска величина | Количина за обрачун | Јединична цена (РСД) | Укупно (РСД) |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6=4*5 |
| 1 | Накнада за подстицај повлашћених произвођача ел. енергије (Службени гласник РС бр.7 од 23.01.2015.године) | kWh | 206.117 | 0,093 | 19.168,88 |
| | Укупно накнаде за подстицај повлашћених произвођача електричне енергије: | | | | **19.168,88** |

5. РЕКАПИТУЛАЦИЈА ОБРАЧУНА

| | | |
|---|---|---|
| 1 | Испоручена електрична енергија | 1.156.316,37 |
| 2 | Приступ систему за пренос/дистрибуцију електричне енергије | 225.624,26 |
| 3 | Накнада за подстицај повлашћених произвођача ел.енергије | 19.168,88 |
| 4 | Основица за обрачун акцизе (4=1+2+3) | 1.401.109,51 |
| 5 | Износ обрачунате акцизе (стопа 7,5%) (5=4*0.075) | 105.083,21 |
| 6 | Основица за ПДВ (6=4+5) | 1.506.192,72 |
| 7 | Порез на додату вредност 20% (7=6*0.20) | 301.238,54 |
| 8 | Такса за јавни медијски сервис | 0,00 |
| 9 | Укупно за обрачун (9=6+7+8) | **1.807.431,26** |

Figure 4.41 *Example of electricity bill for Emergency Center*

Based on electric bills for “TS Poliklinika”, “ZTS Urgentni Centar” and “TS Kotlarnica”, tables 4.7-4.9 showing the consumption for different months are generated. To obtain

more general sense of the power consumption the results from the presented tables, are represented graphically in Figures 4.42-4.44.

*Table 4.7 Overview of electric power consumption in "TS Poliklinika"*

| | Consumption High tariff [kWh] | Consumption Low tariff [kWh] | Total consumption [kWh] | Total for electric energy [RSD] | Total tax-free debt [RSD] | Total charges [RSD] |
|---|---|---|---|---|---|---|
| **Jan 2018** | 229,975.00 | 70,301.00 | 300,276.00 | 1,684,548.36 | 2,250,089.67 | 2,700,107.60 |
| **Feb. 2018** | 218,710.00 | 68,515.00 | 287,225.00 | 1,611,332.25 | 2,157,301.99 | 2,588,762.39 |
| **Mar. 2018** | 238,349.00 | 70,356.00 | 308,705.00 | 1,731,835.05 | 2,313,307.58 | 2,775,969.10 |
| **Apr. 2018** | 173,471.00 | 54,821.00 | 228,292.00 | 1,282,232.82 | 1,738,399.61 | 2,086,079.53 |
| **May 2018** | 192,077.00 | 56,549.00 | 248,626.00 | 1,394,791.86 | 1,885,167.12 | 2,262,200.54 |
| **Jun 2018** | 215,227.00 | 59,813.00 | 275,040.00 | 1,542,974.40 | 2,084,026.19 | 2,500,831.43 |
| **July 2018** | 202,870.00 | 56,698.00 | 259,568.00 | 1,456,176.48 | 1,964,369.19 | 2,357,243.03 |
| **Avg. 2019** | 238,634.00 | 66,497.00 | 305,131.00 | 1,711,784.91 | 2,287,014.91 | 2,744,417.89 |
| **Sept. 2018** | 179,693.00 | 52,716.00 | 232,409.00 | 1,303,814.49 | 1,766,701.40 | 2,120,041.68 |
| **Oct. 2018** | 164,290.00 | 54,298.00 | 218,588.00 | 1,477,654.88 | 1,939,753.60 | 2,327,704.32 |
| **Nov. 2018** | 170,410.00 | 58,039.00 | 228,449.00 | 1,544,315.24 | 2,021,006.37 | 2,425,207.64 |
| **Dec. 2018** | 194,741.00 | 61,483.00 | 256,224.00 | 1,732,074.24 | 2,252,857.57 | 2,703,429.08 |
| **Total** | ***2,418,447.00*** | ***730,086.00*** | ***3,148,533.00*** | ***18,473,534.98*** | ***24,659,995.20*** | ***29,591,994.24*** |

*Table 4.8 Overview of electric power consumption in "ZTS Urgentni Centar"*

| | Consumption High tariff [kWh] | Consumption Low tariff [kWh] | Total consumption [kWh] | Total for electric energy [RSD] | Total tax-free debt [RSD] | Total charges [RSD] |
|---|---|---|---|---|---|---|
| **Jan 2018** | 102,960.00 | 45,900.00 | 148,860.00 | 835,104.60 | 1,090,670.06 | 1,308,804.07 |
| **Feb. 2018** | 97,224.00 | 43,622.00 | 140,846.00 | 790,146.06 | 1,034,370.12 | 1,241,244.14 |
| **Mar. 2018** | 106,116.00 | 47,357.00 | 153,473.00 | 860,983.53 | 1,123,296.58 | 1,347,955.90 |
| **Apr. 2018** | 115,927.00 | 44,119.00 | 160,046.00 | 897,858.06 | 1,178,044.81 | 1,413,653.77 |
| **May 2018** | 133,987.00 | 49,519.00 | 183,506.00 | 1,029,468.66 | 1,351,913.47 | 1,622,296.16 |
| **Jun 2018** | 149,374.00 | 56,743.00 | 206,117.00 | 1,156,316.37 | 1,506,192.72 | 1,807,431.26 |
| **July 2018** | 161,290.00 | 62,762.00 | 224,052.00 | 1,256,931.72 | 1,638,179.60 | 1,965,815.52 |
| **Avg. 2019** | 182,990.00 | 69,972.00 | 252,962.00 | 1,419,116.82 | 1,850,296.25 | 2,220,355.50 |
| **Sept. 2018** | 146,758.00 | 56,722.00 | 203,480.00 | 141,522.80 | 1,497,333.10 | 1,796,799.72 |
| **Oct. 2018** | 143,767.00 | 52,354.00 | 196,121.00 | 1,325,777.96 | 1,685,002.29 | 2,022,002.75 |
| **Nov. 2018** | 138,242.00 | 55,807.00 | 194,049.00 | 1,311,771.24 | 1,658,180.68 | 1,989,816.82 |
| **Dec. 2018** | 147,312.00 | 63,696.00 | 211,008.00 | 1,426,414.08 | 1,793,028.34 | 2,151,634.01 |
| **Total** | ***1,625,947.00*** | ***648,573.00*** | ***2,274,520.00*** | ***12,451,411.90*** | ***17,406,508.02*** | ***20,887,809.62*** |

Table 4.9 *Overview of electric power consumption in "TS Kotlarnica"*

| | Consumption High tariff [kWh] | Consumption Low tariff [kWh] | Total consumption [kWh] | Total for electric energy [RSD] | Total tax-free debt [RSD] | Total charges [RSD] |
|---|---|---|---|---|---|---|
| **Jan 2018** | 20,095.00 | 8,278.00 | 28,373.00 | 159,172.53 | 252,608.85 | 303,130.62 |
| **Feb. 2018** | 18,745.00 | 7,570.00 | 26,315.00 | 147,627.15 | 237,372.38 | 284,846.86 |
| **Mar. 2018** | 17,558.00 | 6,780.00 | 24,338.00 | 136,536.18 | 223,516.06 | 268,219.27 |
| **Apr. 2018** | 11,004.00 | 4,154.00 | 15,158.00 | 85,036.38 | 159,820.76 | 191,784.91 |
| **May 2018** | 8,602.00 | 2,772.00 | 11,374.00 | 63,808.14 | 133,821.48 | 160,585.78 |
| **Jun 2018** | 30,743.00 | 4,652.00 | 35,395.00 | 198,509.85 | 313,899.95 | 376,679.94 |
| **July 2018** | 37,246.00 | 4,478.00 | 41,724.00 | 234,071.64 | 362,589.33 | 435,107.20 |
| **Avg. 2019** | 46,194.00 | 5,144.00 | 51,338.00 | 288,006.18 | 433,877.88 | 520,653.46 |
| **Sept. 2018** | 21,074.00 | 2,831.00 | 23,905.00 | 134,107.05 | 227,988.26 | 273,585.91 |
| **Oct. 2018** | 14,893.00 | 5,008.00 | 19,901.00 | 134,530.76 | 218,300.31 | 261,960.37 |
| **Nov. 2018** | 15,514.00 | 5,389.00 | 20,903.00 | 141,304.00 | 226,347.10 | 271,616.52 |
| **Dec. 2018** | 20,249.00 | 7,447.00 | 27,696.00 | 187,224.96 | 283,492.08 | 340,190.50 |
| **Total** | **261,917.00** | **64,503.00** | **326,420.00** | **1,909,934.82** | **3,073,634.44** | **3,688,361.33** |

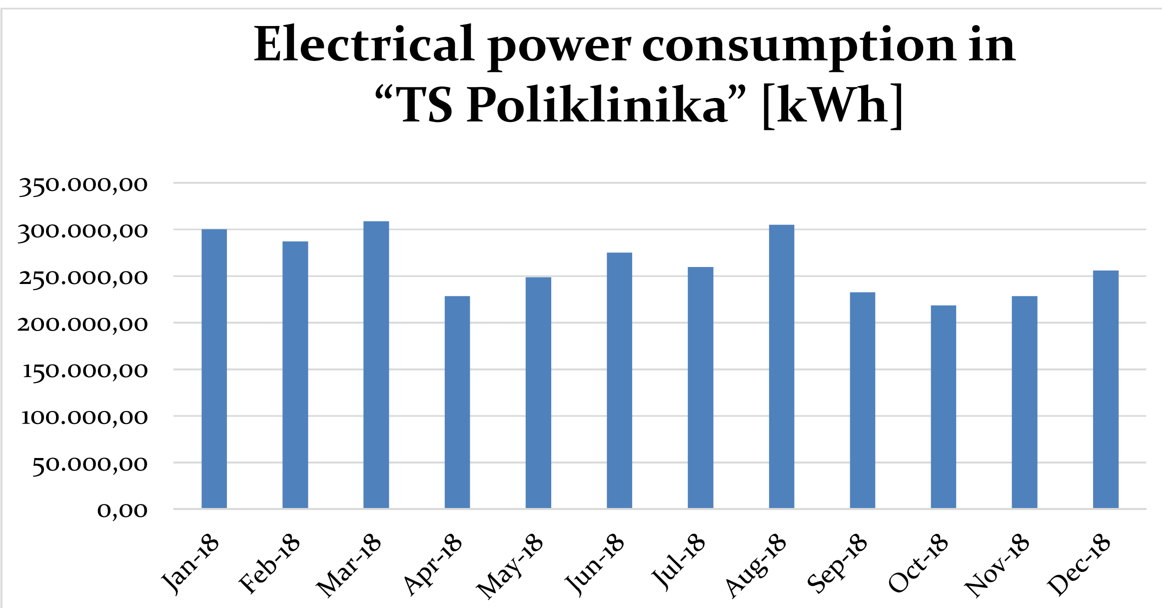


Figure 4.42 *Electric power consumption in "TS Poliklinika" in 2018*

From Figure 4.42 it can be inferred that during year electric energy consumption from "TS Poliklinika" is fairly constant with maximum consumption of around 300 MWh in January, March and August, and minimal consumption around 210 MWh in October.

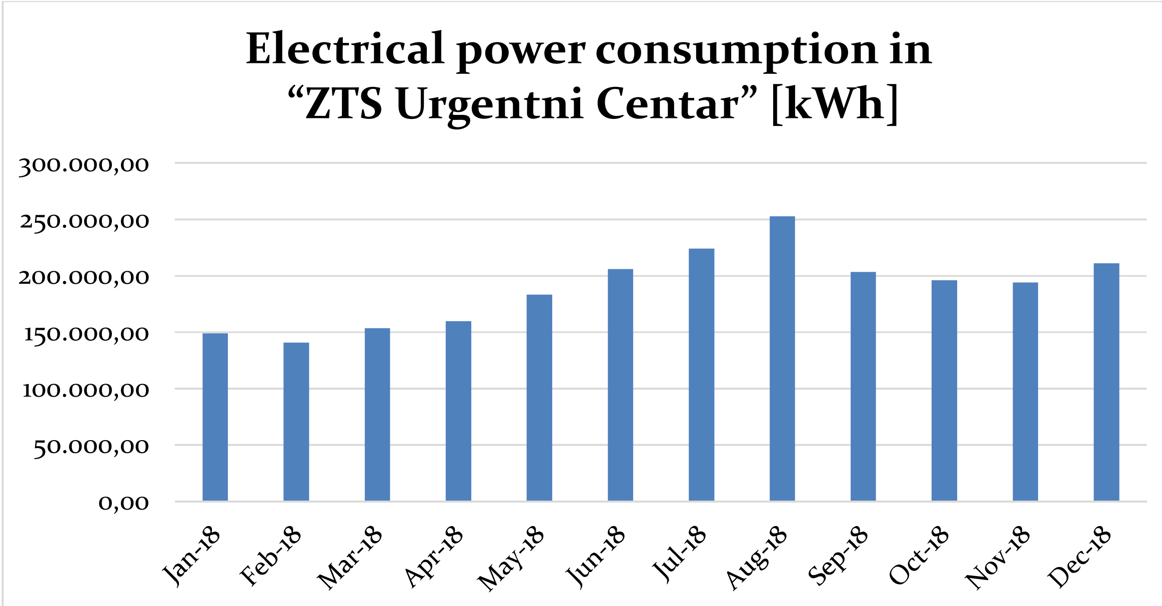


Figure 4.43 *Electric power consumption in "ZTS Urgentni Centar" in 2018*

From Figure 4.43 it can be inferred that during year electric energy consumption from "ZTS Urgentni Centar" is varies slightly with maximum consumption of around 250 MWh in August and minimal consumption around 149 MWh in February.

