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Rescue

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 1: Faculty of Technical sciences public building -

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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
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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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1. Introduction

Energy consumption is constantly increasing since the global population rises and due to the development of industrial sectors, leaving fossil fuel reserves depleted and climate change seriously impacted. Fossil fuels are still dominantly employed for energy harvesting, but finite supply and numerous problems with energy exploitation imply that new solutions have to be incorporated in the energy production process.

Not only that fossil fuels reserves are limited, harder to locate and expensive to transport, but their negative influence on the environment requires active participation in increasing energy efficiency, finding and exploiting of alternate 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.

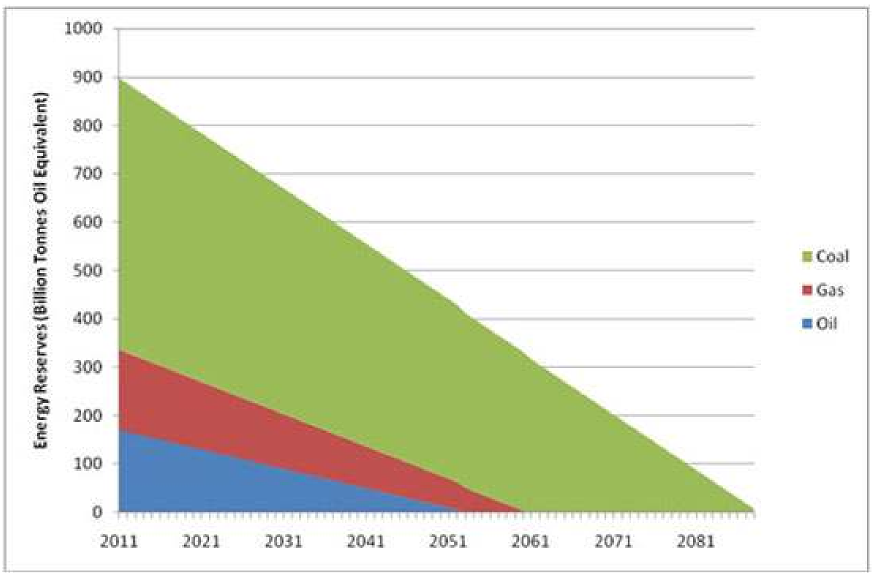


Figure 1.1 The prediction of fossil fuel energy reserves [1].

One of the biggest issues associated with the combustion of fossil fuels is carbon emission. In Figure 1.2 carbon dioxide (CO_2) 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 CO_2 concentration.

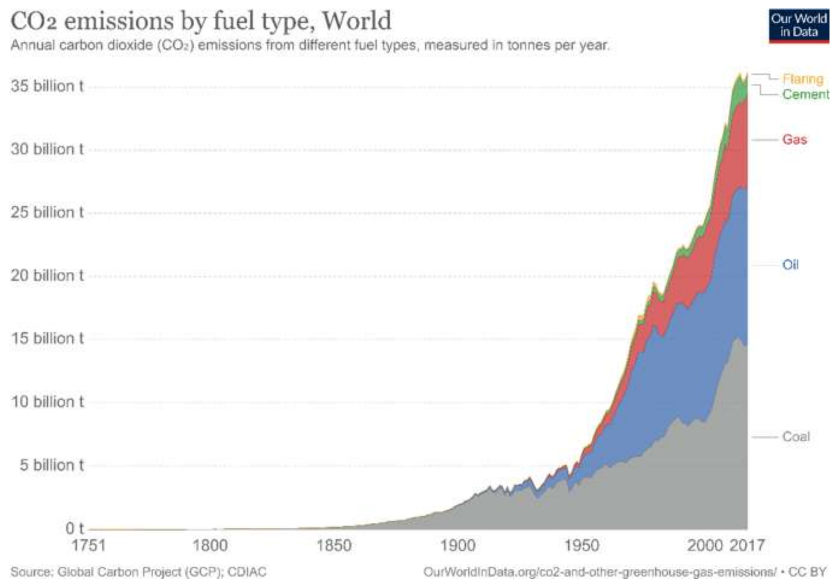


Figure 1.2 Carbon dioxide (CO_2) emission by a specific type of fossil fuel [2].

Carbon dioxide is a major greenhouse gas and thus extremely contributes to 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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's estimated 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 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 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.

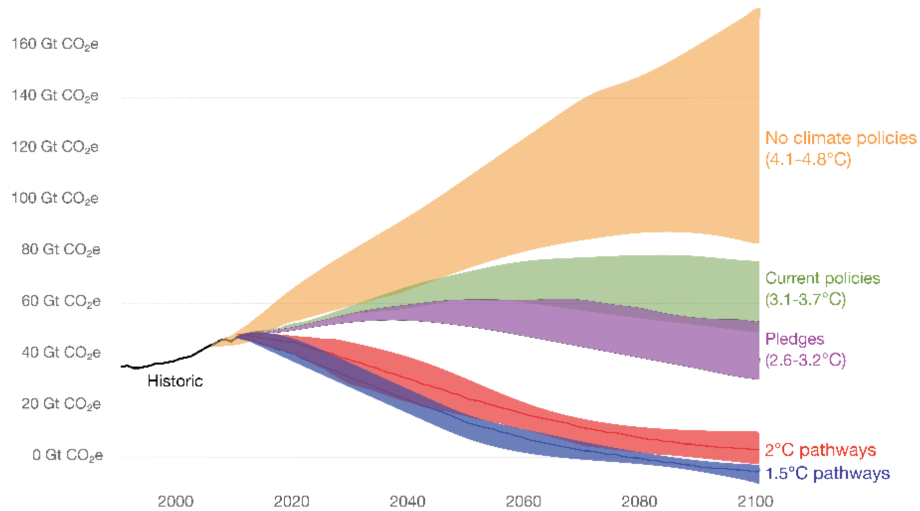


Figure 1.3 The prediction of the CO_2 emission based on different scenarios [2].

According to the HCWH (Health Care Without Harm) Europe climate report published in Dec 2016 [5], the health sector is a major emitter of 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 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 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 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 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].

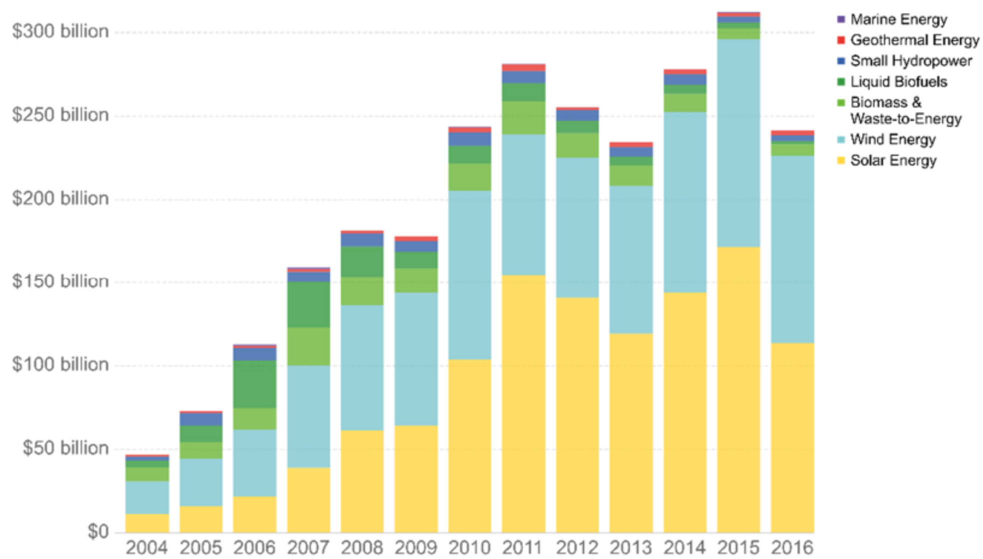


Figure 1.4 Investment in different renewable energy technologies [6].

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 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 world electricity by 2050, which is depicted in Figure 1.5 [8].

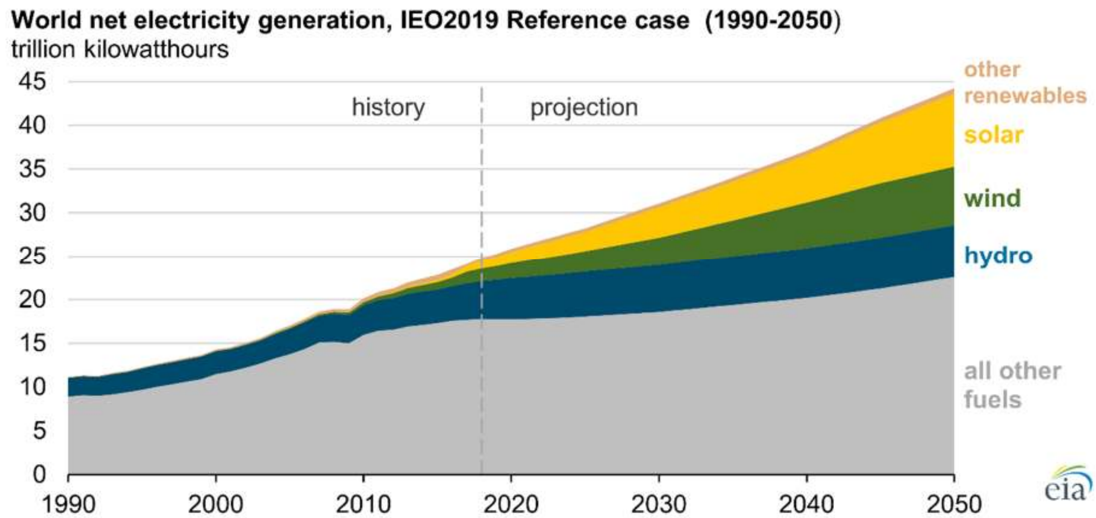


Figure 1.5 World net electricity generation [8].

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 solar PV and wind energy are going to increase significantly beyond 2030, the role of storage is crucial in providing an uninterrupted energy supply.

Following the CO_2 reduction tendency, vehicles that run on fossil fuels should be replaced with electric-powered vehicles. Although currently electric vehicles are more expensive than gasoline-powered 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 we will begin to get some economic return on our initial investment.

The reduction of greenhouse gasses would help in the decrease in environmental pollution that has become a severe problem. Another measure that can be taken is waste management – a series of actions that aim to reduce the generation and promote the reuse and recycling of solid and hazardous waste. Another benefit that can be obtained is energy recovery. Energy recovery from waste 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 public buildings. This results in substantial energy savings and therefore less usage of fossil fuels. This strategy is recognized and adopted by a number of countries worldwide. A zero-energy building would be a preeminent goal. Of course, this is not possible without the renewables which should cover a part of energy necessities. In order to monitor and control the energy consumption of buildings, Building Energy Management Systems (BEMS) are crucial. BEMS provide real-time remote monitoring and integrated control of a wide range of connected systems, allowing modes of operation, energy use, environmental conditions and so on to be monitored and allowing to optimize performance and comfort. To function correctly they

must be properly designed, installed and commissioned and must have a user interface that is easy to operate.

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

Regarding the abovementioned, it is clear how important is to invest in and implement new technologies that enable higher energy efficiency and thus reduce the impact on climate change and provide energy savings. In order to achieve this, it is necessary to analyze the energy performance profile and determine which elements are critical. This document provides a study of energy demand and energy efficiency for the exemplary facility and inspects the possibility of integration of renewables in order to reduce 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].