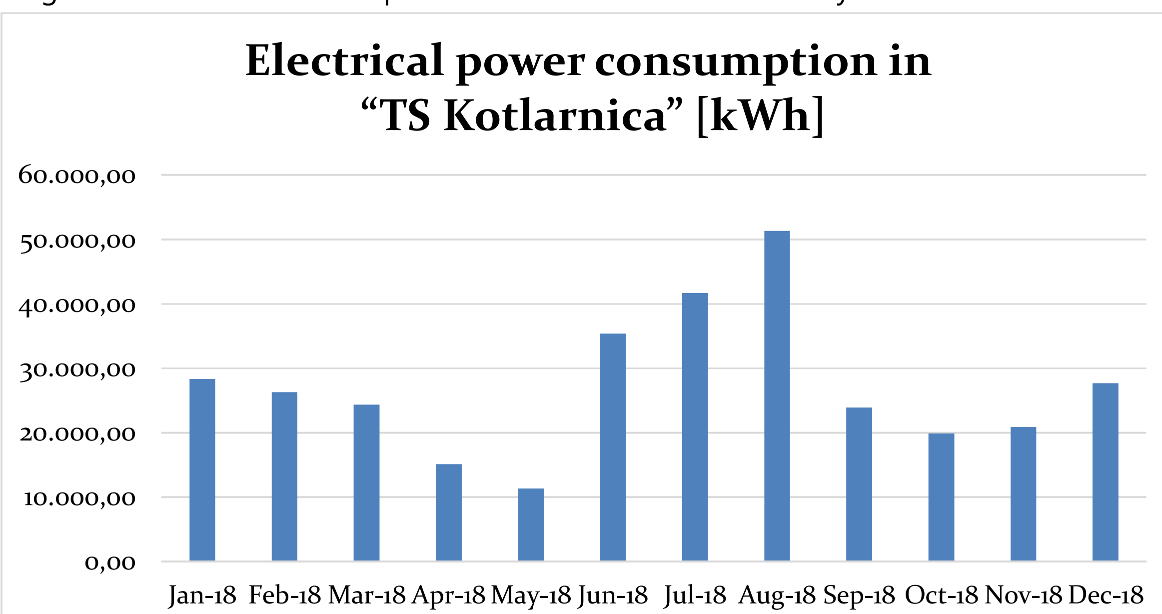


Figure 4.44 *Electric power consumption in "TS Kotlarnica" in 2018*

From Figure 4.44 it can be inferred that during year electric energy consumption from "TS Kotlarnica" is varies noticeably with maximum consumption of around 51 MWh in August and minimal consumption around 11 MWh in April.

## 4.5. Overview of the thermal energy infrastructure with the consumption analysis

Until September 2019, the thermal energy infrastructure of the Medical Rehabilitation Clinic was connected to its own boiler room, which used fuel oil to heat the facility. Figure 4.45 shows the layout of the own boiler room of the Clinical Center of Vojvodina. In addition to rehabilitation, the boiler room is also used to heat other facilities within the clinical center.

Figure 4.45 *Layout of the Clinical Center of Vojvodina boiler room*

In order to increase reliability and reduce the cost of heating the facility, in September 2019, the Medical Rehabilitation Clinic was connected to the district heating system of the public utility company Novosadska Toplana. Natural gas is used as the main energy source for heat production, and the energy supplied is charged per kWh. The layout of the thermal substations of the object in question (the facility is powered by two substations) is given in Figure 4.46.

Figure 4.46 *Layout of the Medical Rehabilitation Clinic thermal substations*

Inside the building, radiator-type heating devices are used for heat transfer and space heating, which are usually located below the windows. A visit to the Medical Rehabilitation Clinic facility concluded that the facility was heated using two types of radiators - cast and

panel radiators. Cast radiators (Figure 4.47.a) vary in dimensions in height and length. The variation in the length of the structure is the result of a different number of pipes, i.e. ribs (which are welded one after the other regularly). At the Medical Rehabilitation Clinic, radiators have between 8 and 30 ribs, depending on the space in which they are installed.

Panel radiators (Figure 4.47.b) belong to flat plate radiators, but they are made of smooth or profiled sheet steel, which in the simplest form has a heating plate through which the heating fluid (hot water) passes. Panel radiators are newer type and are installed in the hydrotherapy space.

a)  b) 

Figure 4.47 *Layout of a cast (a) and a panel (b) radiator*

Table 4.10 shows the number of radiators used by room type, as well as the type of radiator present in the object in question. Also shown is the total number of radiators used within the facility of the Medical Rehabilitation Clinic.

*Table 4.10 Number of heaters by type and premises*

| **Radiator type** | **Premises** | **Number of pieces** |
|---|---|---|
| Cast | Examine rooms | **26** |
| Cast | Offices | **26** |
| Cast | Therapy rooms | **30** |
| Cast | Hospital rooms | **35** |
| Cast | Corridors | **32** |
| Cast | Toilets | **27** |
| Panel | Hydrotherapy | **6** |
| Cast | Storage rooms | **32** |
| | | |
| **Total** | Cast | **208** |
| | Panel | **6** |
| **Total** | | **214** |

## 4.5.2. Thermal energy consumption analysis

To adequately review the thermal energy consumption of the Medical Rehabilitation Clinic facility, an analysis of the fuel oil consumption was conducted for the period from September 2018 to August 2019. This period includes both the heating season and the off-season. At the time of drafting this document, the said facility was connected to the district heating system of JKP "Novosadska Toplana", and there was no information on the consumption of thermal energy supplied by the heating plant. For this reason, fuel oil consumption was analyzed.

Figures 4.48-4.50, show a single fuel oil bill, consisting of three pages. First, Figure 4.48 consists of two segments. The first segment contains data on the energy supplier, as well as data on the user of the service or the consumer. In the second segment, characteristic data are presented such as: name of the energy product, quantity, unit price expressed in dinars per kilogram (RSD / kg), as well as the total price of delivered energy product in dinars (RSD).

On the other side, Figure 4.49 shows the product declaration issued by company “NIS”, and on the third page, Figure 4.50 the energy test report is displayed. The report presents data on density, sulfur content, ignition point, lower heat value, etc. It is important to note that this is the supply of fuel oil to the Clinic Center boiler room, from which more KCV facilities are supplied with heat.

Table 4.11 shows the fuel oil consumption of the entire boiler room from September 2018 to August 2019.

*Table 4.11 Total fuel oil consumption of boiler room KCV*

| Month | Delivered fuel oil [kg] | Total [RSD] |
|---|---|---|
| **September 2018** | 75.000,00 | 5.532.300,00 |
| **October 2018** | 101.160,00 | 7.848.228,24 |
| **November 2018** | 150.440,00 | 11.605.161,60 |
| **December 2018** | 225.440,00 | 15.749.612,16 |
| **January 2019** | 198.820,00 | 13.195.781,04 |
| **February 2019** | 251.360,00 | 17.602.124,88 |
| **Mart 2019** | 125.280,00 | 9.065.260,80 |
| **April 2019** | 147.480,00 | 10.831.689,84 |
| **Maj 2019** | 99.940,00 | 7.358.632,80 |
| **Jun 2019** | 75.040,00 | 5.397.301,20 |
| **July 2019** | 99.720,00 | 7.158.979,68 |
| **August 2019** | 99.220,00 | 6.910.033,20 |
| **Total** | **1.648.900,00** | **118.255.105,44** |

EURO MOTUS DOO
PREDUZEĆE ZA TRGOVINU, PROMET I USLUGE
Dubrovačka 14/4, 11080 Beograd-Zemun, Srbija
tel: 011/31-222-55 fax: 011/31-222-44

PIB: SR101723687, matični broj: 17204637, šifra delatnosti: 4671, tekući računi: OTP banka: 325-9500700034364-20, Procredit banka: 220-0000000130576-50, Sberbank: 285-1001000000718-96

Kupac:
KLINIČKI CENTAR VOJVODINE
KLINIČKI CENTAR VOJVODINE
HAJDUK VELJKOVA 1
21000 Novi Sad
PIB 101696893

**Komercijalista:**
**Interni broj:** 190017
**Datum prometa dobara i usluga** 02.01.2019
**Mesto izdavanja računa:** Beograd
**Po otpremnicama:** VZ190017

**Po tenderu**
**Naš zavodni broj: 787/2018 od dana 20.9.2018**
**Vaš zavodni broj: 3/2102 od dana 17.9.2018**

Република Србија
Аутономна Покрајина Војводина
КЛИНИЧКИ ЦЕНТАР ВОЈВОДИНЕ
НОВИ САД
Примљено: 10 JAN 2019
Орг. јед. X | Број 92/1

**Datum:** 02.01.2019
**DPO:** 02.01.2019
**Valuta:** 03.03.2019

## Račun 190017

1

| Ident | Naziv | Količina | JM | Cena | Iznos | R. % | PDV % | Iznos PDV | Uk. sa PDV |
|---|---|---|---|---|---|---|---|---|---|
| 1006 | ULJE ZA LOŽ.NISKOSUM.GORIVO-MAZUT NSGS<br>Prevoz na relaciji Pančevo-Novi Sad | 24.960,000 | KG | 54,80 | 1.367.808,00 | 0,00 | 20,00 | 273.561,60 | 1.641.369,60 |

**Slovima** milionšeststočetrdesetijedanhiljadatristošezdesetidevet RSD 60/100

| | |
|---|---|
| **Ukupno** | **1.367.808,00** |
| **PDV** | **273.561,60** |
| **Za plaćanje RSD** | **1.641.369,60** |

2

| PORESKE STOPE | Osnova | PDV | Vrednost |
|---|---|---|---|
| Promet proizvoda po opštoj stopi 20% | 1.367.808,00 | 273.561,60 | 1.641.369,60 |

U CENU ROBE URAČUNATA JE I CENA PREVOZA

**Ukupan iznos obračunate akcize: 0,00**

**Akciza uračunata u cenu akciznih dobara**

**Uplatu izvršiti na tekući račun: 340-11014945-85**

**Molimo Vas da se prilikom plaćanja pozovete na broj: 19-300-000010**

ZA NEBLAGOVREMENO PLAĆANJE OBRAČUNAVA SE ZATEZNA KAMATA
ZA SVE EVENTUALNE SPOROVE NADLEŽAN JE PRIVREDNI SUD U BEOGRADU

za EURO MOTUS DOO

KVALITET SRPS ISO 9001 13025 · GLOBALSERT ISO 14001:2015 EMS - 08/17 · GLOBALSERT OHSAS 18001 OH&S - 08/17

**Strana** 1/1

Figure 4.48 *Example of the bill for delivered fuel oil – first page*

| НИС ГАЗПРОМ НЕФТ | НИС а.д. Нови Сад, Блок Прерада<br>Дирекција Производња<br>Сектор Манипулација<br>Декларација о усаглашености производа | Број: 8862<br>Датум: 28.12.2018<br>Време: 10:09 |
|---|---|---|

| | |
|---|---|
| Произвођач | НИС а.д. Нови Сад, Блок Прерада |
| Назив производа | **Ulje za loženje NSG-S** |
| Назив класе производа | |
| Ознака резервоара | **M-FB-1022** |
| Количина,t | **5116,648** |
| Назив државе у којој је производ произведен | Република Србија |

**ВРЕДНОВАНА ДОКУМЕНТА**

*1. Извештај о испитивању*

| Број: | Датум: | Време: | Издавалац |
|---|---|---|---|
| **557534** | **26.12.2018** | **01:55** | НТЦ НИС-Нафтагас д.о.о. Нови Сад<br>Дирекција Лабораторија downstream |

*2. Технички пропис*

**На основу горе наведене документације утврђено је да производ**

**ЗАДОВОЉАВА** захтеве према (*):

| | |
|---|---|
| [] Правилник о техничким и другим захтевима за течни нафтни гас (Сл. Гласник РС бр. 97/10 од 21.12.2010), Правилник о измени Правилника о техничким и другим захтевима за течни нафтни гас (Сл. Гласник РС бр.123/2012 од 28.12.2012) и Правилник о изменама и допунама правилника о техничким и другим захтевима за ТНГ (Сл. Гласник РС бр.63/2013 од 19.07.2013) | [X] Правилник о техничким и другим захтевима за течна горива нафтног порекла (Сл. Гласник РС бр. 111/2015, 106/2016, 60/2017, 117/2017, 120/2017-испр. и 50/2018) |

*3. Подаци о примењеним стандардима*

**SP-03.03.01-006**

Прилог: Извештај о испитивању

(*) Попунити одговарајуће поље знаком (×)

Место издавања:

Потпис овлашћеног лица:

**Dragan Jovanović**

Figure 4.49 *Example of the bill for delivered fuel oil – second page*

NTC NIS-Naftagas d.o.o. Novi Sad
Departman laboratorije downstream
Spoljnostarčevačka 199, 26000 Pančevo, tel/fax: 013/347-568

ATC 01-372
АКРЕДИТОВАНА ЛАБОРАТОРИЈА ЗА ИСПИТИВАЊЕ
SRPS ISO/IEC 17025:2006

Strana 1/1

0 000005 575343

Naručilac NIS a.d. Novi Sad-Blok Prerada-Direkcija proizvodnja-Manipulacija

**IZVEŠTAJ O ISPITIVANJU Br : 557534**

Preuzeo izveštaj: Naručilac ispitivanja

Datum početka ispitivanja: 25.12.2018
Datum završetka ispitivanja: 26.12.2018 01:55

Poreklo uzorka: **M-FB-1022**
Metoda uzorkovanja: SRPS EN ISO 3170:2008
Uzorkivač: Mirko Milenković, Uzorkivač
Datum uzorkovanja: 25.12.2018 15:40

Supstanca: **Ulje za loženje NSG-S SP-03.03.01-006**
Uzorak: U-FB-1022
Prijem: 25.12.2018 16:20
Komentar:

0 000011 745037

| | Svojstvo | Jedinica mere | Metoda | Vrednost | min | max | Merna nesigurnost | Komentar |
|---|---|---|---|---|---|---|---|---|
| 1 | Gustina na 15°C | kg/m³ | SRPS EN ISO 3675:2007 | 945.3 | | | ±0.47 | |
| 2 | Sadržaj sumpora | %(m/m) | SRPS EN ISO 8754:2007 | 0.94 | | 1.00 | ±0.059 | |
| 3 | Tačka paljenja (Pensky-Martens) | °C | SRPS EN ISO 2719:2017 | 146 | 80 | | ±4.4 | |
| 4 | Kinematička viskoznost na 100 °C | mm²/s | SRPS ISO 3104:2003 | 33.01 | 10.00 | 35.00 | ±0.363 | |
| 5 | Tačka tečenja | °C | SRPS ISO 3016:1997 | +12 | | | ±3 | |
| 6 | Sadržaj vode i taloga | %(V/V) | SRPS ISO 3734:2011 | 0.10 | | 1.00 | ±0.023 | |
| 7 | Sadržaj pepela | %(m/m) | SRPS EN ISO 6245:2008 | 0.02 | | 0.15 | ±0.001 | |
| 8 | Ugljenični ostatak | %(m/m) | SRPS EN ISO 10370:2016 | 10.61 | | 12.00 | ±0.292 | |
| 9 | Donja toplotna vrednost | MJ/kg | Računski 1) | 41.37 | 40.50 | | ±0.124 | |

- Merna nesigurnost se prikazuje na zahtev naručioca ispitivanja.

Verifikovao:
Valentina Obradović, Tehničar elektrometrije i sumpora

Odobrio:
Ranko Božić, Smenski rukovodilac laboratorije

Dostavljeno:
-Arhiva Laboratorija

- Rezultati ispitivanja odnose se isključivo na uzorke koji su ispitani
- Zabranjeno je kopiranje i umnožavanje izveštaja, izuzev u celini, bez odobrenja Laboratorije
SA-50.04.01-029, верзија 03.1

BR: 557534
28.12.2018 10:09:43

Figure 4.50 *Example of the bill for delivered fuel oil – third page*

Table 4.12 shows the total consumption of fuel oil by months between September 2018 and August 2019 for the entire boiler room of the Clinical Center. In cooperation with the KCV technical service, the calculation of fuel oil estimates for the facility in question was made. Table 4.13 shows the total energy consumption of heating oil for the period from September 2018 to August 2019, obtained by calculation.

*Table 4.12 Total fuel oil consumption for the KCV*

| Month | Amount of fuel oil consumed [kg] | Total [RSD] |
|---|---|---|
| **September 2018** | 10.591,00 | 781.234,52 |
| **October 2018** | 15.299,00 | 1.186.896,42 |
| **November 2018** | 18.325,00 | 1.413.737,10 |
| **December 2018** | 26.269,00 | 1.835.257,42 |
| **January 2019** | 27.039,00 | 1.794.956,98 |
| **February 2019** | 22.810,00 | 1.597.429,92 |
| **Mart 2019** | 20.369,00 | 1.473.900,84 |
| **April 2019** | 15.014,00 | 1.102.628,16 |
| **Maj 2019** | 13.598,00 | 1.001.247,94 |
| **Jun 2019** | 11.177,00 | 803.939,26 |
| **Jul 2019** | 11.362,00 | 815.609,81 |
| **August 2019** | 11.419,00 | 795.173,48 |
| **Total** | **203.272,00** | **14.602.011,84** |

A visual representation (graph) of the heating energy consumption - fuel oil is given in Figure 4.51, where it can be seen that fuel oil consumption varies over months. It is easy to see that during the winter months the consumption is the highest, during the heating season, while in the other months the consumption is lower, because then the thermal energy is used only to heat the space of the hydrotherapy pool. Graphs show that the highest spending was recorded in January 2019, while in September 2018 it was the lowest. Monthly consumption is also influenced by the amount of fuel oil from the previous month. Therefore, in some months a smaller amount of fuel oil was purchased due to the stocks remaining from the previous month.

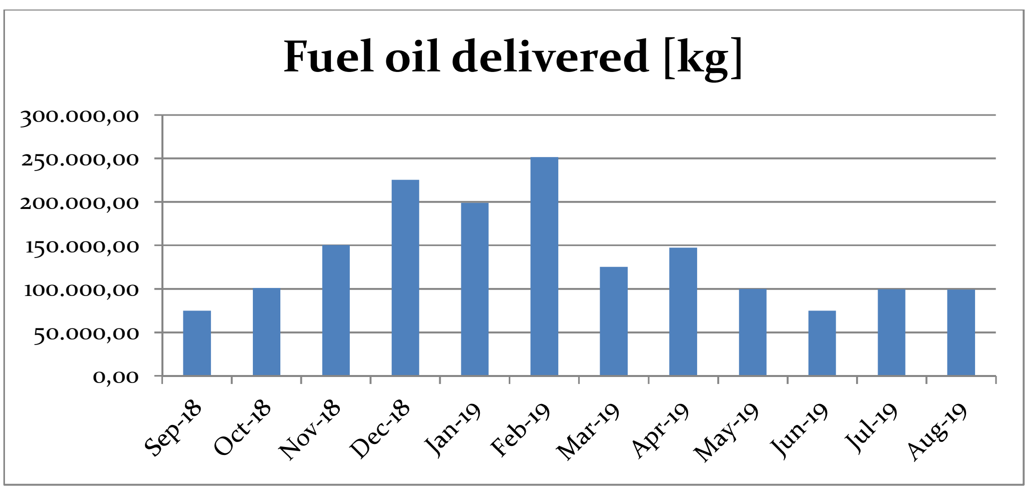


Figure 4.51 *Fuel oil consumption graph*

Since energy from the boiler room was used to heat the building, there is no cost for the approved power and for the access to the system. It is also important to note that the costs of maintaining boiler room and storing fuel oil have not been considered.

Table 4.13 provides an overview of the thermal energy consumption of the Medical Rehabilitation Clinic facility. The values shown are obtained by analyzing the fuel oil consumption for the facility and analyzing the fuel oil test report that is an integral part of the bill, Figure 4.50. The report is issued by the accredited laboratory of NIS naftagas NTC Pancevo. For the analysis of the fuel value of the fuel oil, the relevant data taken from the report is the lower thermal value of the fuel oil, which in this case is 41.37 MJ / kg. based on this value and the calculation of fuel oil consumption, the value of thermal energy consumption per month is expressed in kWh.

*Table 4.13 Consumption of thermal energy for the object in question*

| Month | Total amount of the fuel oil [kg] | Thermal energy consumption [kWh] | Total [RSD] |
|---|---|---|---|
| **September 2018** | 10.591,00 | 121.708,24 | 781.234,52 |
| **October 2018** | 15.299,00 | 175.811,01 | 1.186.896,42 |
| **November 2018** | 18.325,00 | 210.584,79 | 1.413.737,10 |
| **December 2018** | 26.269,00 | 301.874,59 | 1.835.257,42 |
| **January 2019** | 27.039,00 | 310.723,18 | 1.794.956,98 |
| **February 2019** | 22.810,00 | 262.124,92 | 1.597.429,92 |
| **Mart 2019** | 20.369,00 | 234.073,76 | 1.473.900,84 |
| **April 2019** | 15.014,00 | 172.535,88 | 1.102.628,16 |
| **Maj 2019** | 13.598,00 | 156.263,68 | 1.001.247,94 |
| **Jun 2019** | 11.177,00 | 128.442,36 | 803.939,26 |
| **Jul 2019** | 11.362,00 | 130.568,32 | 815.609,81 |
| **August 2019** | 11.419,00 | 131.223,34 | 795.173,48 |
| **Total** | **203.272,00** | **2.335.934,07** | **14.602.011,84** |

A visual representation (graph) of the thermal energy consumption is given in Figure 4.52 where it can be seen that the highest consumption is during the heating season, while in other months the consumption is approximately constant.

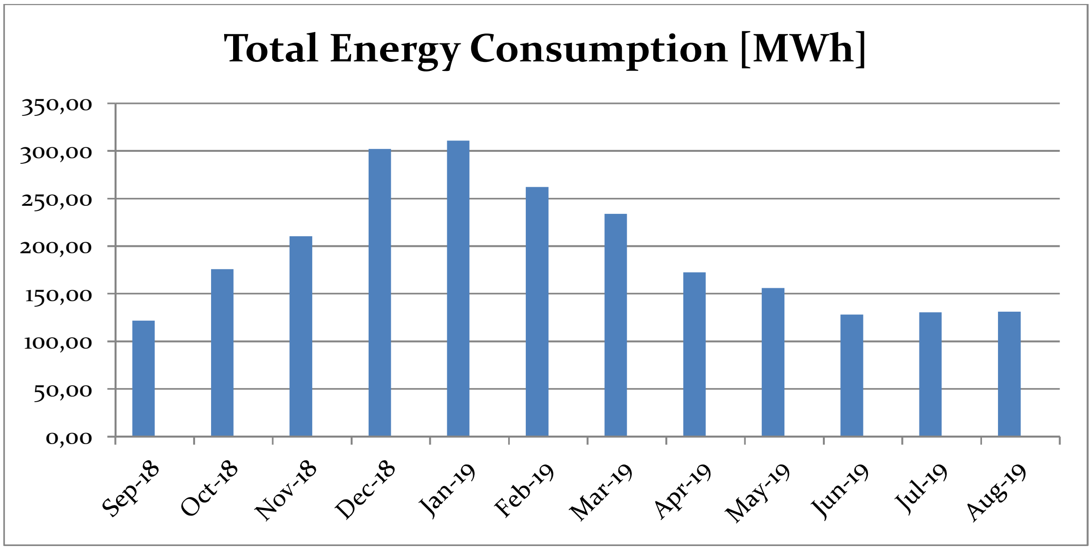


Figure 4.52 *Graph of the thermal energy consumption of the object in question*

# 5. The overview of the potential for the available renewable energy resources

The Republic of Serbia has significant RES potential, which is estimated at 5.65 Mtoe per year. More than 60% of the total potential is biogas potential, whose use is estimated at approximately 30% (1.54 Mtoe), while hydropower has a share of 30% and more than half is utilized (909 ktoe) [19]. In order to achieve the mandatory national targets for the share of renewable energy in gross final consumption, the installation of higher electricity production using wind, biomass and sun are envisaged, as well as a higher RES share in heat production. The projection of the construction of plants for electricity generation using RES until 2030 is presented in the following figure.

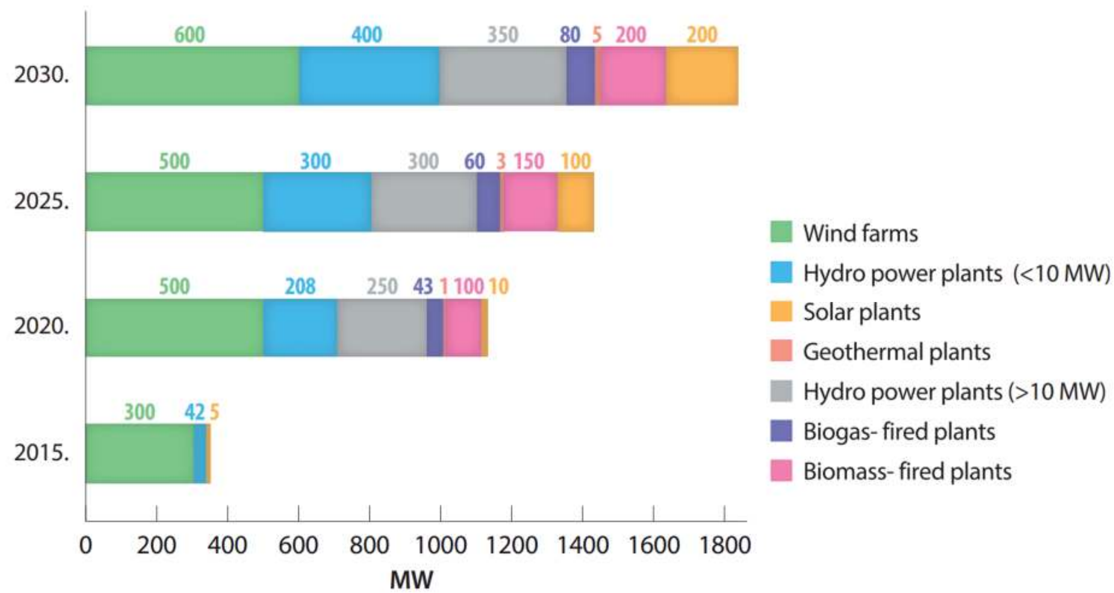


Figure 5.1 *The projection of the construction of plants for electricity generation using RES until 2030 [19].*

According to the Energy Balance of the Republic of Serbia for 2019, the total planned production of primary energy from RES in 2019 is 1.997 Mtoe, accounting for 18.9% of the total domestic production. The estimated participation of individual RES is shown in the following figure. It can be observed that wind energy accounts for 5%, while solar and geothermal energy accounts for only 1%, which is extremely small given their estimated potential [20].

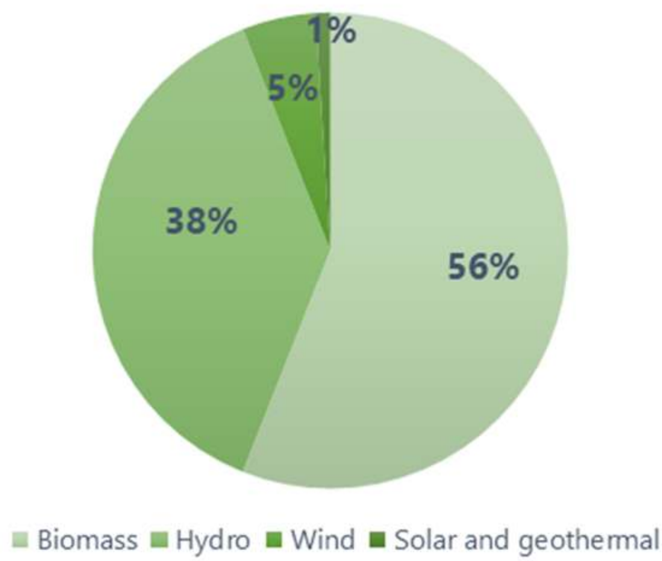


Figure 5.2 *The total planned production of primary energy from individual RES for 2019.*

## 5.2. Potential of the solar energy

Solar energy can be used to generate electricity or heat energy. The average annual global solar radiation in the Republic of Serbia is 30% higher than in Western European countries. In most parts, the number of hours of solar radiation is between 1500 and 2200 hours per year, which is higher than the most European countries [21].

According to calculations of the scientific tool Photovoltaic Geographical Information System (PVGIS) for the EU member states and other European countries, the average value of global horizontal irradiation of the Republic of Serbia is approximately 1353 kWh/m$^2$. The minimum average value of the global horizontal irradiation is 1042 kWh/m$^2$, while the maximum is 1660 kWh/m$^2$ [22]. Global irradiation and solar electricity potential for the horizontally mounted photovoltaic modules is given in the Figure 5.3.


Figure 5.3 *Global irradiation and solar electricity potential of the Republic of Serbia [22].*

Global irradiation and solar electricity potential for the optimally-inclined photovoltaic modules of the Republic of Serbia are shown in the Figure 5.4. The average value of global irradiation is approximately 1531 kWh/m$^2$, where the minimum average value is 1190 kWh/m$^2$, while the maximum is 1925 kWh/m$^2$.