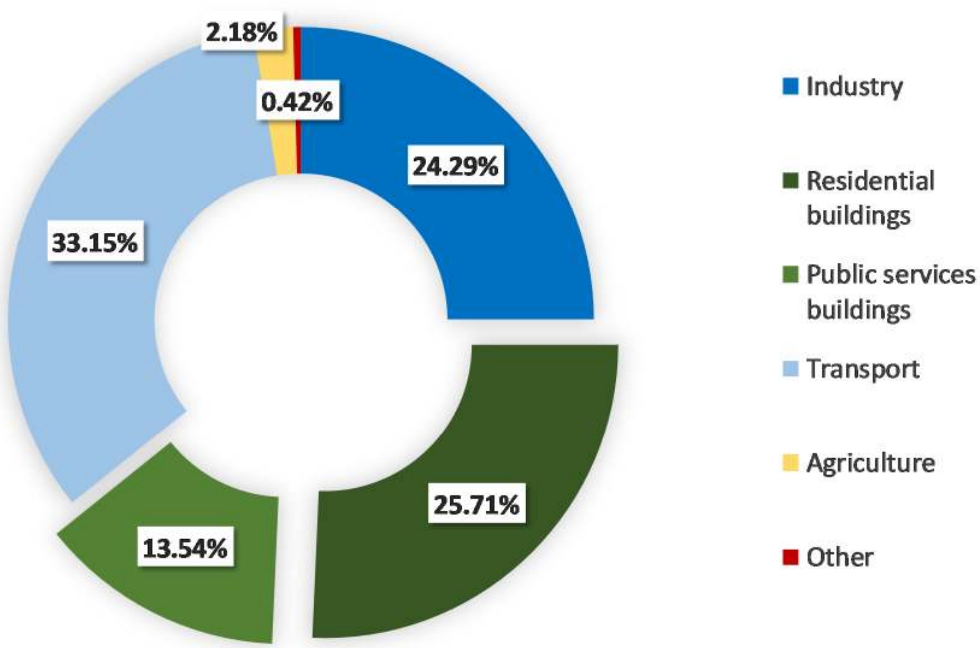


Figure 2.1 Energy consumption by sector in the EU [11].

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."

Reffering 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 then 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.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

"Mašinski institut" facility is located within the campus of the University of Novi Sad and represents one of the nine buildings of the Faculty of Technical Sciences. The facility is located in the South Bačka District, which is one of seven administrative districts of the autonomous province of Vojvodina, Serbia. "Mašinski institut" is located in Liman I, part of the city of Novi Sad, at Vladimir Perić Street No. 2. The geographical coordinates of the facility are north latitude 45° 14' 44.82" and east longitude 19° 51' 01.59", as shown in Figure 3.1 (*source: google.com/maps*).

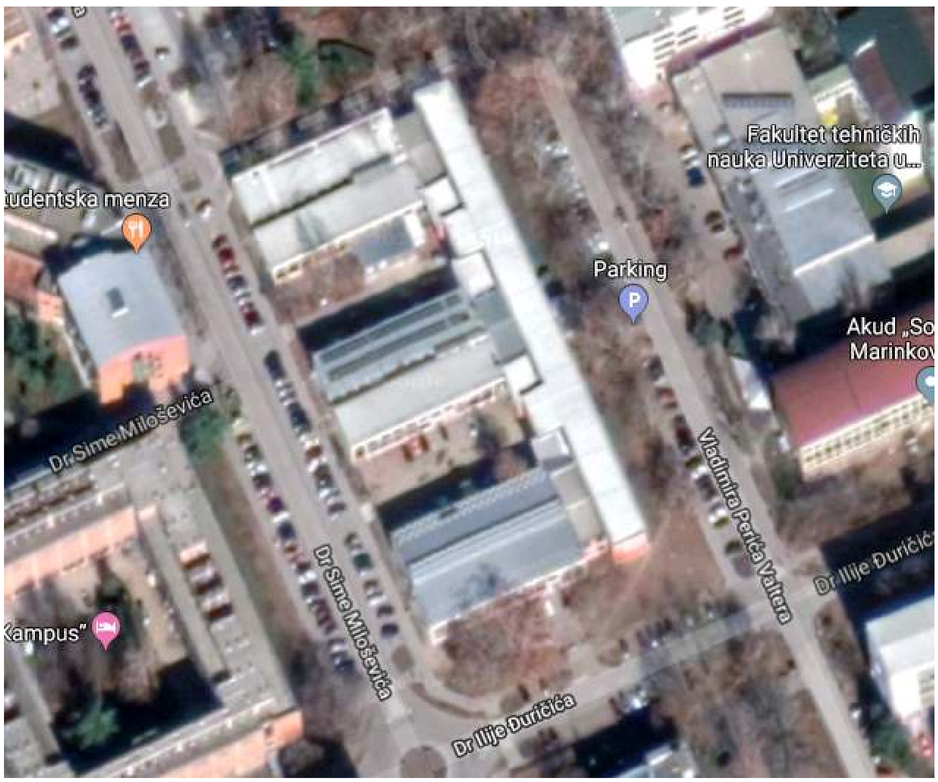


Figure 3.1 Location of "Mašinski institut" facility.

"Mašinski institut" is located at C.P. 3657, C.M. Novi Sad II, as shown in the situational plan given in Figure 3.2 (*source: a3.geosrbija.rs.*). Near the institute is a Student Center with the two student dormitories, the student canteen and the Institute for Student Health Care in Novi Sad. Besides, near the institute is Public Utility Company "Informatika", as well as the central building of the Faculty of Technical Sciences, the Novi Sad School of Business – Higher Education Institution for Applied Studies, the public transport stop and taxi stand.

The Institute consists of a two-story building equipped with laboratories, with a total area of 7225 m^2. The facility is divided into 98 offices, 42 laboratories, 9 computer laboratories

and 24 classrooms. The main entrance to the building, part of the building with laboratories and classrooms, as well as the roof of the "Mašinski Institut" facility, where the photovoltaic power plant is located, are given in the figures below.

Figure 3.2 The main entrance to "Mašinski institut".

Figure 3.3 Part of "Mašinski institut" with laboratories for scientific research.

Figure 3.4 Part of "Mašinski institut" with classrooms and offices.

The "Mašinski institut" 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 (AD3 toilets)
AE Presence of foreign solids:	AE2
AF Presence of corrosive substances or contaminants:	AF3
AG Mechanical stresses - Impact:	AG2
AH Mechanical stresses - Vibrations:	AH2
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 Airmovement:	AR1
AS Wind:	AS1

- Usage

BA Occupants proficiency with equipment:	BA4
BD Emergency evacuation conditions:	BD3
BE The nature of the processed or stored materials:	BE1

– Building construction

CA Construction materials: CA1

CB Object structure: CB1

The Faculty of Mechanical Engineering established the "Mašinski Institut" as an independent organization on January 26, 1966. The construction of the facility began in 1963 and was completed in 1967. The basic role of the facility was to provide space for laboratories, as well as for the organization of teaching and research work in the field of mechanical engineering. Since 1966, to this day, the number of students and employees has grown constantly. With the increase in the number of people, the need for space grew, which affected the redevelopment of the original facility. Thus, a number of modern laboratories and classrooms have been made, through several adaptations of the facility. In this way, the number of rooms required for teaching and research work has been increased.

The energy efficiency assessment covers the parts of a facility owned by the Faculty of Technical Sciences, which are in the function of maintaining all teaching activities for students, spaces for scientific research, entrance halls and rooms for general and legal affairs.

Most of the time, especially while performing general tasks, employees and faculty members work in offices. An example of an office is given in Figure 3.5. Offices are usually equipped with computers and air conditioners, while depending on the case they may have other smaller consumers. Offices contain between 1 and 5 workplaces, usually 3.

In addition, most teaching activities are performed in classrooms. An example of one classroom with 28 students and 1 teaching position is given in Figure 3.6. The number of student places in classrooms varies between 20 and 30 places, most often having 24 students and 1 teaching position. Some classrooms contain computers and projectors, but the largest consumption is mainly the lighting system.

Figure 3.5 – Office with one workplace.

Figure 3.6 – Classroom with 24 students and 1 teaching position.

Figure 3.7 shows an example of a computer laboratory classroom. The classroom is used to teach and to test students' knowledge using appropriate software. The computer laboratory classrooms have 14, 16, 24 or 32 places for students, as well as one place for teaching staff. In accordance with the purpose of the space, computers are the most

common consumers and due to their large number, the power supply to these classrooms must be carefully carried out.

Figure 3.7 – Example of one computer lab classroom.

Figure 3.8 shows an example of a single laboratory. The laboratory is a space intended for experimentation in a controlled environment for the purpose of practical teaching of students, as well as for scientific research work. The equipment in the laboratories, depending on their purpose (study program) may be different, but often the consumers of the highest power are located in these rooms. Of course, this does not have to mean the highest power consumption, since the operation of the devices in laboratories is generally short. In addition to the specific consumers, neither lighting nor a certain number of computer sites should be neglected.

Figure 3.9 shows general-purpose spaces such as communication spaces. The most common type of consumers in these areas is lighting and consumers of plumbing infrastructure.

Figure 3.8 – An example of a laboratory for electric machines and power electronics.

Figure 3.9 – General purpose rooms.

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 3.10 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.

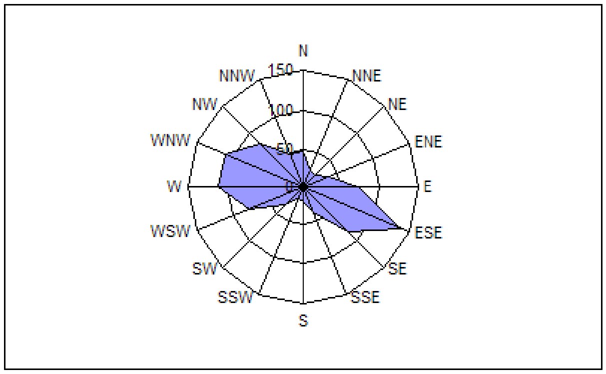


Figure 3.10 – Rose wind for Novi Sad.

Table 3.1 shows the mean values of monthly, annual and extreme climatological values in the period from 1981 to 2010 (according to data of the Republic Hydrometeorological 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 i 19°51E, n. v. 84 m)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Avg**	**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/m²]	53.1	71.8	131	161	173	180	201	198	146	113	76.3	45.9	129.2
Precipitation [mm/m²]													
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/m²	12	10	11	12	13	12	10	9	10	9	11	13	132
Mean number of days >=10 mm/m²	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

3.3. Description of the construction characteristics of the public building

The structure of the building is reinforced concrete (AB) - skeletal (columns, beams, ceilings), with masonry walls. Sewerage was carried vertically through the building and below the ground floor. Due to the deterioration of the sewage installation beneath the floor of the building, there is an intense leakage and flushing of the soil below the foundation and some uneven settling, which is manifested by cracks on the walls (Figure 3.11). The interior surfaces of the walls have partially collapsed due to leaks. Exterior walls are made of multi-layer: 25 cm brick plastered on both sides or 15 cm concrete, plastered on both sides.

Figure 3.11 – Manifestation of uneven flushing and leaking.

The joinery is made of steel profiles with a transparent glass 4 + 12 + 4 (air), which is shown in Figure 3.12.

Figure 3.12 – Appearance of used joinery made of steel profiles.

The climatic data relevant to the study and the location of the facility at the micro site are given in Table 3.2.

Table 3.2 – The climatic data for analysis and the location of the facility.

The climatic data	
Location	Novi Sad
Heating days degree number *HDD*	2679
Number of days of heating season *HD*	181
Mean heating period temperature $\theta_{H,mn}$[°C]	5.2
Internal temperature for winter period $\theta_{H,i}$ [°C]	20
Wind effect	
Position (wind exposure)	Moderately sheltered
Number of facades exposed to the wind	More than one facade

3.3.2. Building comfort conditions

Thermal comfort is ensured by thermal zoning of the building, as urban conditions and design have allowed at the time of construction. External design temperatures for Novi Sad were used in the calculations.