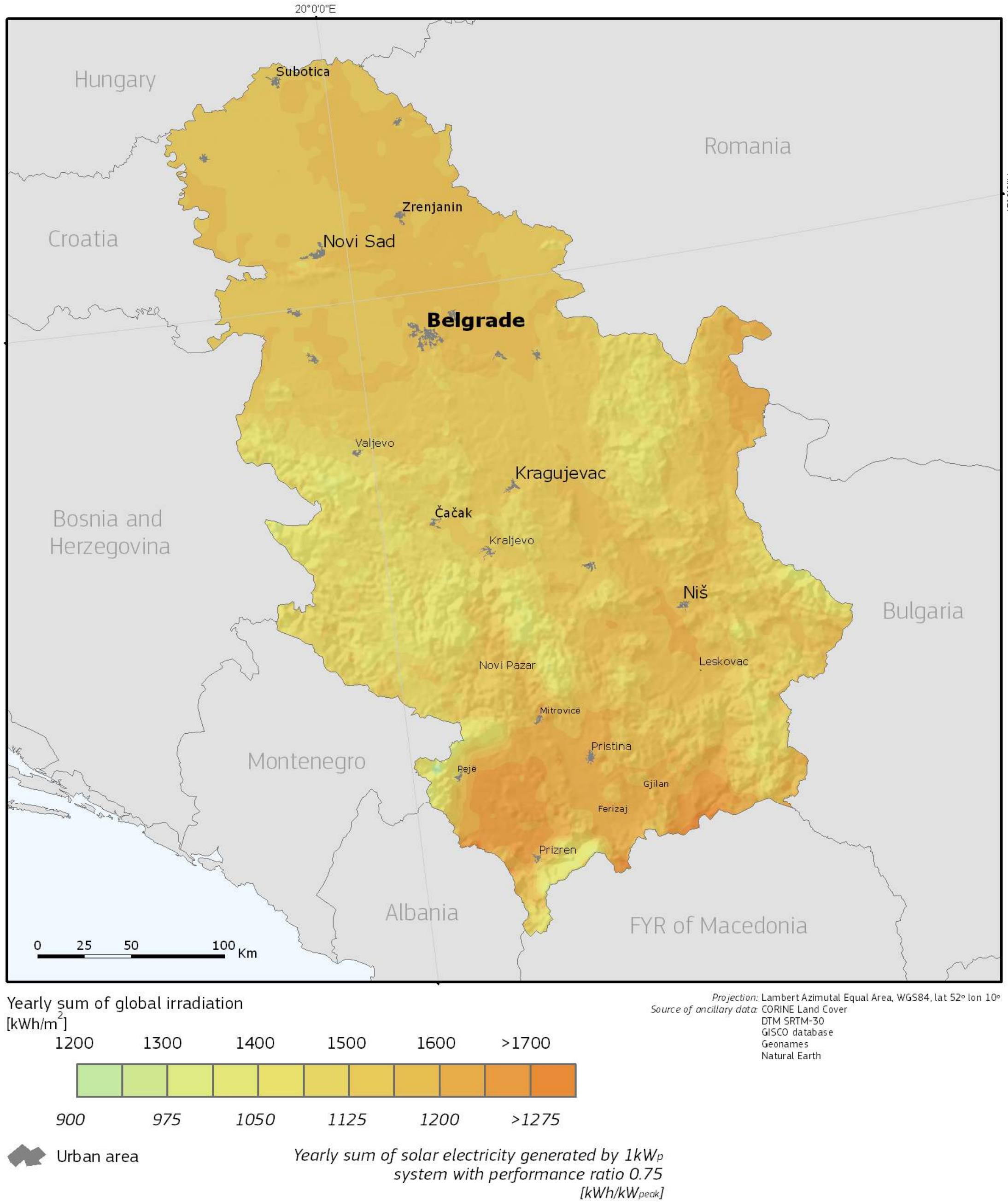


Figure 5.4 *Global irradiation and solar electricity potential for the optimally-inclined photovoltaic modules of the Republic of Serbia [22].*

In the Autonomous Province of Vojvodina, the average value of GHI ranges between 1294 kWh/m$^2$ in the north and 1335 kWh/m$^2$ in the south, or an average value of 1300 kWh/m$^2$. Depending on the season in sunny conditions, the intensity of global radiation in the midday hours can vary from 200 to 1000 W/m$^2$. The ratio of direct and diffuse radiation depends on geographical and microclimatic conditions. The ratio accounts from 40% to 60% and it is slightly higher in the winter period.

According to the Global Solar Atlas the city of Novi Sad has average global horizontal irradiation of 1337 kWh/m$^2$ per year, or 3662 kWh/m$^2$ per day, while the optimum tilt of PV modules is 34°, as shown in Table 5.1 [23].

*Table 5.1 Yearly average parameters for Novi Sad according to the Global Solar Atlas [23].*

| Glossary | Description | Value |
|---|---|---|
| Specific photovoltaic power output | Yearly average value of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity | 1278 kWh/kWp |
| Direct normal irradiation | Average yearly sum of direct normal irradiation | 1222 kWh/m2 |
| Global horizontal irradiation | Average annual sum of global horizontal irradiation | 1336 kWh/m2 |
| Diffuse horizontal irradiation | Average yearly sum of diffuse horizontal irradiation | 627 kWh/m2 |
| Global titled irradiation at optimum angle | Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input | 1547 kWh/m2 |
| Air temperature | Average yearly air temperature at 2 m above ground | 12.5 °C |
| Optimum tilt of PV modules | Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing global titled irradiation input | 35/180° |

Due to changes in the elevation angle of the Sun during the day, month and year, the value of the radiated energy that reaches the surface changes. More energy is received only by the surface at which the angle changes and adjusts to the position of the Sun each month, or even more if the receiving surface follows the Sun's trajectory daily. Nevertheless, the optimal slope of the collector should be 30-40°. The optimum slope for the summer period is 20-30° and for winter is about 60°. Therefore, in the given statistics different values for slope are chosen for the fixed plane.

For the analysis purposes PVGIS program is used. Daily average irradiance on the fixed plane with slope 0° and 35°, and azimuth 0° for the month of July, city of Novi Sad, are shown in Figure 5.5 and Figure 5.6 respectively. The results of this calculation consist of hourly values of the average solar irradiance for the month of July, given in W/m$^2$. The optional temperature graph, presented in Figure 5.7, shows the average air temperature each hour for the month of July. The minimum daily temperature for the month of July is 18°, while the maximum is 27.5°.

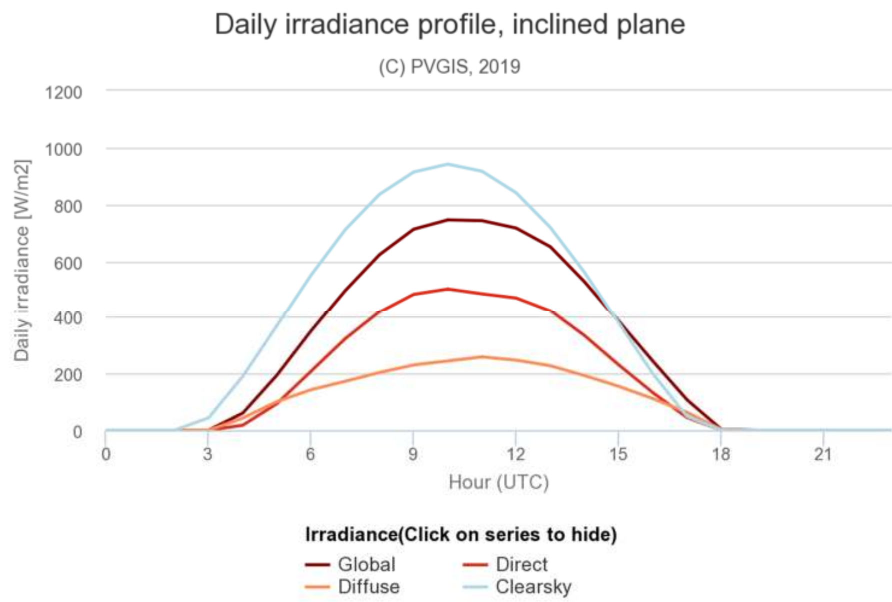


Figure 5.5 *Daily average irradiance on the fixed plane with slope 0° and azimuth 0° for the month of July, city of Novi Sad [22].*

The maximum global irradiance in case of the fixed plane with slope 0° is 745 kWh/m$^2$, while the maximum global clear-sky irradiance is 941 kWh/m$^2$. In Table 5.2 are given the average values of the global irradiance (G), direct irradiance (Gb), diffuse irradiance (Gd) and global clear-sky irradiance (Gcs) for the specific time period of the month of July.

*Table 5.2 Daily average irradiance on the fixed plane with slope 0° and azimuth 0° for the month of July, city of Novi Sad [22].*

| Time | G [W/m$^2$] | Gb [W/m$^2$] | Gd [W/m$^2$] | Gcs [W/m$^2$] |
|---|---|---|---|---|
| 00:45 | 0 | 0 | 0 | 0 |
| 01:45 | 0 | 0 | 0 | 0 |
| 02:45 | 0 | 0 | 0 | 0 |
| 03:45 | 0 | 0 | 0 | 44 |
| 04:45 | 60 | 17 | 43 | 190 |
| 05:45 | 194 | 94 | 101 | 369 |
| 06:45 | 351 | 208 | 143 | 550 |
| 07:45 | 495 | 323 | 172 | 711 |
| 08:45 | 622 | 419 | 203 | 835 |
| 09:45 | 712 | 482 | 230 | 914 |
| 10:45 | 745 | 501 | 244 | 941 |
| 11:45 | 742 | 484 | 258 | 916 |
| 12:45 | 716 | 469 | 247 | 840 |
| 13:45 | 650 | 423 | 227 | 718 |

| Time | G [W/m$^2$] | Gb [W/m$^2$] | Gd [W/m$^2$] | Gcs [W/m$^2$] |
|---|---|---|---|---|
| 14:45 | 526 | 334 | 192 | 559 |
| 15:45 | 385 | 230 | 155 | 379 |
| 16:45 | 243 | 132 | 111 | 199 |
| 17:45 | 107 | 44 | 63 | 48 |
| 18:45 | 3 | 0 | 3 | 0 |
| 19:45 | 0 | 0 | 0 | 0 |
| 20:45 | 0 | 0 | 0 | 0 |
| 21:45 | 0 | 0 | 0 | 0 |
| 22:45 | 0 | 0 | 0 | 0 |
| 23:45 | 0 | 0 | 0 | 0 |

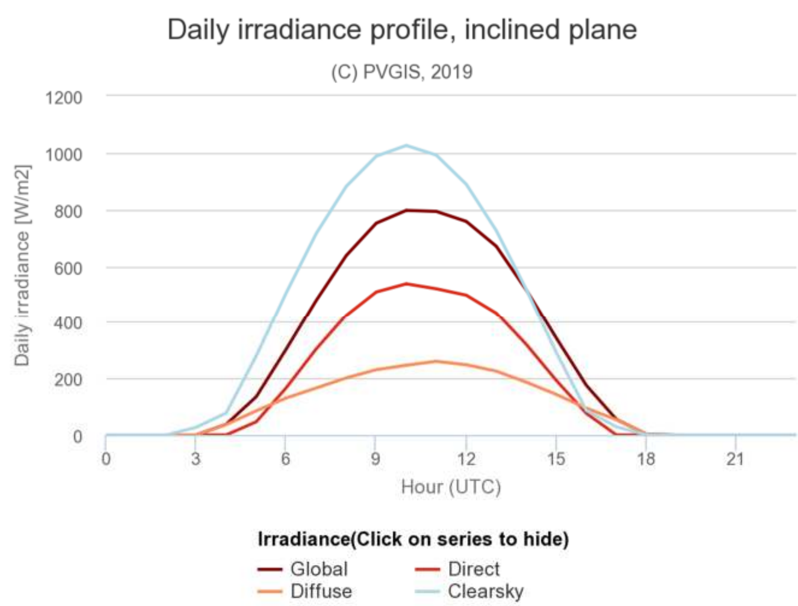


Figure 5.6 *Daily average irradiance on the fixed plane with slope 35°, and azimuth 0° for the month of July, city of Novi Sad [22].*

The maximum global irradiance in case of the fixed plane with slope 30° is 803 kWh/m2, while the maximum global clear-sky irradiance is 1034 kWh/m2. In Table 5.3 the average values of the global irradiance (G), direct irradiance (Gb), diffuse irradiance (Gd) and global clear-sky irradiance (Gcs) for the specific time period of the month of July are given.

*Table 5.3 Daily average irradiance on the fixed plane with slope 30° and azimuth 0° for the month of July, city of Novi Sad [22].*

| Time | G [W/m²] | Gb [W/m²] | Gd [W/m²] | Gcs [W/m²] |
|---|---|---|---|---|
| 00:45 | 0 | 0 | 0 | 0 |
| 01:45 | 0 | 0 | 0 | 0 |
| 02:45 | 0 | 0 | 0 | 0 |
| 03:45 | 0 | 0 | 0 | 27 |
| 04:45 | 37 | 0 | 37 | 78 |
| 05:45 | 135 | 46 | 85 | 279 |
| 06:45 | 303 | 167 | 130 | 505 |
| 07:45 | 478 | 304 | 166 | 715 |
| 08:45 | 637 | 425 | 201 | 881 |
| 09:45 | 751 | 508 | 230 | 988 |
| 10:45 | 796 | 537 | 246 | 1025 |
| 11:45 | 793 | 519 | 260 | 991 |
| 12:45 | 757 | 497 | 248 | 888 |
| 13:45 | 670 | 433 | 225 | 725 |
| 14:45 | 515 | 319 | 186 | 517 |
| 15:45 | 342 | 192 | 143 | 290 |
| 16:45 | 175 | 76 | 95 | 86 |
| 17:45 | 55 | 0 | 54 | 29 |
| 18:45 | 3 | 0 | 3 | 0 |
| 19:45 | 0 | 0 | 0 | 0 |
| 20:45 | 0 | 0 | 0 | 0 |
| 21:45 | 0 | 0 | 0 | 0 |
| 22:45 | 0 | 0 | 0 | 0 |
| 23:45 | 0 | 0 | 0 | 0 |

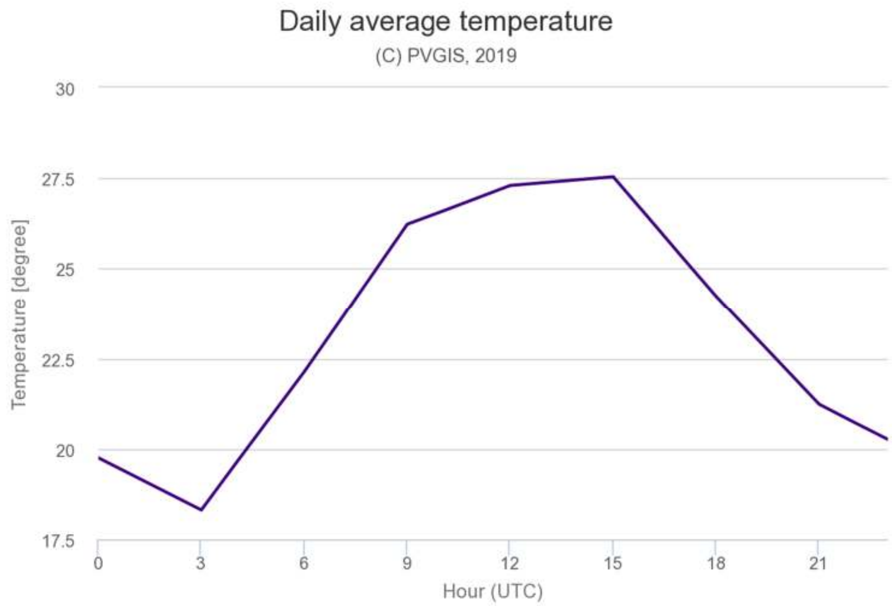


Figure 5.7 *Daily average temperature for the month of July, city of Novi Sad [22].*

Monthly average irradiance on the fixed plane with slope 0° and azimuth 0° for the year of 2016, city of Novi Sad, are shown in Figure 5.8. In Table 5.4 the monthly average values of the global horizontal irradiaton, direct normal irradiaton and global irradiation optimum angle of the year 2016 are given.

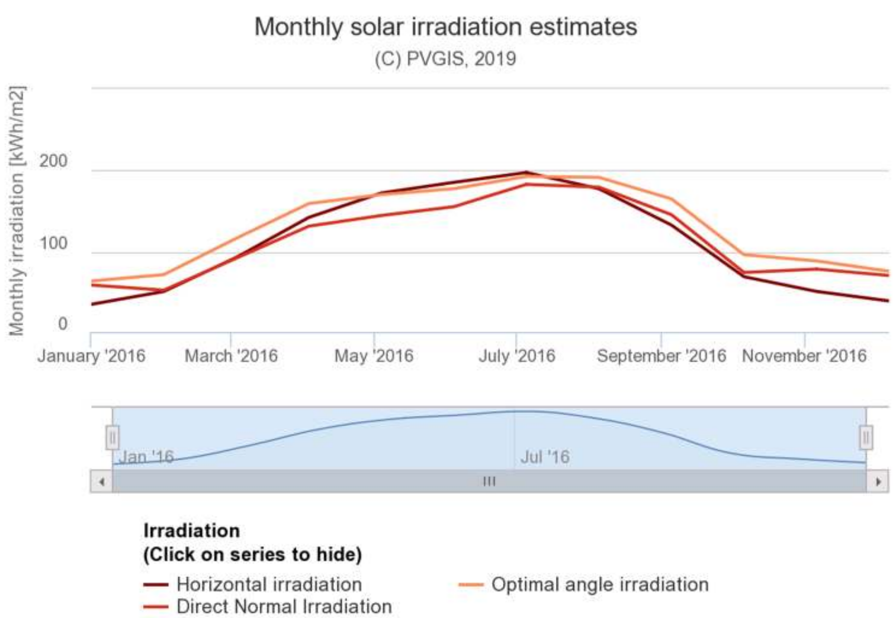


Figure 5.8 *Monthly average irradiance on the fixed plane with slope 0°, and azimuth 0° for the year of 2016, city of Novi Sad [22].*

The maximum monthly average value of the global horizontal irradiation is approximately 200 kWh/m$^2$ in month of July, whereas the minimum value is 35 kWh/m$^2$ in month of January.

*Table 5.4 Monthly average irradiance on the fixed plane with slope 0° and azimuth 0° for the year of 2016, city of Novi Sad [22].*

| Month | Global horizontal irradiation [kWh/m$^2$] | Direct normal irradiation [kWh/m$^2$] | Global irradiation optimum angle [kWh/m$^2$] |
|---|---|---|---|
| January | 35.15 | 58.9 | 63.9 |
| February | 50.95 | 52.56 | 71.67 |
| March | 92.93 | 92.01 | 116.41 |
| April | 142.15 | 131.36 | 159.2 |
| May | 172.17 | 144.49 | 170.26 |
| June | 185.26 | 155.32 | 177.49 |
| July | 197.34 | 182.81 | 192.57 |
| August | 177.43 | 179.39 | 191.42 |
| September | 132.69 | 145.45 | 164.93 |
| October | 69.14 | 74.35 | 96.19 |
| November | 51.04 | 78.52 | 88.56 |
| December | 39.32 | 70.62 | 75.84 |

Approximately 55% of the total energy consumed in households in Serbia as well as in Vojvodina is used in the form of electricity. A significant part of this energy is used for heating the sanitary water. Utilizing solar energy can help reduce the cost of heating hot water by about 60 to 70% during the year. According to the Serbian Energy Efficiency Agency estimates, Serbia's energy consumption could be reduced by more than 50% with more efficient heating and energy efficiency improvements in the industry.

Depending on system efficiency the Republic of Serbia has the potential to produce from 700 to 900 kWh of energy per square meter of solar thermal collector annually, which is high in comparison with the countries with a good reputation for energy solar usage. In the Republic of Serbia, 3.3 kWh could be produced per square meter and would be most effectively used in the tourism, health sector and households, primarily for heating hot water.

In the Republic of Serbia and Autonomous Province of Vojvodina, the use of solar energy for heating domestic hot water or space is almost negligible, although there has been an increase in the implementation with the support of state institutions, donations and financing from users in the past years. Greater use of solar systems in the Republic of Serbia is prevented mainly by the lack of state support for individuals as well as poor public awareness. The enormous savings of conventional energy would be achieved if each household had at least one unit of the solar collector to heat the domestic hot water. Viewed within the state's electricity system, this would represent a significant burden on the system.

The technically usable energy potential for the conversion of solar energy to thermal energy (for hot water preparation and other purposes) is estimated at 0.194 Mtons per year, assuming the application of solar thermal collectors to 50% of available facilities in the country.

## 5.3. Waste

The current situation in local self-governments of the Republic of Serbia is characterized by unreliable and incomplete data on the amount of municipal waste generation. The quantities of municipal waste annually were calculated on the basis of waste measurements in the reference to local governments. The urban population generates an average of 1 kg of municipal waste per citizen per day, while the rural population generates 0.7 kg of waste per citizen per day. Based on the census, the urban population is 57%, while 43% is rural. On average, a resident of the Republic of Serbia generates 0.87 kg of municipal waste per day or 318 kg per year. The population of 7 443 183 produces about 2 374 374 tons of waste a year. In Fig 5.9, the morphological composition of municipal waste in the Republic of Serbia, is shown [24]. According to a report from the Environmental Protection Agency on waste management in 2011-2017, a total of 2.15 Mtons of waste was generated in 2017, of which municipal public utility companies collected 1.80 Mtons, or 83,7% [25]. Most municipal waste is landfilled and only 3% is officially recycled.

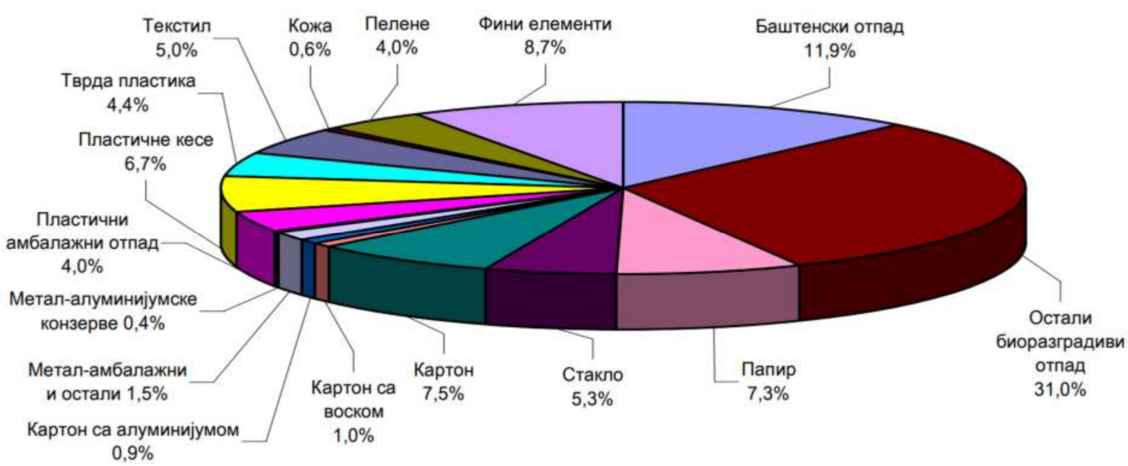


Figure 5.9 *The morphological composition of municipal waste in the Republic of Serbia [24].*

According to the results of statistical surveys on waste conducted at the Statistical Office of the Republic of Serbia in the period 2010-2013, the generated waste quantities recorded an increase [26]. The Table 5.5 and Figure 5.10 show the share of individual economic sectors in the total amount of waste generated in the years 2010-2013.

*Table 5.5 Share of individual sectors in the total amount of waste generated in the years 2010-2013 [26].*

| Year | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| Total | **33 615 918** | **49 004 760** | **55 002 585** | **58 388 403** |
| Mining | 26 460 274 | 41 522 482 | 47 896 363 | 50 807 563 |
| Manufacturing industry | 1 135 357 | 1 126 609 | 759 832 | 821 286 |
| Electricity, gas and steam supply | 6 020 287 | 6 355 668 | 5 744 350 | 6 199 079 |
| Water supply and wastewater management | - | - | - | 33 106 |
| Construction | - | - | 363 706 | 328 235 |
| Service sectors | - | - | 238 336 | 199 132 |

In 2013, Mining accounted for 87% of the total amount with 50 Mtons, followed by Electricity, gas and steam supply at 10.6% or 6 Mtons, Manufacturing by 1.4% or 750 000 tons and the remaining 1% is waste generated by other Service sectors. The largest increase in waste generated compared to the previous year was recorded in 2011, at 45.8%. Although the scope of the survey was expanded in 2012 and 2013, the largest increase in generated waste compared to the previous year remained in 2011.

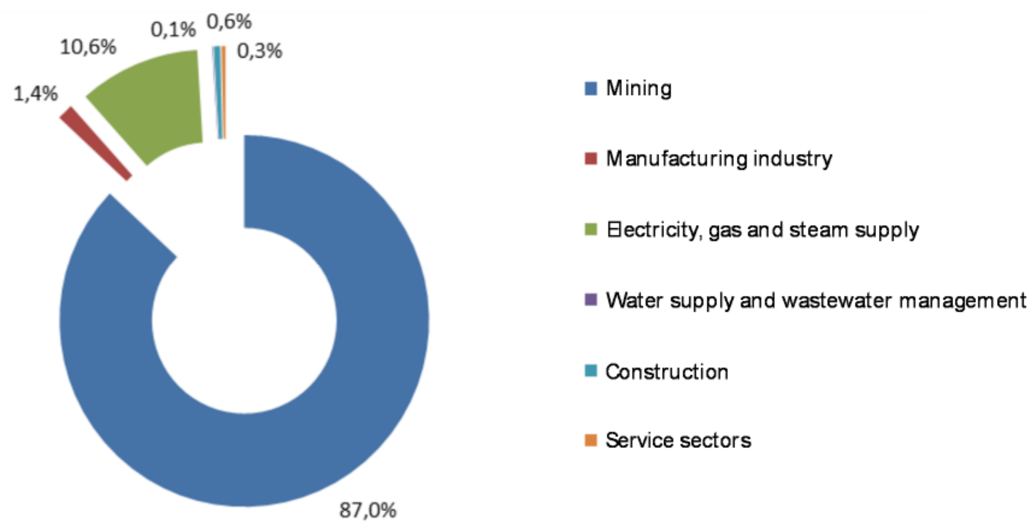


Figure 5.10 *Share of individual sectors in the total amount of waste [26].*

Generated quantities of hazardous and non-hazardous waste in the period of 2010-2013, presented in the Figure 5.11, also recorded an increase.

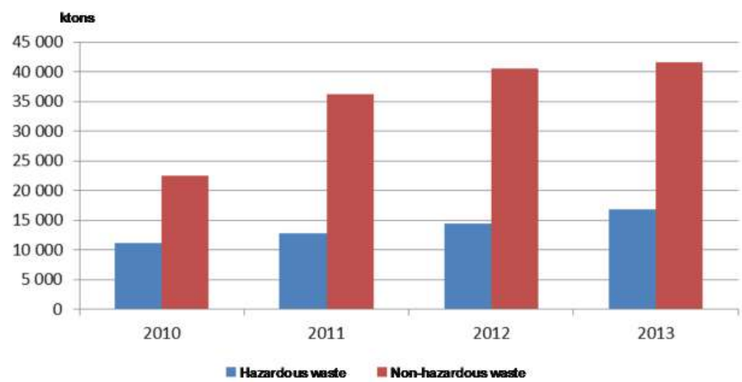


Figure 5.11 *Generated quantities of hazardous and non-hazardous waste in the period 2010-2013 [26].*

Mineral and combustion wastes are the most represented types of waste in the total amount of waste generated in observed years. Other types of waste were changing their share depending on the sectors covered by the survey. Until 2011, in addition to the aforementioned types of waste, vegetable waste, acid, base or saline waste as well as metallic iron waste were generated in large quantities. In 2012 and 2013, with the inclusion of the Construction and Services sectors in the scope of the survey, there were changes in the structure and an increase in the types of mineral waste generated in the bulk by the Construction (Land and Iron Metals) sector, as household and similar waste generated largely by the service sectors.

There is no exact data on the quantities of waste oils generated on the territory of the Republic of Serbia. It is estimated that about 50,000 tons of various mineral oils are consumed annually. In addition, it is estimated that around 10,000 - 15,000 tons of motor and other oils and lubricants are consumed annually in the city of Belgrade. There is no regulated waste oil collection system in the territory of the Republic of Serbia. Waste oil collection and recovery capacities are approximately 25,000 t per year. Some operators carry out collection and temporary storage. To a lesser extent, the collection and regeneration of self-produced oil and the regeneration of oil by private entrepreneurs are present. Part of the waste oil is exported for final disposal, and part of the waste oil is illegally collected and disposed of, most often for energy purposes. There is a growing trend of organized collection and collection of edible waste oils. They are most commonly used for biodiesel production. There are also certain capacities for the treatment of oil emulsions by ultrafiltration and the subsequent disposal of the resulting oil concentrate by solidification. Cement plants have the capacity to use waste oils for energy purposes [27].

# 6. The optimal renewable energy system topologies and building energy management system for the exemplary facilities

In this section, in accordance with the features of the location and buildings considered so far and taking into account previous analysis of the energy demand and potential for renewable energy sources, the recommendation for the optimal renewable energy system, as well as topology of the smart building energy system are proposed. This system would improve the energy efficiency of the exemplary object and provide higher reliability and better performance on the energy flow control.

One of the possible strategies for the increase in energy efficiency is to incorporate renewable energy sources into traditional power systems. If the power is partially produced by the renewables, the power share coming from the fossil fuels is decreased and thus greenhouse gas emission is reduced. Furthermore, the reduction in the energy provided by the power grid would lead to a significant money savings. Also, reduced risk of loss from grid blackouts is another benefit regarding less dependence of the object on the energy coming from the grid. This concept provides sustainable renewable energy to the grid and reduces the need for grid expansion.

According to the analysis of the renewables potential of the exemplary objects, the following systems are going to be constituted:

- Photovoltaic system on the roof of Radiology clinic;
- Photovoltaic system on the roof of Emergency center;
- Photovoltaic system on the parking inside KCV complex;
- Solar thermal system on the roof of Medical Rehabilitation clinic;
- Charging station for electric vehicles and assistive devices;
- Biodiesel backup generator system with biodiesel production;
- Building energy management system.

## 6.1. Photovoltaic system on the roof of Radiology clinic

The facility in question has flat roof making the PV power plant construction and utilization completely justified. The installed power of the PV plant is 50 kW, the panel slope is 10 degrees and azimuth angle is 90 degrees. The block diagram of the PV system on the rooftop of the Radiology clinic is given in Figure 6.2.