The air comfort in the building is provided by natural ventilation and floor height. Since the windows are mostly steel, without thermal break, the sealing is poor.

Light comfort in the building is ensured by the introduction of natural light through large transparent surfaces as well as the use of artificial lighting.

Sound comfort is ensured by the application of rubberized floor coverings.

3.3.3. Thermal characteristics of the building insulation

According to the design characteristics, the heat transfer coefficient of the outer wall is 1.326 W/m^2 ^{0}K, and the thermal characteristics of the materials that make up this wall are shown in the following figure.

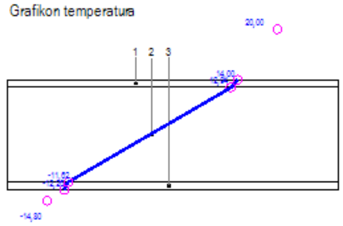
Oznaka sklopa: SZ, Tip konstrukcije: Spoljni zid, Deo termičkog omotača

Rsi=0,13 m²K/W ; Rse=0,04 m²K/W ; ν min=15 ; η min=7 ; U max=0,4 W/m²K ; Fx=1 ; α=0
Površina sklopa A= 0 m² (Istok 0, Jug 0, Zapad 0, Sever 0, Horizontalna 0 m²)
Površina u stalnoj senci Ash =0m²

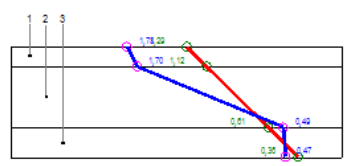
n.	d [cm]	Opis	ρ [kg/m³]	c [J/kgK]	λ [W/mK]	μ [-]
1	2	Produžni krečni malter	1800,0	1050,0	0,870	20,0
2	25	Opeka puna	1200,0	920,0	0,470	5,0
3	2	Cementni malter	2100,0	1050,0	1,400	30,0

n.	d [cm]	Opis	R [m²K/W]	Δθ [ºC]	θ [ºC]	Δθ.dif [ºC]	θ.dif [ºC]	Δp [kPa]	p' [kPa]	p i/e [kPa]	r [m]	S24 [W/m²K]	D [-]	u24 [W/m²K]
/	/	Unutra	/	/	20	/	20	/	2,337	/	/	/	/	/
/	/	Prelaz	0,13	6,000	14,000	4,310	15,690	0,554	1,783	1,285	/	/	/	/
1	2	Produžni krečni malter	0,023	1,062	12,938	0,763	14,927	0,085	1,697	1,121	0,400	10,90	0,25	9,06
2	25	Opeka puna	0,532	24,554	-11,615	17,639	-2,712	1,210	0,487	0,608	1,250	6,12	3,26	6,12
3	2	Cementni malter	0,014	0,646	-12,262	0,464	-3,176	0,019	0,469	0,361	0,600	14,93	0,21	8,52
/	/	Prelaz	0,04	1,846	/	1,326	/	0,067	/	/	/	/	/	/
/	/	Spolja	/	/	-14,8	/	-5,0	/	0,401	/	/	/	3,72	/
/	/	Ukupno	0,754	/	/	/	/	/	/	/	/	/	13,96	/

Grafikon temperatura



Grafikon difuzije
debljina slojeva je srazmerna sa difuznim otporom slojeva



Provera letnje stabilnosti
Faktor prigušenja amplitude oscilacije temperature ν= 23,0 >= ν.min= 15 , sklop zadovoljava
Faktor kašnjenja amplitude oscilacije temperature η= 9,9 >= η.min= 7 , sklop zadovoljava

Provera kondezacije
Kondezacija u sloju 2, ; 13,0 dana za isušenje ; Isušenje u roku od 90dana

Provera koeficijenta prolaza toplote
Osnovni U= 1,326 W/m²K

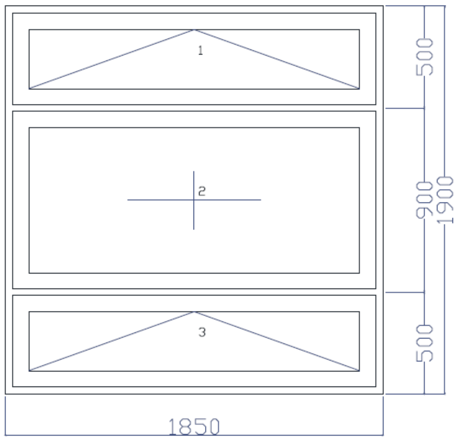
U= 1,326 W/m²K, U max=0,4 W/m²K, U > Umax, sklop NE zadovoljava

ELABORAT ENERGETSKE EFIKASNOSTI ZGRADE Novi Sad, Trg Dositeja Obradovića 6

Figure 3.13 – Calculation of thermal characteristics of the outer wall - report

The thermal characteristics of the materials that make up the portals on the exterior wall are given in Figure 3.14 and Figure 3.15.

Sklop Č1 (POS-1)

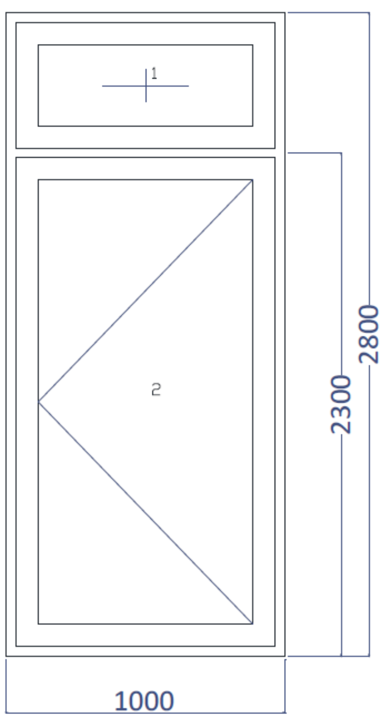


Koficijent prolaza toplote U [W/(m^{2}K)]	3,836
Faktor rama (F_{fr})	0,279
Površina [m^2]	3,515

Opis
Čelični ram bez termičkog prekida sa dvostrukim prozirnim staklom 4+12+4 (vazduh) bez sloja za poboljšanje

Figure 3.14 – Calculation of thermal characteristics of the portal - frame Č1.

Sklop Č2 (POS-2)



Koficijent prolaza toplote U [W/(m^{2}K)]	3,732
Faktor rama (F_{fr})	0,244

Opis
Čelični ram bez termičkog prekida sa dvostrukim prozirnim staklom 4+12+4 (vazduh) bez sloja za poboljšanje

Figure 3.15 – Calculation of thermal characteristics of the portal - frame Č2.

The thermal characteristics of the floors are given in Figure 3.16.

Sklop P1 (Basement floor)

Heat transfer coefficient *U* [W/(m²K)]	**4,372**
Area [m2]	
Northside	-
Eastside	-
Southside	-
Westside	--
Ventilation	Not Ventilated

Construction of frame P1

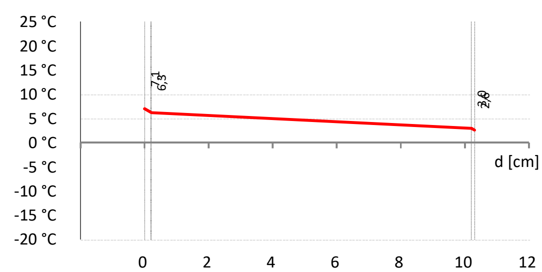
rR. b.	**Name of the construction layer**	**δ [cm]**	**λ [W/mK]**	**ρ [kg/m3]**	**μ [-]**
1	Linoleum	0,2	0,190	1200	500
3	Concrete	10,0	2,330	2500	90
5	Bituminous cardboard	0,1	0,190	1100	2000

Temperature calculation

$\theta = \theta_i - (\theta_i - \theta_e) \cdot F_x = 20-(20-(-14,8)) \cdot 0,5 = 2,60o$ °C

Tempearture DEW point θ_s = *10.68 °C*

Description	**λ [W/mK]**	**R [(m²·K)/W]**	**Δθ [°C]**	**θ [°C]**
Inside				20
Transition		0,17	12,934	7,07
Linoleum	0,190	0,011	0,801	6,27
Stone aggregate concrete	2,330	0,043	3,265	3,00
Bituminous cardboard	0,190	0,005	0,400	2,60
Transition			0,000	2,60
Outside				2,60
Total resistance		0,229		



Note: Because the surface temperature is less than the dew point temperature, dew can occur.

Figure 3.16 – Calculation of floor thermal characteristics – report.

The thermal characteristics of the roof are given in Fig 3.17.

Sklop P3 (Roof construction)

Temperature transfer coefficient U [W/(m2K)]	**0,236**
Area [m2]	
Northside	
Eastside	
Southside	
Westside	
Ventilation	Not Ventilated
Ventilation parameters	-

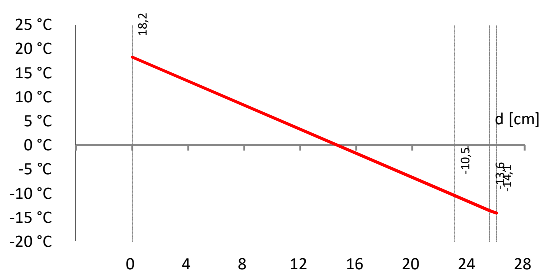
Construction of the frame P3a

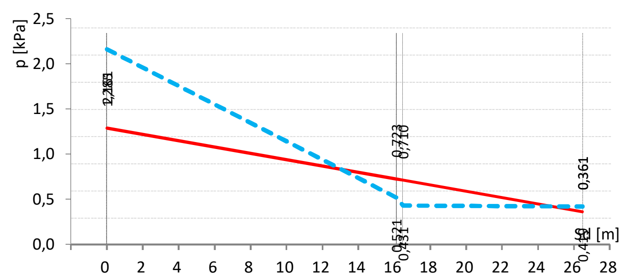
RR. b.	Name of the construction layer	δ [cm]	λ [W/mK]	ρ [kg/m3]	μ [-]
1	Wood – spruce, pine	23,0	0,140	550	70
2	Board	2,5	0,140	520	15
3	Roofing board tin	0,3	0,190	1100	2000

Temperature DEW point Θs = 10.68 °C

Description	λ [W/mK]	R [(m²·K)/W]	Δθ [°C]	θ [°C]	μ [-]	r [m]	$\Delta\theta_{dif}$ [°C]	θ_{dif} [°C]	p′ [kPa]	ps [kPa]
Inside				20				20	2,337	1,285
Transition		0,1	1,751	18,25			1,257707	18,74	2,161	1,285
Wood – spruce, pine	0,140	1,643	28,762	-10,51	70	16	20,66233	-1,92	0,521	0,723
Board	0,140	0,179	3,126	-13,64	15	0,4	2,245905	-4,17	0,431	0,710
Roofing board tin	0,190	0,026	0,461	-14,10	2000	10	0,330976	-4,50	0,419	0,361
Transition		0,040	0,700	-14,80			0,503083	-5,00	0,401	0,361
Inside				-14,80				-5,00		
Total resistance		1,988								

Temperature transfer coefficient U3a [W/(m²K)] 0,503





Condensation check

Condensation calculation	Condensatioj in the zone (layer 2 – board)
Drying time	27,02

Summer stability

	Value	Minimum	Satisfies
Oscillation amplitude damping factor - temperature *ν* [-]	166,8	25	Yes
Oscillation delay factor – temperature *η* [h]	15,4	10	Yes

Figure 3.17 – Calculation of thermal characteristics of the roof – report.

3.3.4. Thermal examination of the facility

In order to fully examine the condition of the outer sheath, thermal inspection of one part of the building was performed. This examination covers the most important circuits as well

as the thermal envelope of the building. For thermal imaging, a Flir T640bx camera with two lenses and a base optic of 25° x 19° /0.25 m and a wide-angle lens f = 13.1 mm 45 ° were used. Figure 3.18 shows the layout of the part of the facility for which a thermal examination was performed, and where it is possible to see the state of the portal (steel circuit) on the facility. The thermal preview of the facility, given in Figure 3.19, was performed at an outside temperature of 14 °C. The thermal imaging of the facility confirmed the calculations results of the heat transfer coefficient and it is evident that the portals used on the facility are extremely energy inefficient. It is also possible to notice that parts of the sheath require energy remediation, given the unwanted heat flow.

Figure 3.18 – External wall thermal measurement - the part of the facility for which a thermal inspection was performed.

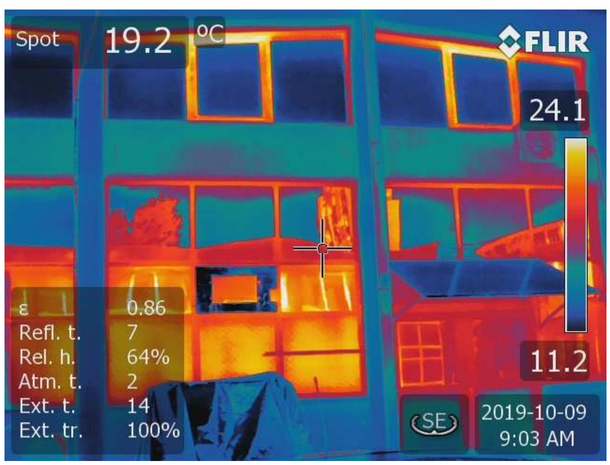


Figure 3.19 – External wall thermal measurement - thermal imaging.

4. Current energy demand overview for the public building

4.1. The electrical infrastructure of the exemplary object and consumption analysis

In order to implement different strategies for the increase of energy efficiency, it is necessary to analyze the electrical installation infrastructure of the object, as well as existent power supply units and the consumption of electrical energy in the exemplary object.

Here, "Mašinski institut", as a part of the building complex of the Faculty of Technical Sciences in Novi Sad, will be referred to as exemplary object.

4.1.1. The power supply of the "Mašinski institut"

"Mašinski institut" is supplied from the transformer station located within the object. The transformer station is placed in the ground level of the object, near the main entrance, in a hallway on the right side of the building called the "G" sector. The transformer station is called "TS Mašinski fakultet" and a three-phase oil transformer with a nominal power of 630 kVA, a turn ratio of 10/0.4 kV/kV and a Yy0 transformer connection was used for the object power supply. In Figure 4.1, the transformer station is depicted.

Figure 4.1 Transformer station "TS Mašinski fakultet".

Aluminum cable with the 3x150 mm^2 cross-section was used as a high-voltage cable. On the low-voltage side copper busbar 3x(2x80x5) + 1x(80x5) mm^2 was used. The main circuit breaker is set to the nominal value of the 1250 A. Single line diagram of the transformer station is illustrated in Figure 4.2.

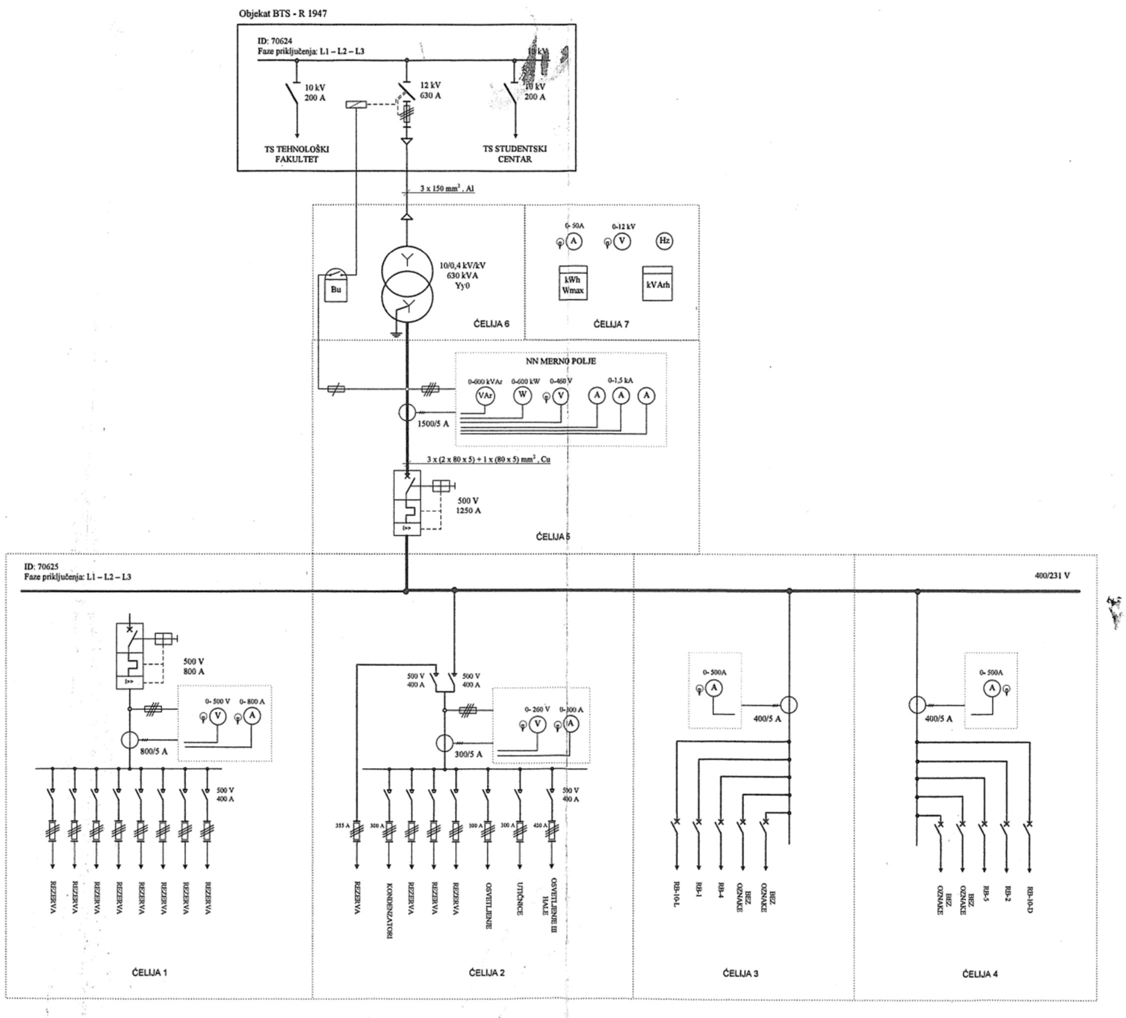


Figure 4.2 Transformer station single line diagram.

Table 4.1 shows all outgoing feeders on the low-voltage side of the transformer, together with the cross-sections of the cable lines. These feeders are used to supply different blocks of the “Mašinski institut”. The low-voltage side of the transformer is constituted from five cells and the main circuit breaker with the nominal current 1250 A is placed in the first cell.

In the second cell, five feeders are located and three of them have a reserve function. Feeders RB-2 and RB-3 are connected to the circuit breaker with nominal current 320 A and cable type PP00-Y 4x185mm^2 is used. Feeder RB-10-D has reserve function and is supplied with the PP00-Y 4x150mm^2 cable. Two more feeders have the same function and one is supplied from the 320 A circuit breaker, while the other is supplied from the contactor.

In the third cell, five outgoing feeders, supplied from the circuit breakers with nominal current 320 A, are located. For the feeder RB-10-L cable type PP00-Y 4x150mm^2 was used and for the feeders RB-1 and RB-4 the type PP00-Y 4x185mm^2 was employed. Two remaining feeders withe the cable type PP00-Y 4x150mm^2 are used as a reserve.
In the fourth cell, there are eight feeders and only one is used as a reserve. For the reserve feeder, as a protective element, fuse with nominal current 200 A and gG characteristics is used. The second feeder is protected with fuse with nominal current 100 A and gG characteristics and the used cable type is PP00-Y 4x50mm^2. The fuse with current 200 A and gG characteristic and cable PP00-Y 4x185mm^2 were used for the third feeder and for the fourth feeder 35 A, gG fuse and cable PP00-Y 4x16mm^2. The fifth and sixth feeder are protected with 200 A, gG fuse and the used cable type is NAYY-J 4x50mm^2. The same fuse was used for the protection of the seventh feeder, but here the cable type is NAYY-J 4x70mm^2. The fifth cell is the reserve.

Table 4.1 An overview of the feeders located on the low-voltage side of the transformer station.

Cell	Breaker mark	Nominal breaker current [A]	Cable type	Note
2	RB-10-D	Breaker not installed	PP00-Y 4x150mm2	Reserve
2	RB-2	320	PP00-Y 4x185mm2	
2	RB-5	320	PP00-Y 4x185mm2	
2	-	320	PP00-Y 4x150mm2	Reserve
2	-	Breaker not installed		Reserve
3	RB-10-L	320	PP00-Y 4x150mm2	
3	RB-1	320	PP00-Y 4x185mm2	
3	RB-4	320	PP00-Y 4x185mm2	
3	-	320	PP00-Y 4x150mm2	Reserve
3	-	320	PP00-Y 4x150mm2	Reserve
4	-	200A gG	PP00-Y 4x185mm2	Feeder 1 - Reserve
4	-	100 A gG	PP00-Y 4x50mm2	Feeder 2
4	-	200A gG	PP00-Y 4x185mm2	Feeder 3
4	-	35A gG	PP00-Y 4x16mm2	Feeder 4
4	-	200A gG	NAYY-J 4x50mm2	Feeder 5
4	-	200A gG	NAYY-J 4x50mm2	Feeder 6
4	-	200A gG	N2XH-J 4x70mm2	Feeder 7
5	-			Feeder 8 - Reserve

All active feeders are employed to supply different areas in the “Mašinski institut” (such as laboratories, teaching rooms, offices, etc.) through the distribution cabinets placed in

the various locations in the object. Regarding the installation time and maintenance of the distribution cabinets, different conditions of the cabinets were noticed during the visual inspection of the object. Some cabinets completely lost functionality and became inefficient and thus represent a danger for both the users and the equipment.

Figure 4.3 Distribution cabinets in the Machine Insitute.

Considering that the object was connected to the power grid infrastructure during the object construction period (the year 1967), the document that provides the permission for the object connection was not available for this study at the time of creation.

4.1.2. Description and classification of the consumers in the object

In the exemplary object, various rooms are located with different types of electrical consumers. In this section typical consumer types are described and the lighting system, as the most common consumer, is described in the separate section.

One of the most important types of electrical consumers are computers, shown in Figure 4.4. Computers are usually placed in laboratories and teaching rooms. Approximately 600 computers are located in 98 cabinets and 9 computer laboratories.

Figure 4.4 Typical computer from the teaching room.

For the temperature control and ventilation of the rooms, air conditioning systems are usually used. These systems can use a significant amount of power, especially when the climate conditions imply long times of active work. In the exemplary facility, there are 135 air-conditioning units, with the individual capacity of 12000 BTU, as well as one central climate control device. Figure 4.5 shows one typical air-conditioning device in the exemplary object.

Figure 4.5 The indoor and outdoor unit of the air-conditioning system.

Further, in the laboratories, there are different devices and equipment dedicated to practical teaching and research activities. Bellow some of the most important devices will be given.