Figure 6.1 *Location of the PV plant*

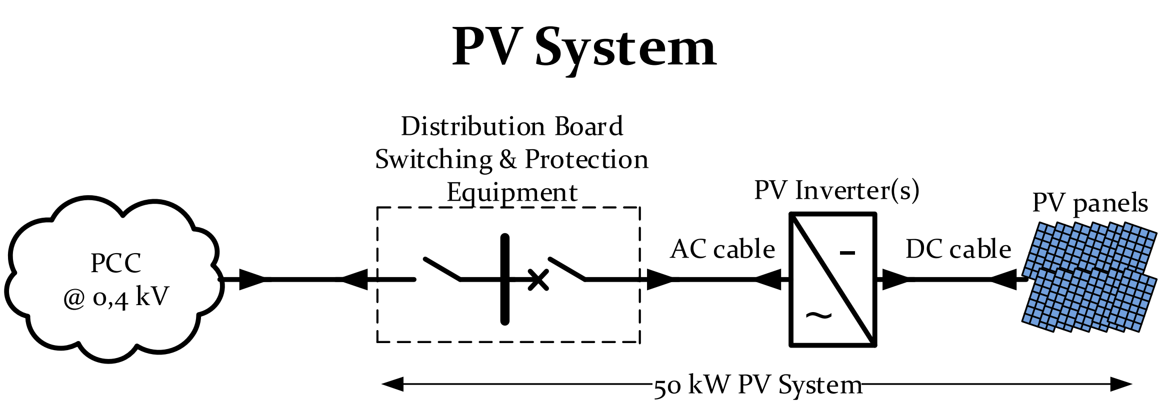


Figure 6.2 *Block diagram of the PV plant on the Radiology clinic roof*

PV strings, i.e. a series of the PV panels, are directly connected to three-phase inverter unit(s) which transform the DC voltage from the output of PV strings to AC voltage. The DC cables that connect PV strings with the inverters are planned for external mounting. The inverter(s) have built-in DC/DC converters with the algorithm for the maximum power point tracking thus enabling highly efficient energy conversion. Other electrical equipment such as protective and switch devices are placed inside the distribution board. The point between the board and the distribution power grid is called the point of common coupling (PCC) and the voltage level in the PCC is 0.4 kV.

Using the PVGIS software tool, it is possible to predict the total monthly electrical energy production of the PV plant and this projection is depicted in Figure 6.3. The total estimated value of the energy produced annually is 51.36 MWh.

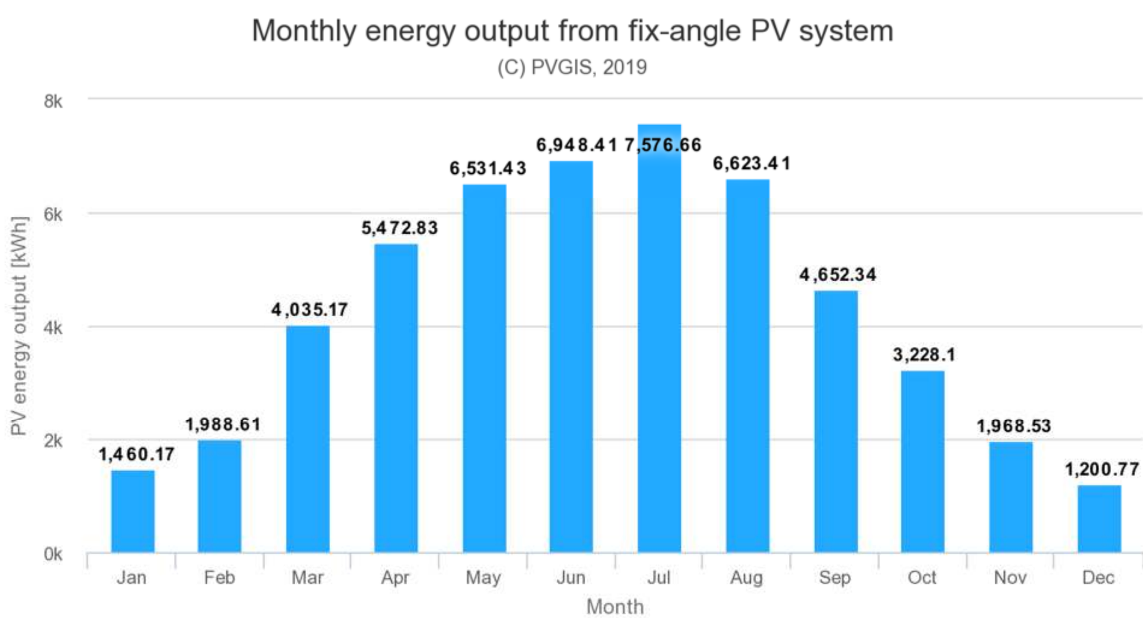


Figure 6.3 *Estimated electrical energy production of the PV plant, located on the Radiology clinic rooftop.*

## 6.2. Photovoltaic system on the roof of Emergency center

The facility in question has flat roof making the PV power plant construction and utilization completely justified. The installed power of the PV plant is 50 kW, the panel slope is 10 degrees and azimuth angle is 90 degrees. The block diagram of the PV system on the rooftop of the Emergency center is given in Figure 6.5.

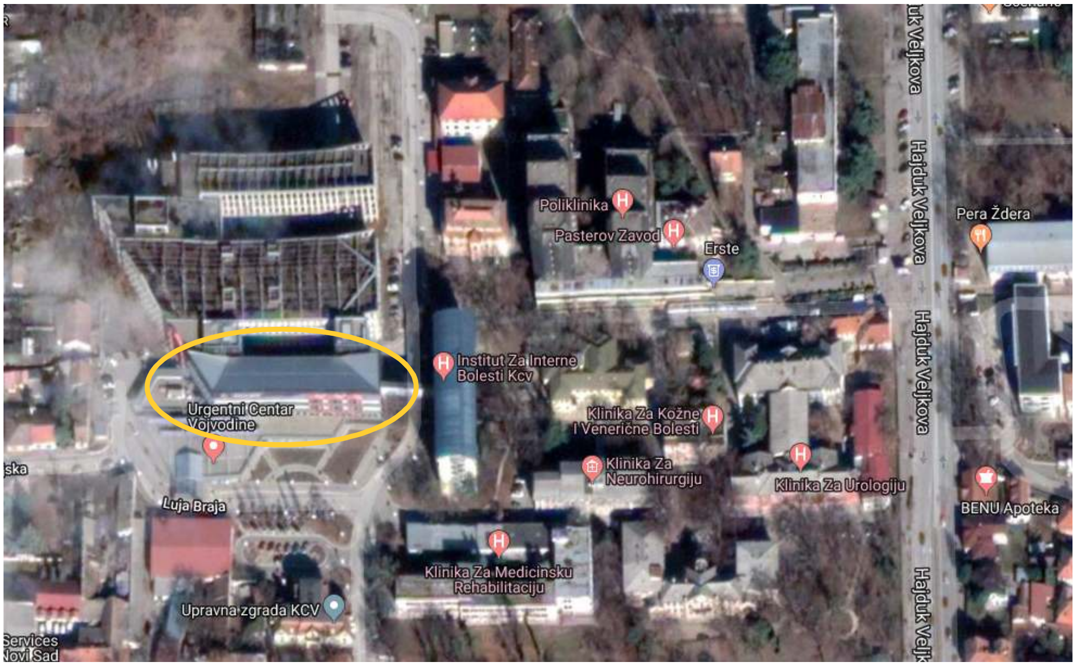


Figure 6.4 *Location of the PV plant*

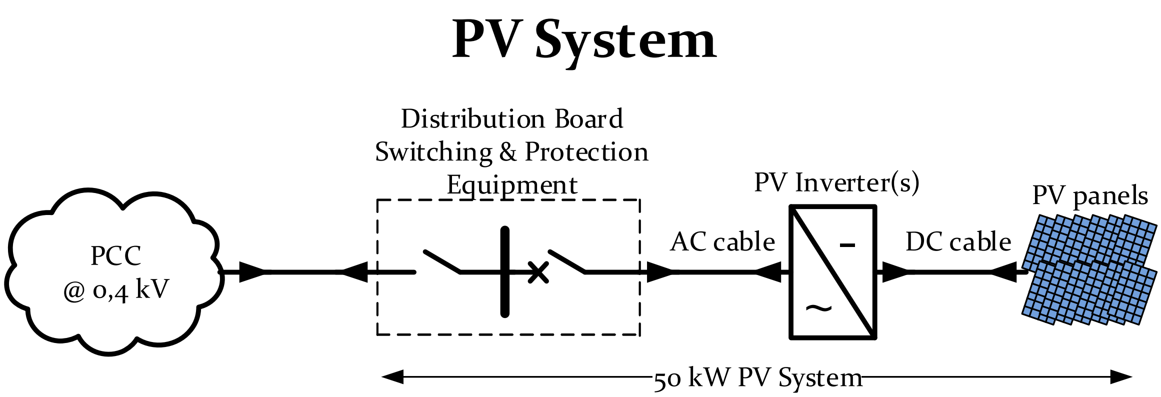


Figure 6.5 *Block diagram of the PV plant on the Emergency center rooftop*

PV strings, i.e. a series of the PV panels, are directly connected to three-phase inverter unit(s) which transform the DC voltage from the output of PV strings to AC voltage. The DC cables that connect PV strings with the inverters are planned for external mounting. The inverter(s) have built-in DC/DC converters with the algorithm for the maximum power point tracking thus enabling highly efficient energy conversion. Other electrical equipment such as protective and switch devices are placed inside the distribution board. The point between the board and the distribution power grid is called the point of common coupling (PCC) and the voltage level in the PCC is 0.4 kV.

Using the PVGIS software tool, it is possible to predict the total monthly electrical energy production of the PV plant and this projection is depicted in Figure 6.6. The total estimated value of the energy produced annually is 51.38 MWh.

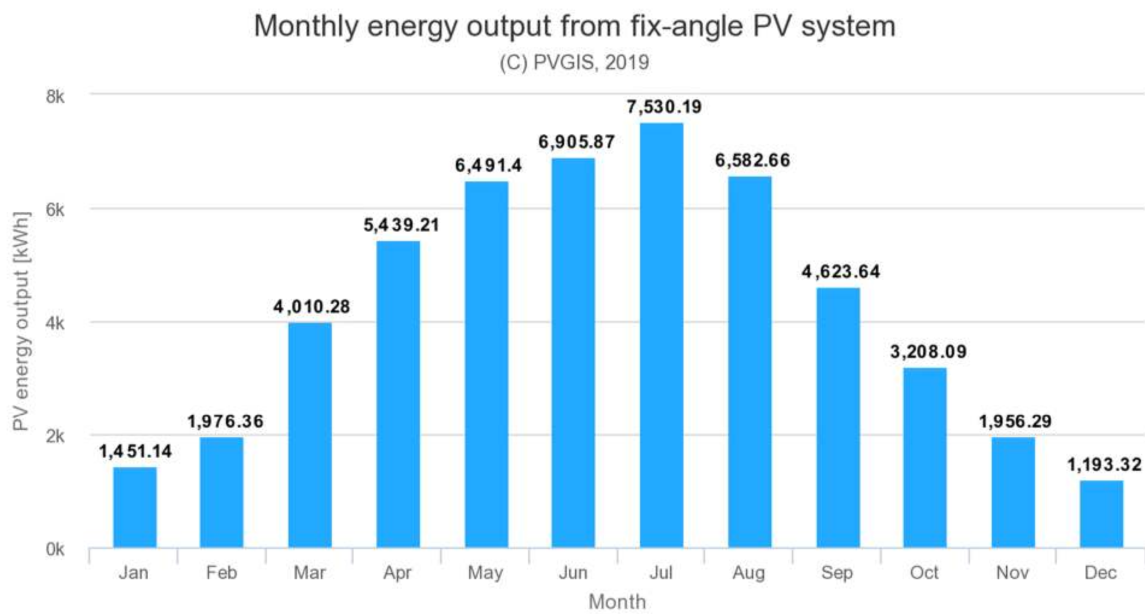


Figure 6.6 *Estimated electrical energy production of the PV plant, located on the Emergency center rooftop.*

## 6.3. Photovoltaic system on the parking inside KCV complex

For this PV power plant the supporting structure needs to be constructed, so that passenger vehicles can park below the PV plant but also the construction must withstand different weather conditions like strong wind etc. Supporting structure will be set so that the utilization of the PV panels is maximized. The installed power of the PV plant is 150 kW, the panel slope is 10 degrees and azimuth angle is 90 degrees. The location of the PV plant is shown in Figure 6.7 and block diagram of the PV system on the parking is given in Figure 6.8.


Figure 6.7 *Location of the PV plant*

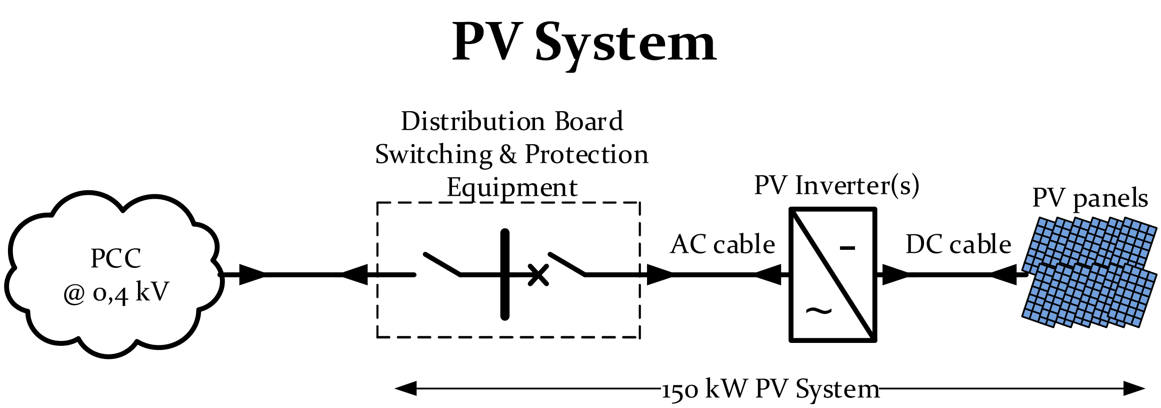


Figure 6.8 *Block diagram of the PV plant on KCV parking*

PV strings, i.e. a series of the PV panels, are directly connected to three-phase inverter unit(s) which transform the DC voltage from the output of PV strings to AC voltage. The DC cables that connect PV strings with the inverters are planned for external mounting. The inverter(s) have built-in DC/DC converters with the algorithm for the maximum power point tracking thus enabling highly efficient energy conversion. Other electrical equipment such as protective and switch devices are placed inside the distribution board. The point between the board and the distribution power grid is called the point of common coupling (PCC) and the voltage level in the PCC is 0.4 kV.