Figure 4.6 shows the welding aperture with the nominal power of 120 kVA. This aperture is located in the welding laboratory and is used for the student training courses.

Figure 4.6 Welding aperture.

Figure 4.7 depicts the hydraulic dynamic test machine used to test elasticity and strain of different materials. The power of this device is 30 kW and it is used for the teaching and research activities.

Figure 4.7 Hydraulic dynamic test machine.

A part of the equipment in the machine-processing laboratory is shown in Figure 4.8 and Figure 4.9. Besides the consumers, machine plates with important technical data such as nominal power and efficiency can be seen in figures. The power of the drill depicted in Figure 4.8 is 15 kW. A molding device is a CNC machine and the power of this machine is 10 kVA.

Figure 4.8 Pillar drill machine and its plate.

Figure 4.9 Moulder machine and its plate.

One of the laboratories in the exemplary object is the laboratory for the machine commissioning. The experimental setup for the commissioning of the synchronous machines, placed in this laboratory, is depicted in Figure 4.10. This setup is used in the practical courses for students.

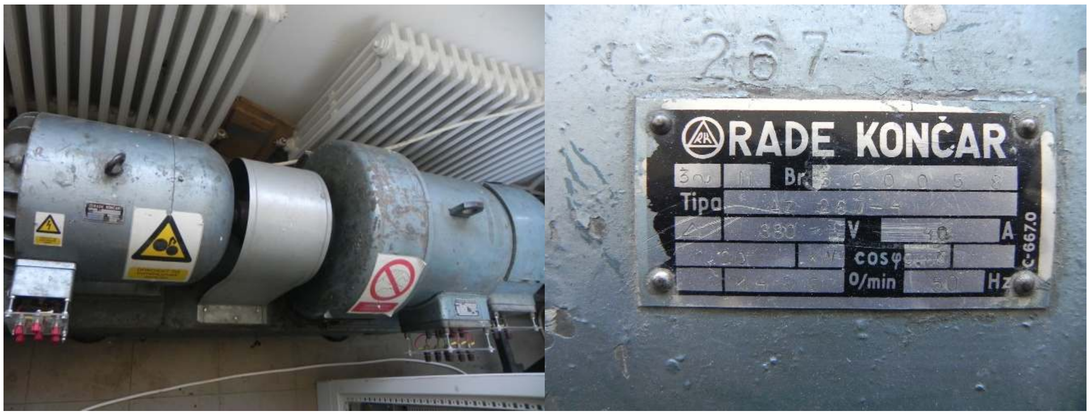


Figure 4.10 Laboratory setup for synchronous machine commissioning.

4.1.3. Lighting system

The lighting system in the exemplary object is based on the incandescent and fluorescent light bulbs. During the visual inspection of the object, it is concluded that there are 25 different types of lights. A brief description of the lights used is given in Table 4.2.

Table 4.2 Description of different types of light.

Light type	Description
Type 1	Installation type: Ceiling light Optics: Metalic diffuser Light sources: 1 fluo TL-D source 36 W Electromagnetic ballast Total number: 20
Type 2	Installation type: Ceiling light Optics: Metalic diffuser Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 10
Type 3	Installation type: Ceiling light Optics: Metalic diffuser

Light type	Description
	Light sources: 3 fluo TL-D sources 36 W Electromagnetic ballast Total number: 50
Type 4	Installation type: Ceiling light Optics: No diffuser Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 13
Type 5	Installation type: Ceiling light Optics: No diffuser Light sources: 3 fluo TL-D sources 36 W Electromagnetic ballast Total number: 34
Type 6	Installation type: Ceiling light Optics: No diffuser Light sources: 4 fluo TL-D sources 36 W Electromagnetic ballast Total number: 15
Type 7	Installation type: Ceiling light Optics: No optics Light sources: 1 fluo TL-D source 36 W Total number: 21
Type 8	Installation type: Ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 158
Type 9	Installation type: Ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 8
Type 10	Installation type: Ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 7
Type 11	Installation type: Ceiling light Optics: Aluminum raster

Light type	Description
	Light sources: 1 fluo TL-D source 36 W Electromagnetic ballast Total number: 2
Type 12	Installation type: Ceiling light Optics: Plastic diffuser Light sources: 3 fluo TL-D sources 58 W Electromagnetic ballast Total number: 26
Type 13	Installation type: Ceiling light Optics: Aluminum raster Light sources: 4 fluo TL-D sources 18 W Electromagnetic ballast Total number: 29
Type 14	Installation type: Built-in ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 71
Type 15	Installation type: Ceiling light Optics: Aluminum diffuser Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 8
Type 16	Installation type: Built-in ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 124
Type 17	Installation type: Built-in ceiling light Optics: Aluminum raster Light sources: 4 fluo TL-D sources 18 W Electromagnetic ballast Total number: 144
Type 18	Installation type: Ceiling light Optics: Aluminum raster Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 287

Light type	Description
Type 19	Installation type: Wall reflector Optics: Safety glass Light sources: 1 metal-halogen source 100 W Total number:23
Type 20	Installation type: Ceiling light Optics: Plastic diffuser Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Note: Increased level of protection Total number: 18
Type 21	Installation type: Ceiling light Optics: Metalic diffuser Light sources: 1 halogen bulb 250W Total number: 3
Type 22	Installation type: Ceiling light Optics: Aluminum raster Light sources: 3 fluo TL-D sources 36 W Electromagnetic ballast Total number: 28
Type 23	Installation type: Ceiling light Optics: Aluminum raster Light sources: 4 fluo TL-D sources 36 W Electromagnetic ballast Total number: 9
Type 24	Installation type: Ceiling light Optics: Plastic diffuser Light sources: LED source 20 W Electromagnetic ballast Total number: 12
Type 25	Installation type: Ceiling light Optics: Plastic diffuser Light sources: 2 fluo TL-D sources 36 W Electromagnetic ballast Total number: 23

4.1.4. Analysis of the energy consumption

In order to establish appropriate measures for the enhancement of energy efficiency, it is necessary to analyze the energy consumption in the exemplary object. A detailed analysis is given for the period from January 2018 to December 2018. This period is chosen as a reference since it covers the entire faculty year (2 semesters), calendar year and all seasons. During the analysis, all relevant parameters for the energy consumption were taken from the electricity bills for the exemplary object. One electricity bill with the most important parameters is given in Figure 4.11. It can be seen that the bill is split into 5 segments.

1. ОЧИТАНЕ ВРЕДНОСТИ 1

Број бројила	Датум очитавања	Обрач. величина	Стање бројила				Обрач. константа	Коеф. свођења	Енергија за обрачун		Стање макс.	Константа максигр.	Коеф. свођења снаге	Снага (kW)
			Претходно стање		Ново стање									
			ВТ	НТ	ВТ	НТ			ВТ	НТ				
10630417	01.07.2019	kWh	1.720,789	395,503	1.774,175	404,316	800		42.709	7.050	0,257	1		205,6
	01.07.2019	kVArh	702,051	120,226	723,141	122,849	800		16.872	2.098				

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	42.709			7,800000	333.130,20
2	Активна електрична енергија у НТ	kWh	7.050			5,020000	35.391,00
	Укупно за испоручену електричну енергију:						**368.521,20**

3. ОБРАЧУН ЗА ПРИСТУП СИСТЕМУ ЗА ПРЕНОС/ДИСТРИБУЦИЈУ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ 3 Реактивна енергија за cosΦ(0.95) = 16.356

Р.бр.	Назив тарифе	Обрачунска величина	Количина за обрачун	Јединична цена (РСД)	Укупно (РСД)
1	2	3	4	5	6
1	Одобрена снага	kW	540	93,0270	50.234,58
2	Виша дневна тарифа за активну енергију	kWh	42.709	0,9710	41.470,44
3	Нижа дневна тарифа за активну енергију	kWh	7.050	0,3240	2.284,20
4	Реактивна енергија	kVArh	16.356	0,4540	7.425,62
5	Прекомерна реактивна енергија	kVArh	2.614	0,9070	2.370,90
6	Прекомерна снага	kW	0	372,1100	0,00
	Укупно за приступ систему за дистрибуцију електричне енергије:				**103.785,74**

4. ОБРАЧУН НАКНАДЕ ЗА ПОДСТИЦАЈ ПОВЛАШЋЕНИХ ПРОИЗВОЂАЧА ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ 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. енергије (Службени гласник РС бр.7 од 23.01.2015.године)	kWh	49.759	0,093	4.627,59
	Укупно накнаде за подстицај повлашћених произвођача електричне енергије:				**4.627,59**

5. РЕКАПИТУЛАЦИЈА ОБРАЧУНА 5

1	Испоручена електрична енергија	368.521,20
2	Приступ систему за пренос/дистрибуцију електричне енергије	103.785,74
3	Накнада за подстицај повлашћених произвођача ел.енергије	4.627,59
4	Основица за обрачун акцизе (4=1+2+3)	476.934,53
5	Износ обрачунате акцизе (стопа 7,5%) (5=4*0.075)	35.770,09
6	Основица за ПДВ (6=4+5)	512.704,62
7	Порез на додату вредност 20% (7=6*0.20)	102.540,92
8	Такса за јавни медијски сервис	0,00
9	Укупно за обрачун (9=6+7+8)	**615.245,54**

Figure 4.11 An example of the electricity bill for the exemplary object.

The first segment shows the parameters taken from electricity meters. The difference represents total energy consumption for the entire month. It is clear that the metering is double-tariff for active power. For the reactive power, although double-tariff metering is shown, the reactive power energy consumption is charged as it is a single rate tariff. Lower tariff is charged in the period from 0 am to 8 am during the summertime or between 11 pm until 07 am during the wintertime, while the higher tariff is charged in the remaining period. Regarding the purpose of the object, the highest consumption is during the higher tariff period.

The second segment presents calculated active power consumption for the month, considering the consumption in the lower and higher tariff, expressed in kWh, as well as the equivalent cost for the power usage expressed in dinars (RSD). It can be seen that the electricity contract price for the higher tariff is 7.80 RSD and for the lower tariff is 5.02 RSD.

The third segment is dedicated to the costs for the connection to the transmission or distribution power network, charged active power in both tariffs, charged reactive power, charged exceeding reactive power and exceeding active power. It can be seen that the reactive energy cost is 0.454 RSD for 1 kVArh, while the price for the exceeding reactive power is almost twice as high (0.907 RSD). For exceeding the maximal approved power, the amount of 372.11 RSD per 1 kW has to be additionally paid.

The fourth segment shows the special tariff for privileged electricity producers according to the Official Gazette of the Republic of Serbia num. 7 from 23rd January 2015, i.e. 0.093 RSD per 1 kW of the energy consumed.

The fifth segment is the recapitulation of the billed statements where previous segments are summarized, excise duty and value-added tax addressed.

Table 4.3 shows an overview of the power energy consumption from January 2018 to December 2018.

Table 4.3 Electrical energy consumption in the "Mašinski institut" during 2018.

	Consumption in higher tariff [kWh]	**Consumption in lower tariff [kWh]**	**Total consumption [MWh]**	**Total energy cost [RSD]**	**Total cost with taxis without VAT [RSD]**	**Total cost [RSD]**
Jan 2018	25,442.4	7,366.4	32.809	171,580.95	276,429.79	331,715.75
Feb 2018	21,521.6	5,973.6	27.495	144,201.81	240,571.87	288,686.24
Mar 2018	29,407.0	8,091.0	37.498	211,150.76	324,373.94	389,248.73
Apr 2018	27,434.0	6,653.0	34.087	193,501.91	302,708.14	363,249.77

	Consumption in higher tariff [kWh]	Consumption in lower tariff [kWh]	Total consumption [MWh]	Total energy cost [RSD]	Total cost with taxis without VAT [RSD]	Total cost [RSD]
May 2018	34,020.0	6,536.0	40.556	233,287.24	353,784.49	424,541.39
Jun 2018	35,978.0	5,747.0	41.725	242,181.41	366,443.76	439,732.51
Jul 2018	24,285.0	5,614.0	29.899	170,219.81	272,310.88	326,773.06
Avg 2018	28,278.0	7,498.0	35.776	201,945.80	313,364.77	376,037.72
Sep 2018	23,552.0	6,725.0	30.277	170,062.97	272,469.86	326,963.84
Oct 2018	30,208.0	7,613.0	37.821	273,839.66	393,852.96	472,623.55
Nov 2018	26,482.0	7,491.0	33.973	244,164.42	355,571.26	426,685.51
Dec 2018	29,142.0	6,497.0	35.639	259,922.54	375,589.15	450,706.98
Total	335,750.0	81,805.0	417.555	2,516,059.28	3,847,470.88	4,616,965.06

Table 4.3 shows the trend of energy consumption increase, especially during the winter period when additional heating is needed and also during the summer when additional cooling is needed. Slight consumption decline is visible during January and February, during the examination period, when no teaching is arranged, and also in July, August and September when there are no activities (curricular activities) in the Faculty during the vacation period. In Figure 4.12 energy consumption per month, expressed in MWh, in the period from January 2018 to December 2018.

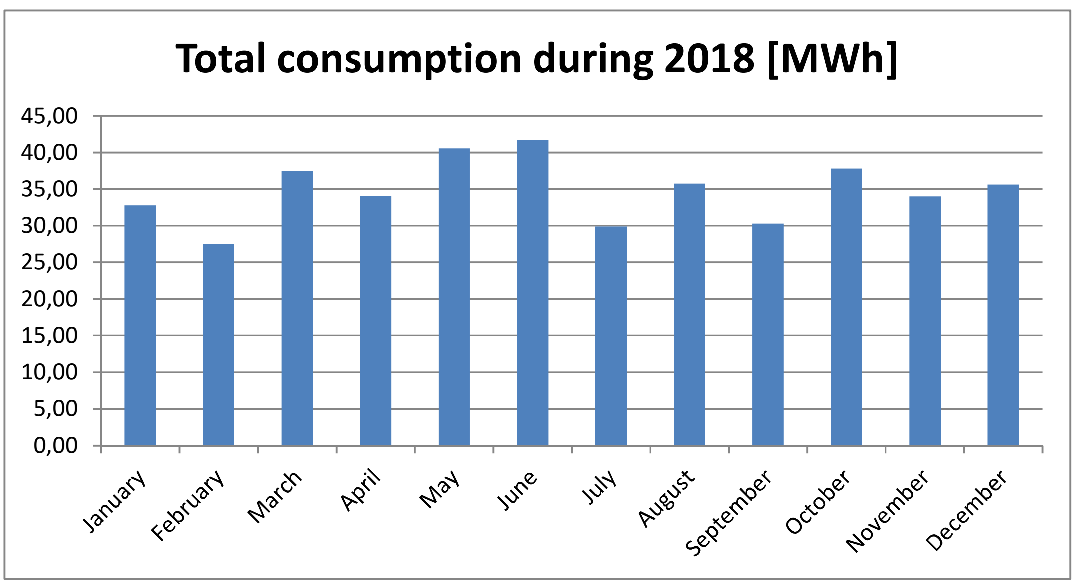


Figure 4.12 Electrical energy consumption per month in the "Mašinski institut" during 2018.

It can be seen that the highest energy consumption was in June. This is probably because the weather conditions lead to the substantial use of air-conditioning systems. During July, the consumption was the somewhat lower since most of the employees started to take their vacation in this period. During the winter, the highest consumption was in December since the semester was ongoing. Moreover, in this period, additional heating devices were employed since temperatures were low. The lowest consumption was in February, when there are no teaching activities. Also, the average temperature for this month was higher than usually. In Figure 4.14, Figure 4.13 and Figure 4.15 electrical energy bills are depicted, for February, June and December, respectively.

Specifikacija potrošnje po mestima primopredaje

Ugovor/Javna nabavka: U-19-2017
Kupac: PIB 100724720 Naziv: Fakultet tehničkih nauka
Adresa Računa: Fakultet tehničkih nauka Trg Dositeja Obradovića 6 21000 Novi Sad
Period isporuke: 1.2.2018. - 1.3.2018.
Specifikacija: 2024

ED broj: 1410158384, Adresa MPP: II istraživački i tehnološki centar Trg Dositeja Obradovića 5 Novi Sad 21101
Tarifni model: T2 Niski napon — Spec.: 2

Tarifna stavka		Jed. Mere	Potrošnja	Jed.Cena	P.%	Iznos (RSD)
ANT	Aktivna energija niža tarifa	kWh	1.654,000	3,64000	0,00	6.020,56
AVT	Aktivna energija viša tarifa	kWh	10.639,500	5,69000	0,00	60.538,76
DNT	Distribucija - Aktivna energija niža tarifa	kWh	1.654,000	0,74400	0,00	1.230,58
DVT	Distribucija - Aktivna energija viša tarifa	kWh	10.639,500	2,23300	0,00	23.758,00
OIE	Naknada za podsticaj povlašćenih proizvođača EE	kWh	12.293,500	0,09300	0,00	1.143,30
PRE	Prekomerna reaktivna energija	kVArh	3.350,438	2,54000	0,00	8.510,11
PSN	Prekomerna snaga	kW	0,000	595,37600	0,00	0,00
REN	Reaktivna energija	kVArh	4.044,562	1,27000	0,00	5.136[illegible]
SNA	Odobrena snaga	kW	150,000	148,84400	0,00	22.326,60
AKC	Akciza	RSD	128.664,500	0,07500	0,00	9.649,84

Ukupan iznos Obračuna:	**138.314,34**
PDV:	**27.662,87**
Zaduženje za obračunski period:	**165.977,21**
Taksa za javni mediski servis:	
Ukupno zaduženje za obračunski period:	**165.977,21**

ED broj: 1410159208, Adresa MPP: TS Mašinski fakultet laboratorija Vladimira Perića 2 Novi Sad 21101
Tarifni model: T1 Srednji napon — Spec.: 3

Tarifna stavka		Jed. Mere	Potrošnja	Jed.Cena	P.%	Iznos (RSD)
ANT	Aktivna energija niža tarifa	kWh	5.973,600	3,64000	0,00	21.743,90
AVT	Aktivna energija viša tarifa	kWh	21.521,600	5,69000	0,00	122.457,90
DNT	Distribucija - Aktivna energija niža tarifa	kWh	5.973,600	0,32400	0,00	1.935,45
DVT	Distribucija - Aktivna energija viša tarifa	kWh	21.521,600	0,97100	0,00	20.897,47
OIE	Naknada za podsticaj povlašćenih proizvođača EE	kWh	27.495,200	0,09300	0,00	2.557,05
PRE	Prekomerna reaktivna energija	kVArh	0,000	0,90700	0,00	[illegible]
PSN	Prekomerna snaga	kW	0,000	372,11000	0,00	0,00
REN	Reaktivna energija	kVArh	8.725,600	0,45400	0,00	3.961,42
SNA	Odobrena snaga	kW	540,000	93,02700	0,00	50.234,58
AKC	Akciza	RSD	223.787,770	0,07500	0,00	16.784,08

Ukupan iznos Obračuna:	**240.571,85**
PDV:	**48.114,37**
Zaduženje za obračunski period:	**288.686,22**
Taksa za javni mediski servis:	
Ukupno zaduženje za obračunski period:	**288.686,22**

Figure 4.13 The electricity bill for the "Mašinski institut", February 2018.

ПРИВРЕДА

ЈП ЕПС Београд
11000 Београд, ул.Балканска 13

ПИБ: 103920327
Матични број: 20053658

ЕЛЕКТРИЧНУ ЕНЕРГИЈУ - ЈУН 2018

	23458816
...ња:	Београд
...вања:	17.07.2018
...мета и акцизе:	01.07.2018
...спећа:	01.08.2018
...еста мерења:	4015008380
...ор број:	18.01-35052/4-18 01.03.18-28.02.19
...егорија:	Потрошња на средњем напону
...ста снабдевања:	Комерцијално снабдевање
Одобрена снага (kW):	540
Период обрачуна:	02.06.2018 - 01.07.2018

Место мерења: 1410159208
TS "MAŠINSKI FAKULTET" - LABORATORIJA
VLADIMIRA PERIĆA 2
21101 NOVI SAD

Приликом уплате на текући рачун 845-484849-65 позвати се на број 62-4015008313-1806 модел 97.

ПИБ: 100724720
МБ: 08067104
4010034310
FAKULTET TEHNIČKIH NAUKA NOVI SAD
TRG DOSITEJA OBRADOVIĆA 6
NOVI SAD
21101 NOVI SAD

1. ОЧИТАНЕ ВРЕДНОСТИ

Број бројила	Датум очитавања	Обрач. величина	Стање бројила				Обрач. константа	Коеф. свођења	Енергија за обрачун		Стање макс.	Константа максигр.	Коеф. свођења снаге	Снага (kW)
			Претходно стање		Ново стање									
			ВТ	НТ	ВТ	НТ			ВТ	НТ				
10630417	01.07.2018	kWh	1.296,484	298,786	1.341,457	305,97	800		35.978	5.747	0,244	1		195,2
	01.07.2018	kVArh	537,517	97,318	554,78	99,346	800		13.810	1.622				

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	35.978			6,110000	219.825,58
2	Активна електрична енергија у НТ	kWh	5.747			3,890000	22.355,83
						Укупно за испоручену електричну енергију:	**242.181,41**

3. ОБРАЧУН ЗА ПРИСТУП СИСТЕМУ ЗА ПРЕНОС/ДИСТРИБУЦИЈУ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ Реактивна енергија за cosΦ(0.95) = 13.715

Р.бр.	Назив тарифе	Обрачунска величина	Количина за обрачун	Јединична цена (РСД)	Укупно (РСД)
1	2	3	4	5	6
1	Одобрена снага	kW	540	93,0270	50.234,58
2	Виша дневна тарифа за активну енергију	kWh	35.978	0,9710	34.934,64
3	Нижа дневна тарифа за активну енергију	kWh	5.747	0,3240	1.862,03
4	Реактивна енергија	kVArh	13.715	0,4540	6.226,61
5	Прекомерна реактивна енергија	kVArh	1.718	0,9070	1.558,23
6	Прекомерна снага	kW	0	372,1100	0,00
	Укупно за приступ систему за дистрибуцију електричне енергије:				**94.816,09**

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	41.725	0,093	3.880,43
	Укупно накнаде за подстицај повлашћених произвођача електричне енергије:				**3.880,43**

5. РЕКАПИТУЛАЦИЈА ОБРАЧУНА

1	Испоручена електрична енергија	242.181,41
2	Приступ систему за пренос/дистрибуцију електричне енергије	94.816,09
3	Накнада за подстицај повлашћених произвођача ел.енергије	3.880,43
4	Основица за обрачун акцизе (4=1+2+3)	340.877,93
5	Износ обрачунате акцизе (стопа 7,5%) (5=4*0.075)	25.565,85
6	Основица за ПДВ (6=4+5)	366.443,78
7	Порез на додату вредност 20% (7=6*0.20)	73.288,76
8	Такса за јавни медијски сервис	0,00
9	Укупно за обрачун (9=6+7+8)	**439.732,54**

644

Figure 4.14 The electricity bill for the "Mašinski institut", June 2018.