Using the PVGIS software tool, it is possible to predict the total monthly electrical energy production of the PV plant and this projection is depicted in Figure 6.9. The total estimated value of the energy produced annually is 155.14 MWh.

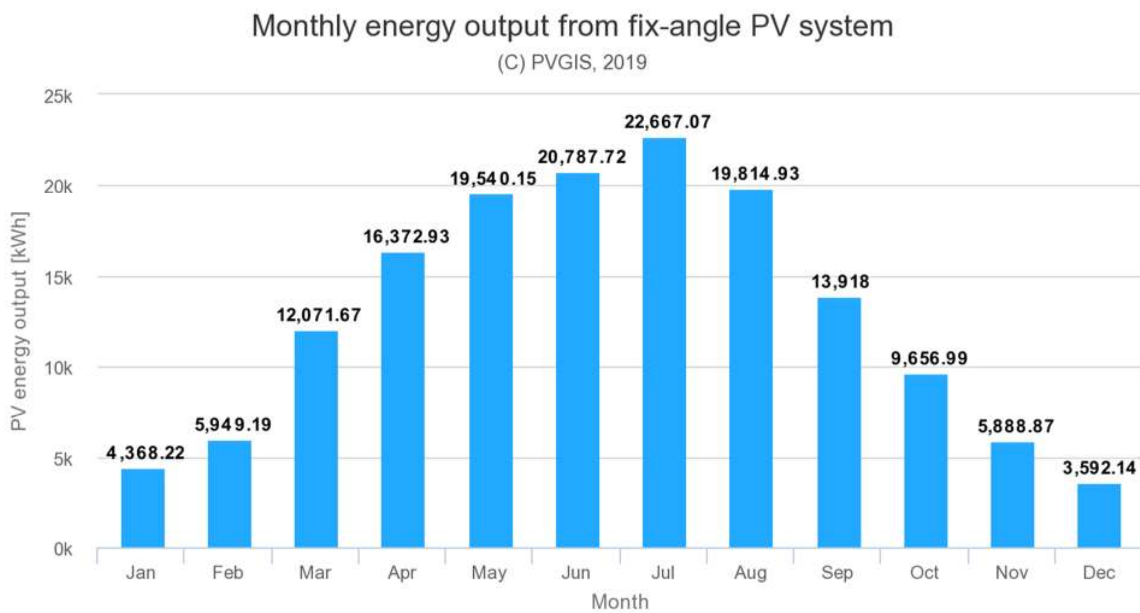


Figure 6.9 *Estimated electrical energy production of the PV plant, located on the KCV parking*

## 6.4. Solar-thermal system on the roof of Medical Rehabilitation clinic

During the power consumption analysis it is confirmed that this facility has a huge need for energy that is used for heating water mainly in swimming pools and equipment used for rehabilitation. However current system uses different previously described methods for heating water which is rendered as inefficient and non-environmental friendly. On the other hand analysis of the solar potential has confirmed that the location of this facility hold great solar potential thus the conclusion to install a 30 kW solar-thermal system on the rooftop of this facility is completely justified.

In Figure 6.10, the average monthly solar irradiance that is expected on the location of this facility is shown, whereby in Figure 6.11 a block diagram of the solar-thermal system planned to be installed on the facility rooftop, is shown. As can be observed in Figure 6.11, solar-thermal system has classical configuration. The cold water is pumped through the boiler where it is heated and then returned to the swimming pool. The heat energy is generated by the solar collector located on the rooftop of the building.

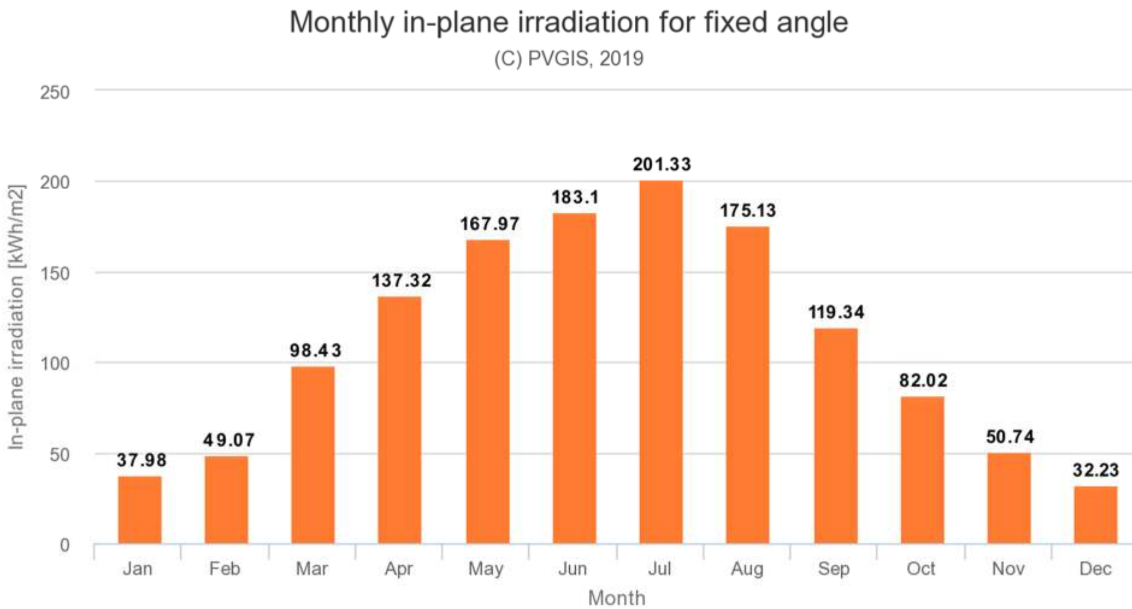


Figure 6.10 *Monthly solar irradiance on the location of the Medical Rehabilitation Clinic*

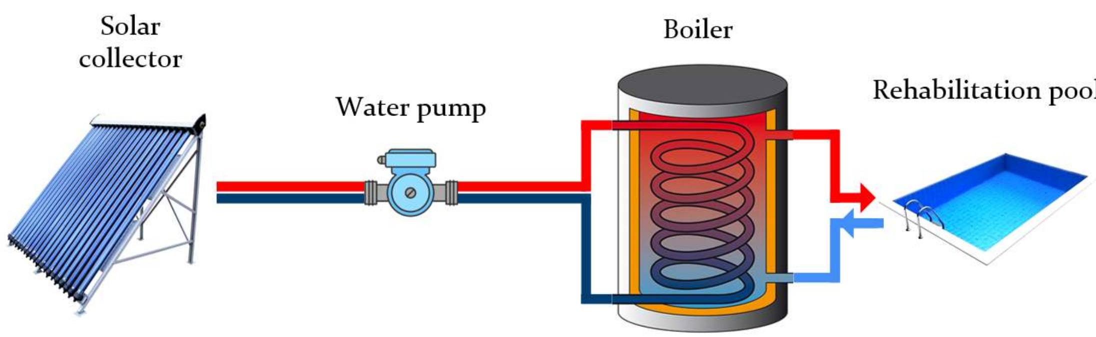


Figure 6.11 *Block diagram of solar thermal system located on Medical Rehabilitation clinic roof*

Based on the available software for solar thermal system performance prediction and available weather data for the location and heat demand of the Medical Rehabilitation Clinic values shown in tables 6.1 and 6.2 are obtained. Solar thermal energy ($Q_{sol}$) delivered to the system on a monthly basis is shown in Figure 6.12, and it can be inferred that highest energy delivery occurs in May and Jun and lowest in November and December [28].

*Table 6.1 Solar thermal system properties*

| Parameter | Value |
|---|---|
| Number of collectors | 20 |
| Number of arrays | 1 |
| Tilt angle | 45° |
| Orientation | 0° |
| Collector field yield | 19991.1 kWh |
| Temperature setting | 45°C |

*Table 6.2 Overview of solar thermal energy (annual values)*

| Parameter | Value |
|---|---|
| Collector area | 51.6 m2 |
| Solar fraction total | 43.5% |
| Total annual field yield | 19991.1 kWh |
| Collector field yield relating to gross area | 387,4 kWh/m2/Year |
| Collector field yield relating to aperture area | 442.3 kWh/m2/Year |
| Max. energy savings | 23519 kWh |
| Max. reduction in CO2 emissions | 7072 kg |

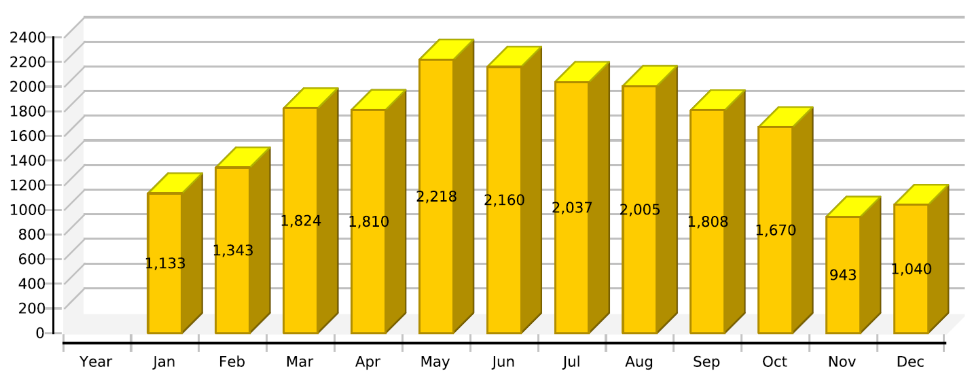


Figure 6.12 *Solar thermal energy delivered to the system [kWh] [28]*

## 6.5. Biodiesel generator and biodiesel production system

As previously described waste oil is one of the waste products of hospital kitchen operation. Proper environmental friendly disposal of the waste oil is expensive and relatively complicated therefore a system that enables the waste oil recycling and reusing

is completely justified. The principal scheme of the waste oil processing system is shown in Figure 6.12. It employs standard industrial waste oil processor that is available on the market and as a result a biodiesel fuel is obtained. This biodiesel fuel can be used either for vehicles like emergency vans or for diesel generators in KCV complex that operate during partial or complete power failure.


Figure 6.13 *System for bio-diesel production from waste oil*

This system offers a viable solution for waste oil disposal as well as for supplying all consumers that require fuel for its operation. It is estimated that the amount of waste oil produced at hospital kitchen is sufficient to ensure a steady amount of waste oil for constant bio fuel production.

When it comes to the KCV complex, and more precisely hospital kitchen the consumption of cooking oil is estimated to be between 150 and 160 liter per month. At the same time this is roughly the amount of the waste oil that is generated on monthly bases that if not recycled must be properly stored or disposed. Therefore recycling of the waste oil and converting it to biodiesel has two fold positive impact which is firstly elimination of the necessity for storage of expensive and complicated disposal procedures and secondly replacing the regular diesel fuel that is used on daily bases in KCV with more environmental friendly biodiesel.

The amount of the biodiesel produced is sufficient for normal operation of the backup generators with the power of the 2x250 kW.

## 6.6. Building energy management system

Building energy management systems (BEMS) are computer-based control systems that control and monitor the mechanical and electrical equipment in buildings such as ventilation, heating, lighting, power systems, and so on. Energy management systems power equipment only when it is necessary, which eliminates the waste of lighting, heating, and cooling portions of the building that are not used around-the-clock. Optimized control enhances building's current mechanical systems and increases the ability to manage comfort and air quality throughout the building. By reducing unnecessary use of equipment, energy management systems can prolong the life of equipment of the building and reduce maintenance costs. The monitoring facilities of a BEMS enable monitoring of the status of renewable energy sources, environmental conditions, and energy utilization, providing the building operator with a real-time reporting of the building operation process. Energy meters that are connected to a BEMS provide real-time energy consumption patterns and record the energy performance of the building. This data can be logged, archived and analyzed for energy management purposes.

Therefore, BEMS is going to be integrated into the exemplary object and implemented as a centralized architecture consisting of a central server that interacts with different sensor and actuator devices. Sensor devices send their data to a local base station. The automation system is also included in BEMS and provides automatic control of all supervised systems. Here, a programmable logic controller (PLC) will be used as an element dedicated to the automation of the entire system. All the required components with interfaces for measurements and sensors are going to be provided and standardized bus systems and communication capable devices used. Moreover, the expandability of the BEMS has to be ensured.

The focus of a power management system is on the request for improved transparency of energy consumption and energy quality as well as on ensuring the availability of power distribution.

BEMS should communicate with all installed systems: PV systems, Electric vehicle and assistive device charging station, Solar-thermal system, and Waste oil processing system as depicted in Figure 6.14.

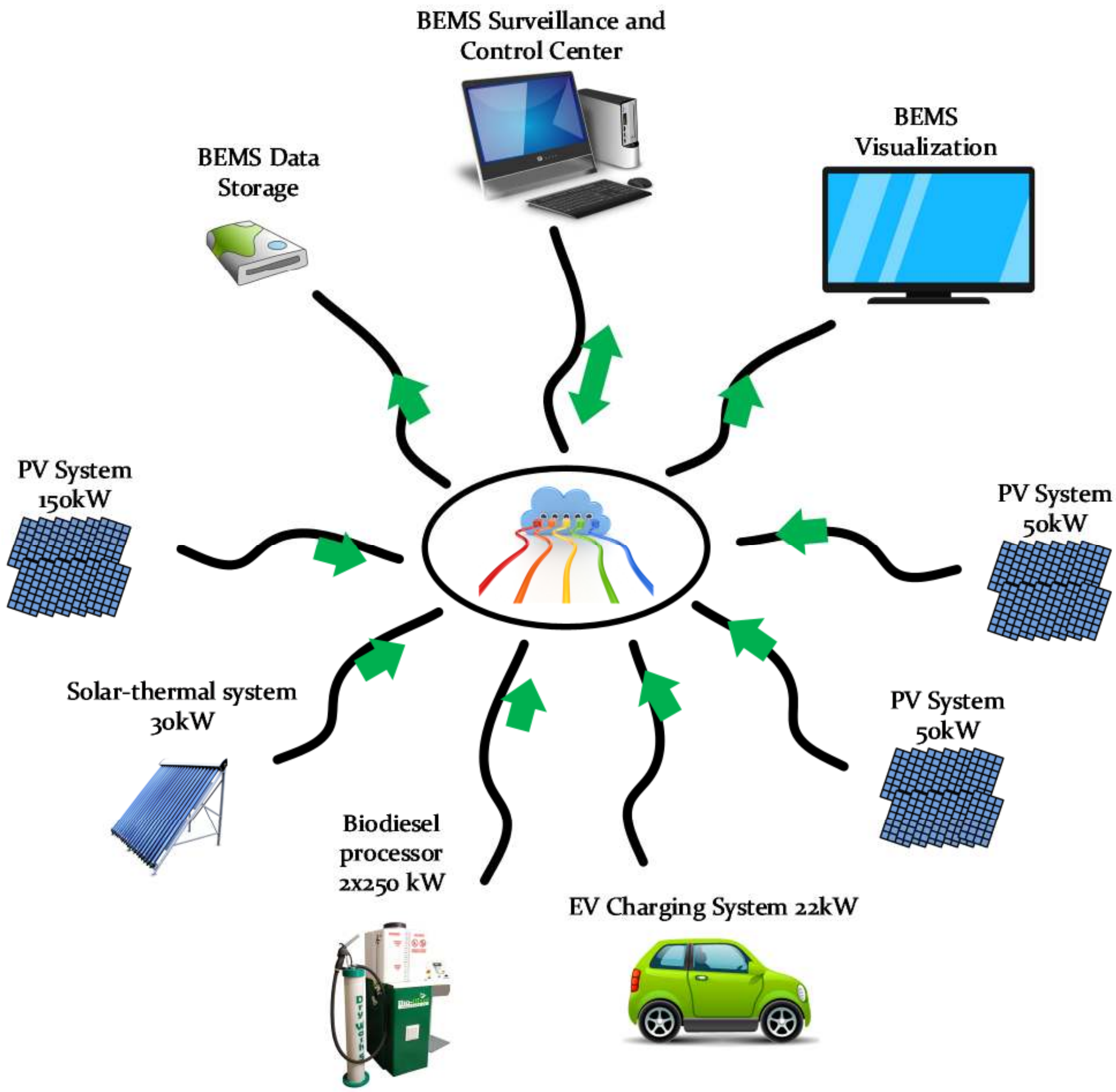


Figure 6.14 *BEMS system configuration*

At the PCC point of all of these systems smart meters will be placed and collect information about electrical quantities and consequently reconstruct the power quality, production and consumption. Sensing devices are going to be placed in all systems to monitor environmental variables such as solar irradiation, temperature, humidity, air speed and direction, etc. This data is sent to the BEMS system and processed. Based on all inputs, BEMS provides outputs – control signals for controllers so that the automation of all ongoing processes is possible regarding the energy efficiency maximization.

In this manner, the maximal energy efficiency should be realized, as well as optimal and coordinate operation of all units.

# 7. Conclusion

With the development of the society, energy security will become a critical issue going forward, and the one issue that will impact the speed of the development the most. It will be very hard to imagine a swift development in the future for the society that is heavily dependent on the fossil fuels, first and foremost due to the limited amount of resources. Additionally, the influence of the classical fuels on the environment will make any development of the society unsustainable.

Recognizing these issues going forward, many organizations (governmental and other) have adopted measures and strategies in order to foster the development of modern, sustainable and renewable technologies. This has particularly been underlined by several very important EU directives regarding the energy performance of buildings, energy efficiency and the utilization of renewable energy sources. Enticed by EU legislative, the national law makers have been developing national strategies and legislation in these areas as well. Most of the goals, given by the directives have been directly adopted or slightly adjusted to better fit the opportunities in the given region. It can be easily observed that both of the cross-border countries have made significant progress in adopting the adequate legislation regarding the energy efficiency measures and renewable energy sources. However, in order to have the possibility to fully implement the policies with the best possible results, it is still necessary to influence the attitude of the general public. The inherent inertness of the public towards the modern energy efficiency and renewable energy sources needs to be changed (instigating a change in behavior). This can be achieved by showing the public the benefits of the developed technologies, the inherent synergy and the sustainability it offers.

It is important to note that the targeted Programme regions in Republic of Serbia (Vojvodina province) and Republic of Croatia (Osijek-Baranja County, Brod-Posavina County) have very similar and high renewable energy potential. The most important potential in the region lies within the potential of solar energy for both electricity and thermal energy production. The average value of the global solar irradiation for horizontal plane in the region is in the range of 1294 kWh/m$^2$ to 1300 kWh/m$^2$, which represents a serious potential for the electrical energy generation. Similarly, the potential for the thermal energy generation is also very good, with 700 kWh/m$^2$ to 900 kWh/m$^2$ of thermal energy possibly generated from the solar thermal collectors. After the solar energy potential, the next possible renewable energy source to utilize is wind energy, with an average potential range of 200 W/m2 to 300 W/m2. Furthermore, the potential of sub geothermal energy, for heat pump base HVAC is also significant, and considering the average temperatures in the region it can provide the thermal energy for heating almost all year. Also, there is very high energy potential for cooling in the summer months. An additional potential is represented by waste management, and in particular the utilization of the waste oil for biodiesel production with approximate capacity of 25,000 t per year.

Considering the potential of the region, and by further analyzing the micro location of the exemplary facility, it is not hard to conclude that there is a possibility of modernizing

public buildings in the region and making the energy efficient, sustainable and much more in line with the EU directives. In that regard, for the Clinical center of Vojvodina public building, and according to the available potential, there are several systems planned for installation. First and foremost, three PV power plants of 50 kW, 50 kW and 150 kW will be installed on the roof tops and parking lot of the partner public facilities. Additionally, PV solar collector system of 30 kW will be installed for heating the water for the rehabilitation pool. Additionally, to further diversify the energy mix the installation of biodiesel production system that will supply 2 biodiesel generators of 250 kW power is proposed. All of these systems will be operated by the smart building energy management system (BEMS) in order to increase the energy efficiency and provide the facility with the optimal use of different energy systems.

According to the analysis given in Chapter 6, the diagram of the estimated electrical energy production of the PV systems during the year is created. The Figure 7.1 shows the estimated production of energy of the PV system that will be installed on the rooftop of the Radiology Clinic. Highest production around 7.5 MWh will be in July, as expected. In Figure 7.2 a comparison of the total consumption for 2018 and the estimated values of system in MWh, is shown for Radiology Clinic. The total power consumption is very high, so the PV system production will be used for self-consumption, which is expected given the installed capacity of the system. Nevertheless, the free RES energy will yield significant financial savings and significantly impact the KCV carbon footprint. The highest share of the PV system in final consumption is for the month of July, around 3% while the lowest is during December, approximately 0.5%. This production could be used to cover the consumption at TS “Kotlarnica”, however there would be instances where the generation would surpass the consumption.

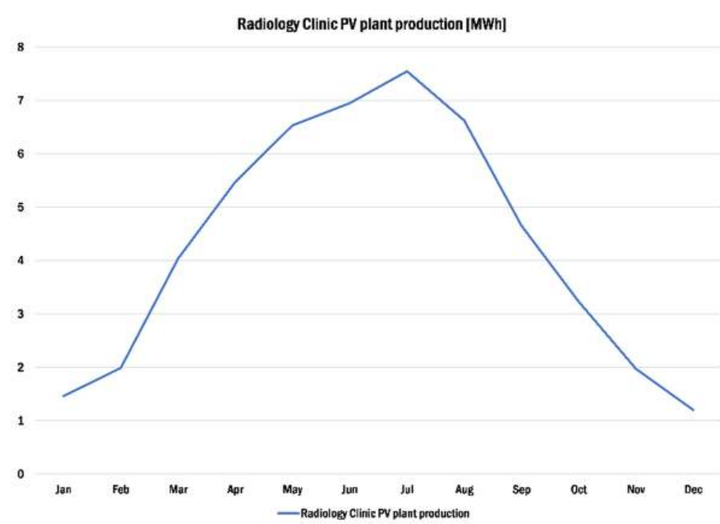


Figure 7.1 *Radiology Clinic PV plant production*

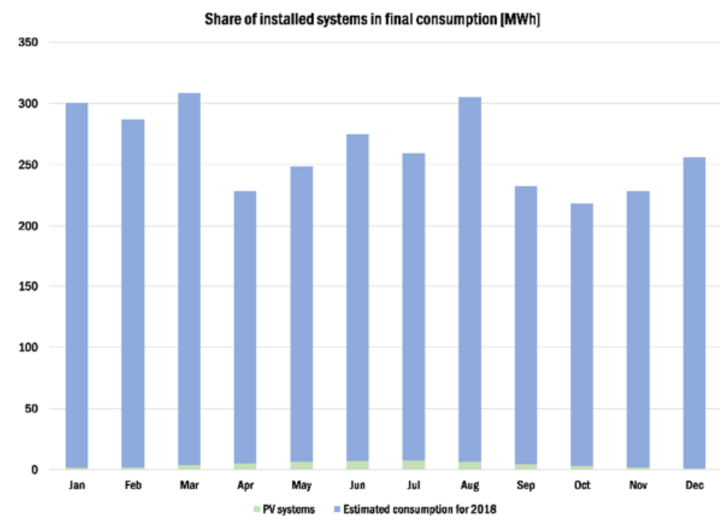


Figure 7.2 *Comparison of the estimated consumption for 2018 and PV system generation for the Radiology Clinic*

The Figure 7.3 shows the estimated energy production of the PV system that will be installed on the rooftop of the Emergency Center and Hospital parking. Highest production around 30 MWh will be in July, as expected. In Figure 7.4 a comparison of the total consumption for 2018 and the estimated values of PV system generation in MWh, is shown for Emergency Center. The highest share of the PV systems in final consumption is for the month of May, around 14% while the lowest is during December, approximately 2.3%.

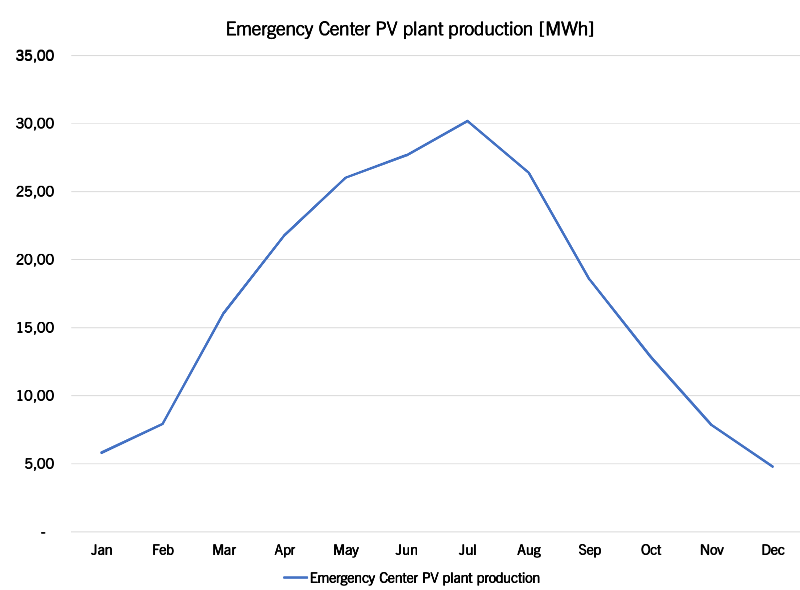


Figure 7.3 *Emergency Clinic and Hospital parking PV plants production*

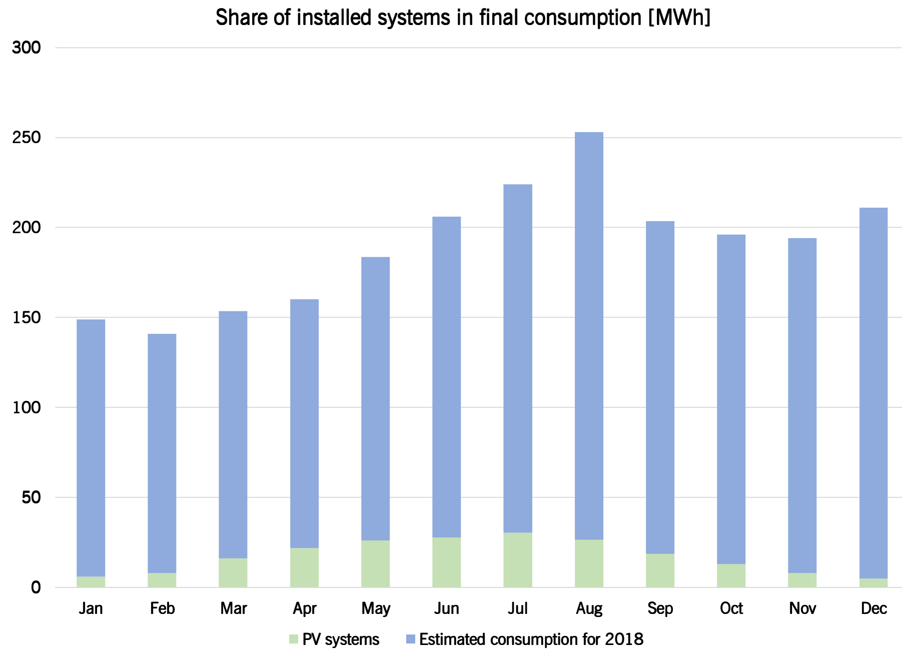


Figure 7.4 *Comparison of the estimated consumption for 2018 and PV system generation for the Emergency Center*

The Figure 7.5 shows the estimated share of thermal energy generated from the solar thermal system for the hot water preparation. If the daily water consumption is estimated at 3000l, the highest share can be expected in Jun and August with 59 %, while the lowest is in November, December and January with 26 %. Total yearly share is just above 40 %.

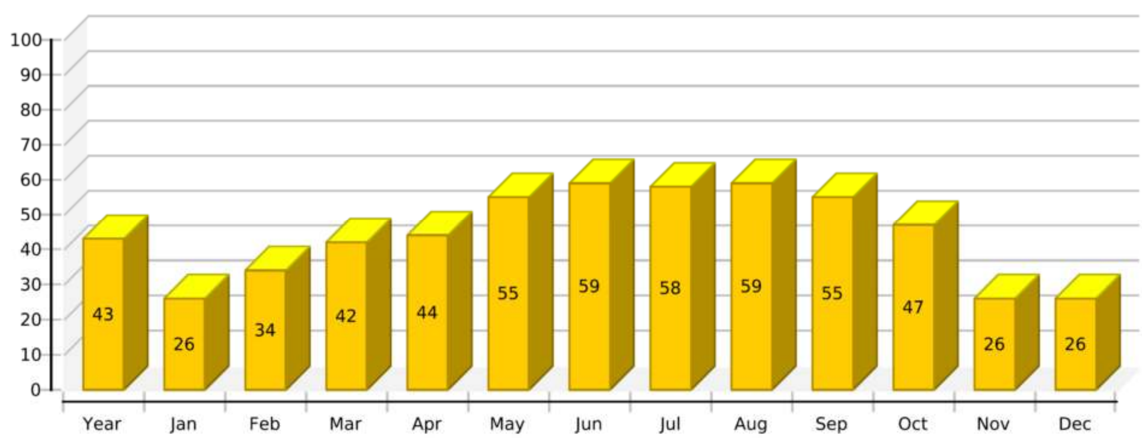


Figure 7.5 *Estimated share of solar thermal system in hot water preparation [in %] [28]*

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