ЕЛЕКТРОПРИВРЕДА СРБИЈЕ

ЈП ЕПС Београд
11000 Београд, ул.Балканска 13

ПИБ: 103920327
Матични број: 20053658

ОБРАЧУН ЗА ЕЛЕКТРИЧНУ ЕНЕРГИЈУ - ДЕЦЕМБАР 2018

Обрачун број: 24545627
Место издавања: Београд
Датум издавања: 16.01.2019
Датум промета и акцизе: 01.01.2019
Датум доспећа: 31.01.2019

Приликом уплате на текући рачун 845-484849-65 позвати се на број 44-4015008313-1812 модел 97.

Број места мерења: 4015008380
Уговор број: 18.01-35052/4-18 01.03.18-28.02.19
Категорија: Потрошња на средњем напону
Врста снабдевања: Комерцијално снабдевање
Одобрена снага (kW): 540
Период обрачуна: 02.12.2018 - 01.01.2019

ПИБ: 100724720
МБ: 08067104
4010034310
FAKULTET TEHNIČKIH NAUKA NOVI SAD
TRG DOSITEJA OBRADOVIĆA 6
NOVI SAD
21101 NOVI SAD

Место мерења: 1410159208
"TS ""MAŠINSKI FAKULTET"" - LABORATORIJA"
VLADIMIRA PERIĆA 2
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)
10630417	01.01.2019	kWh	1.508,681	341,824	1.548,711	350,723	800		32.024	7.119	0,183	1		146,4
	01.01.2019	kVArh	619,801	108,026	636,723	110,038	800		13.538	1.610				

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	32.024			6,110000	195.666,64
2	Активна електрична енергија у НТ	kWh	7.119			3,890000	27.692,91
	Укупно за испоручену електричну енергију:						**223.359,55**

3. ОБРАЧУН ЗА ПРИСТУП СИСТЕМУ ЗА ПРЕНОС/ДИСТРИБУЦИЈУ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ Реактивна енергија за cosΦ(0.95) = 12.866

Р.бр.	Назив тарифе	Обрачунска величина	Количина за обрачун	Јединична цена (РСД)	Укупно (РСД)
1	2	3	4	5	6
1	Одобрена снага	kW	540	93,0270	50.234,58
2	Виша дневна тарифа за активну енергију	kWh	32.024	0,9710	31.095,30
3	Нижа дневна тарифа за активну енергију	kWh	7.119	0,3240	2.306,56
4	Реактивна енергија	kVArh	12.866	0,4540	5.841,16
5	Прекомерна реактивна енергија	kVArh	2.281	0,9070	2.068,87
6	Прекомерна снага	kW	0	372,1100	0,00
	Укупно за приступ систему за дистрибуцију електричне енергије:				**91.546,47**

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	39.143	0,093	3.640,30
	Укупно накнаде за подстицај повлашћених произвођача електричне енергије:				**3.640,30**

5. РЕКАПИТУЛАЦИЈА ОБРАЧУНА

1	Испоручена електрична енергија	223.359,55
2	Приступ систему за пренос/дистрибуцију електричне енергије	91.546,47
3	Накнада за подстицај повлашћених произвођача ел.енергије	3.640,30
4	Основица за обрачун акцизе (4=1+2+3)	318.546,32
5	Износ обрачунате акцизе (стопа 7,5%) (5=4*0.075)	23.890,97
6	Основица за ПДВ (6=4+5)	342.437,29
7	Порез на додату вредност 20% (7=6*0.20)	68.487,46
8	Такса за јавни медијски сервис	0,00
9	Укупно за обрачун (9=6+7+8)	**410.924,75**

668

Figure 4.15 The electricity bill for the "Mašinski institut", December 2018.

Analyzing the electricity bill for June 2018, when the consumption was the highest, it can be seen that electrical energy consumption in higher tariff was 35,978 kWh and in lower tariff 5,747 kWh, with the total cost of 242,181.41 RSD for the active power delivery. On the other hand, the lowest consumption was in February with 21,521.60 kWh in the higher tariff and 5,973.60 kWh in the lower tariff, with the total cost of 144,201.81 RSD. Therefore, the consumption in the lower tariff is similar, while the consumption in the higher tariff is significantly different. These results are expected considering the habits of the people that use the exemplary object.

During the winter, energy consumption is smaller and the maximum is in December, with 29,142 kWh in higher, 6,497 kWh in lower tariff and total cost of 259,922.54 RSD. During the semester, especially in June and December, reactive power consumption is higher, while this is not the case in the vacation period. Reactive power consumption monthly did not exceed the contract limit of 7,000 RSD and therefore does not affect the total cost. There was no excessive active power consumption. Analyzing the bill for June, the price for the connection to the system was somewhat lower than the 30 % of the total price for electrical energy cost, while this amount for August is about 50 %, mostly because power is fixed to 540 kW by contract. Moreover, the value read from the max graph is below 0.3 in each month (the maximal value is in June – 0.257).

4.2. The thermal infrastructure of the exemplary object and consumption analysis

The thermal infrastructure of the "Mašinski institut" is connected to the district heating system of the utility company "Novosadska toplana". The main heating energy source is natural gas and delivered power is charged per kWh. In the exemplary object, there is no connection with the remotely controlled system for the delivery of warm water. The exemplary object is supplied with two heat substations and they are depicted in Figure 4.16.

Figure 4.16 Heat substations in the ***"****Mašinski institut****"****.*

In the exemplary object, for the transmission of the heat power and space heating radiators are used. Usually, they are placed beneath the windows. Through the visual inspection of the "Mašinski institut", it is concluded that two types of radiators were installed – panel and cast iron radiators.

The height and length of the cast iron radiators vary. This is because there is a different number of tubes that are connected in series. Depending on the room they are built-in, the number of tubes in the cast iron radiators is between 12 and 38.

Panel radiators have a straight front panel and are made of steel sheet. In their simplest form, the heating fluid (warm water) is circulating through the heating panel. The dimensions of the panel radiators in the exemplary object vary only in the length – 120 cm, 140 cm or 160 cm. The height of the panel radiators is 60 cm, while the depth is 10 cm.

This cast iron radiator type is depicted in Figure 4.17 (a), while the panel radiator is shown in Figure 4.17 (b).

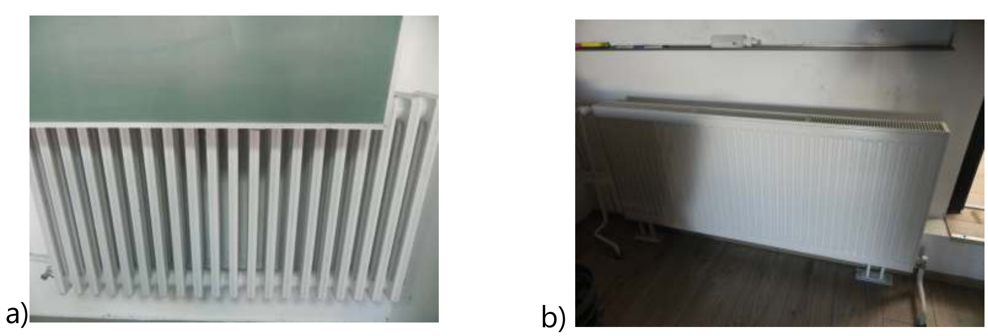


Figure 4.17 Two types of radiators in the "Mašinski institut" – cast iron (a) and panel (b) radiator.

In Table 4.4 the number of radiators located in different rooms is presented, together with the total number of radiators.

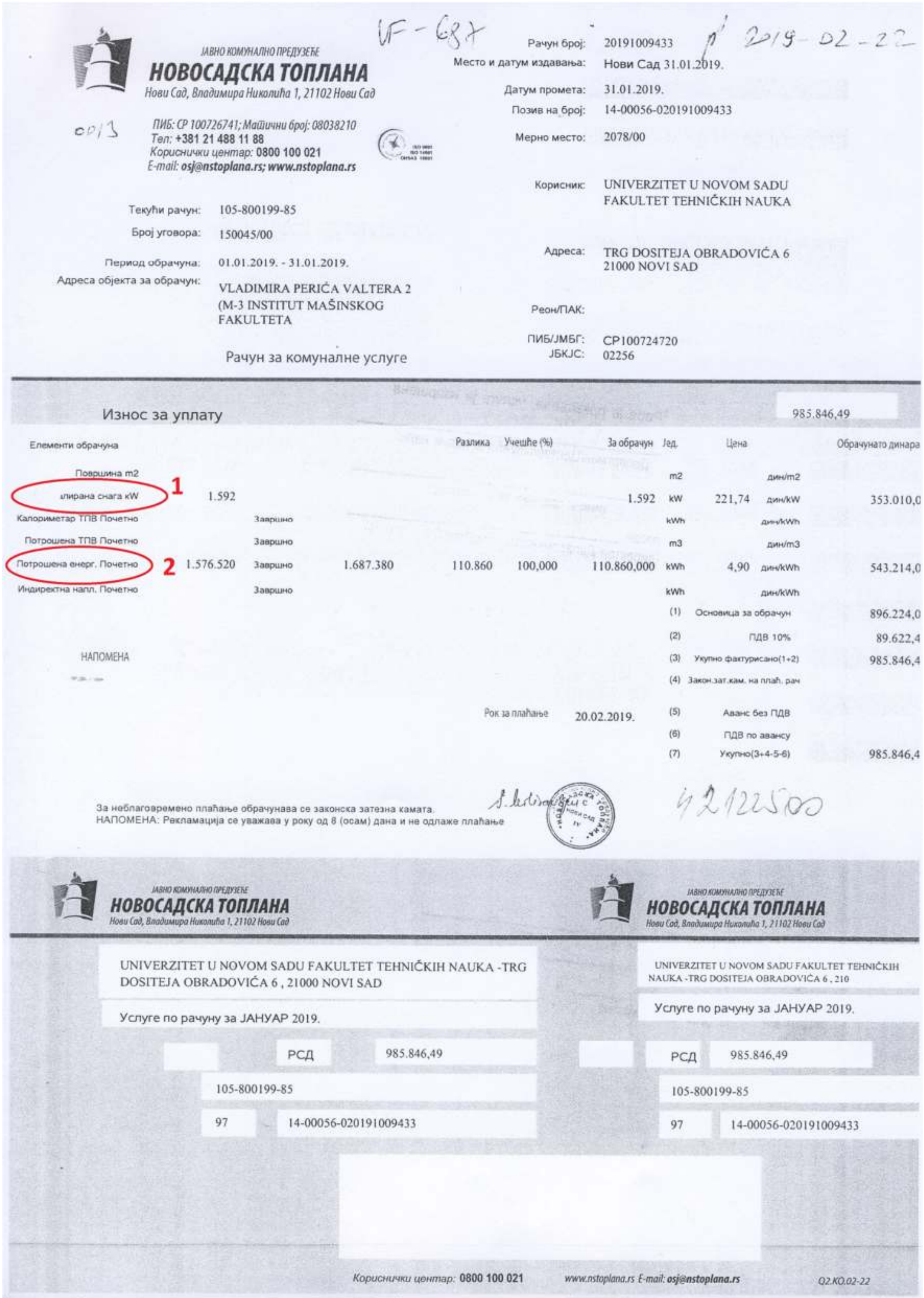
Table 4.4 The number of radiators according to the room purpose and radiator type.

Rooms	**Number of radiators**	
	Cost iron	**Panel**
Cabinets	99	23
Classrooms	20	31
Computer classrooms	4	28
Laboratories	153	15
Hallways	24	2
Toilets	3	0
Total per type	301	99
Total	400	

4.2.2. The analysis of the heat energy consumption

In order to adequately investigate the thermal energy balance of the exemplary object, the analysis of the delivered heat energy in the period from January 2018 to December 2018. This period includes the heating season, as well as the period when the heating is not activated.

Figure 4.18 shows the heating bill for the "Mašinski institut". It is divided into three segments. In the first segment, the data about heat energy provider and consumer are given. In the second segment information about installed power, warm water consumption data taken from calorimeter and water meter, energy consumed, data from the meter taken in the beginning and the end of the month, price expressed in RSD per kWh, as well as the total cost of the energy consumed, expressed in RSD. In the exemplary object, especially interesting data are installed power (1) and consumed heat energy (2). The third segment is the payment slip with the information about consumer and bank account, together with the total cost for the delivered heat energy.



UF - 687 2019-02-22

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
НОВОСАДСКА ТОПЛАНА
Нови Сад, Владимира Николића 1, 21102 Нови Сад

ПИБ: СР 100726741; Матични број: 08038210
Тел: +381 21 488 11 88
Кориснички центар: 0800 100 021
E-mail: osj@nstoplana.rs; www.nstoplana.rs

Рачун број: 20191009433
Место и датум издавања: Нови Сад 31.01.2019.
Датум промета: 31.01.2019.
Позив на број: 14-00056-020191009433
Мерно место: 2078/00
Корисник: UNIVERZITET U NOVOM SADU FAKULTET TEHNIČKIH NAUKA

Текући рачун: 105-800199-85
Број уговора: 150045/00
Период обрачуна: 01.01.2019. - 31.01.2019.
Адреса објекта за обрачун: VLADIMIRA PERIĆA VALTERA 2 (M-3 INSTITUT MAŠINSKOG FAKULTETA

Адреса: TRG DOSITEJA OBRADOVIĆA 6 21000 NOVI SAD
Реон/ПАК:
ПИБ/ЈМБГ: CP100724720
ЈБКЈС: 02256

Рачун за комуналне услуге

Износ за уплату 985.846,49

Елементи обрачуна				Разлика	Учешће (%)	За обрачун	Јед.	Цена		Обрачунато динара
Површина m2							m2		дин/m2	
1 …лирана снага kW	1.592					1.592	kW	221,74	дин/kW	353.010,0
Калориметар ТПВ Почетно		Завршно					kWh		дин/kWh	
Потрошена ТПВ Почетно		Завршно					m3		дин/m3	
Потрошена енерг. Почетно 2	1.576.520	Завршно	1.687.380	110.860	100,000	110.860,000	kWh	4,90	дин/kWh	543.214,0
Индиректна напл. Почетно		Завршно					kWh		дин/kWh	

НАПОМЕНА

(1)	Основица за обрачун	896.224,0
(2)	ПДВ 10%	89.622,4
(3)	Укупно фактурисано(1+2)	985.846,4
(4)	Закон.зат.кам. на плаћ. рач	
(5)	Аванс без ПДВ	
(6)	ПДВ по авансу	
(7)	Укупно(3+4-5-6)	985.846,4

Рок за плаћање 20.02.2019.

4212215/00

За неблаговремено плаћање обрачунава се законска затезна камата.
НАПОМЕНА: Рекламација се уважава у року од 8 (осам) дана и не одлаже плаћање

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ **НОВОСАДСКА ТОПЛАНА** Нови Сад, Владимира Николића 1, 21102 Нови Сад

UNIVERZITET U NOVOM SADU FAKULTET TEHNIČKIH NAUKA -TRG DOSITEJA OBRADOVIĆA 6 , 21000 NOVI SAD

Услуге по рачуну за ЈАНУАР 2019.

РСД 985.846,49

105-800199-85

97 14-00056-020191009433

UNIVERZITET U NOVOM SADU FAKULTET TEHNIČKIH NAUKA -TRG DOSITEJA OBRADOVIĆA 6 , 210

Услуге по рачуну за ЈАНУАР 2019.

РСД 985.846,49

105-800199-85

97 14-00056-020191009433

Кориснички центар: 0800 100 021 www.nstoplana.rs E-mail: osj@nstoplana.rs Q2.KO.02-22

Figure 4.18 An example of the heating bill for the exemplary object.

"Mašinski institut" is connected to two meters from the utility company "Novosadska toplana" through two heat substations. Total energy consumption per month, considering the period from January 2018 to December 2018 is given in Table 4.5.

Table 4.5 Heat energy consumption for the "Mašinski institut" during 2018.

Month	Consumed energy 1st substation [kWh]	Consumed energy 2nd substation [kWh]	Total consumption 1st + 2nd [kWh]	Total cost [RSD]
Jan 2018	102,930.00	98,080.00	201,010.00	1,756,764.61
Feb 2018	86,620.00	84,190.00	170,810.00	1,582,027.41
Mar 2018	88,120.00	86,180.00	174,300.00	1,602,220.55
Apr 2018	42,580.00	43,660.00	86,240.00	1,092,705.39
May 2018	0.00	0.00	0.00	593,720.75
Jun 2018	0.00	0.00	0.00	593,720.75
Jul 2018	0.00	0.00	0.00	593,720.75
Aug 2018	0.00	0.00	0.00	593,720.75
Sep 2018	0.00	0.00	0.00	593,720.75
Oct 2018	9,920.00	14,800.00	24,720.00	736,750.67
Nov 2018	39,950.00	40,070.00	80,020.00	1,005,003.28
Dec 2018	79,630.00	76,590.00	156,220.00	1,415,721.28
Total	449,750.00	443,570.00	893,320.00	12,159,796.98

Figure 4.19 illustrates the heat energy consumption per month, during 2018. The chart shape is characteristic of the remotely controlled system that is active only during the heating season (October – April). It can be seen that the highest consumption is in January, when the outside temperature is very low, while there is no heat energy consumption during the summer. Therefore, during the summer only installed power is charged.

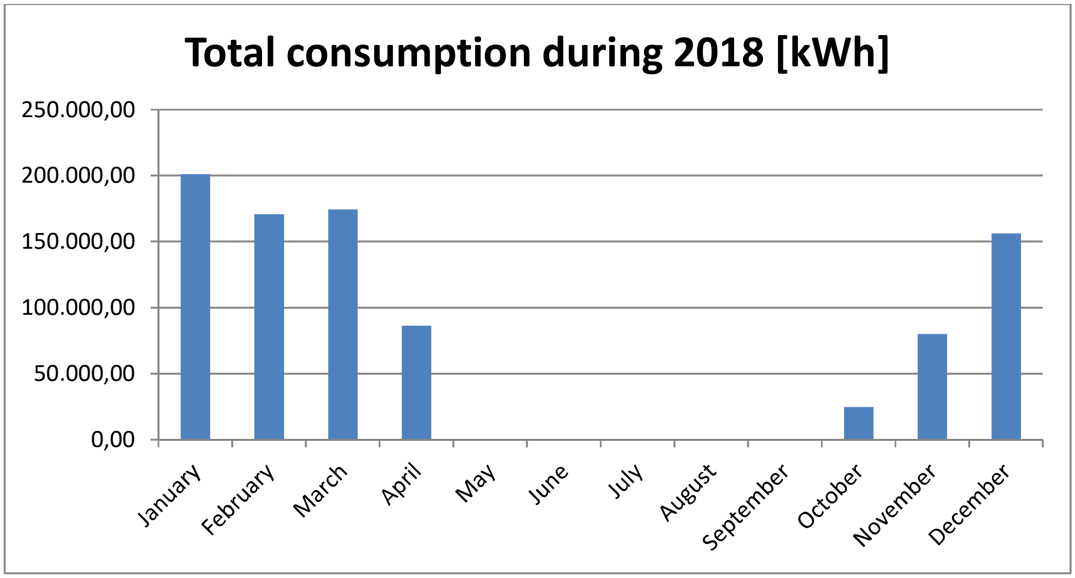


Figure 4.19 Heat energy consumption per month in the "Mašinski institut" during 2018.

In Figure 4.20 and Figure 4.21, the heating bills for the January and July, months with specific consumption, are given, respectively, for one heat meter.

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
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0017

Рачун број: 20181007693
Место и датум издавања: Нови Сад 31.01.2018.
Датум промета: 31.01.2018.
Позив на број: 30-00056-020181007693
Мерно место: 2077/00
0007890
Корисник: FAKULTET TEHNIČKIH NAUKA U NOVOM SADU
Адреса: TRG DOSITEJA OBRADOVIĆA 6, 21000 NOVI SAD
Реон/ПАК:
ПИБ/ЈМБГ: СР100724720

2018-02-12

IF 568

Текући рачун: 105-800199-85
Број уговора: 150037/00
Период обрачуна: 01.01.2018. - 31.01.2018.
Адреса објекта за обрачун: VLADIMIRA PERIĆA VALTERA 2 (M-2 MAŠINSKI FAKULTET

Рачун за комуналне услуге

Износ за уплату 787.408,36

Елементи обрачуна				Разлика	Учешће (%)	За обрачун	Јед.	Цена		Обрачунато динара
Површина m2							m2		дин/m2	
Инст. ангажована снага kW	760,04					760,04	kW	229,48	дин/kW	174.413,98
Кал. иметар ТПВ Почетно		Завршно					kWh		дин/kWh	
Испоручена ТПВ Почетно		Завршно					m3		дин/m3	
Испоручена енерг. Почетно	1.161.230	Завршно	1.264.160	102.930	100,000	102.930,000	kWh	5,26	дин/kWh	541.411,80
Електна напл. Почетно		Завршно					kWh		дин/kWh	

НАПОМЕНА

(1)	Основица за обрачун	715.825,78
(2)	ПДВ 10%	71.582,58
(3)	Укупно фактурисано(1+2)	787.408,36
(4)	Закон.зат.кам. на плаћ. рач	
(5)	Аванс без ПДВ	
(6)	ПДВ по авансу	
(7)	Укупно(3+4-5-6)	787.408,36

Рок за плаћање 20.02.2018.

42/22500

Рачун је пуноважан без печата и потписа. За неблаговремено плаћање обрачунава се законска затезна камата.
НАПОМЕНА: Рекламација се уважава у року од 8 (осам) дана и не одлаже плаћање.

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
НОВОСАДСКА ТОПЛАНА
Нови Сад, Владимира Николића 1, 21102 Нови Сад

Уплатилац: FAKULTET TEHNIČKIH NAUKA U NOVOM SADU -TRG DOSITEJA OBRADOVIĆA 6 , 21000 NOVI SAD
Сврха уплате: Услуге по рачуну за ЈАНУАР 2018.
Шифра плаћања:
Валута: РСД
Износ: 787.408,36
Рачун примаоца: 105-800199-85
Модел и позив на број: 97 30-00056-020181007693

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
НОВОСАДСКА ТОПЛАНА
Нови Сад, Владимира Николића 1, 21102 Нови Сад

Уплатилац: FAKULTET TEHNIČKIH NAUKA U NOVOM SADU -TRG DOSITEJA OBRADOVIĆA 6 , 21000 NOVI SAD
Сврха уплате: Услуге по рачуну за ЈАНУАР 2018.
Шифра плаћања:
РСД 787.408,36
Рачун примаоца: 105-800199-85
Модел и позив на број: 97 30-00056-020181007693

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Figure 4.20 The heating bill for the "Mašinski institut", January 2018.

UF-3546 | Рачун број: 20181055309 PL 10.08.18

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0013

Место и датум издавања: Нови Сад 31.07.2018.
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Позив на број: 63-00056-020181055309
Мерно место: 2077/00

Корисник: UNIVERZITET U NOVOM SADU FAKULTET TEHNIČKIH NAUKA

Текући рачун: 105-800199-85
Број уговора: 150037/00
Период обрачуна: 01.07.2018. - 31.07.2018.
Адреса објекта за обрачун: VLADIMIRA PERIĆA VALTERA 2 (M-2 MAŠINSKI FAKULTET

Адреса: TRG DOSITEJA OBRADOVIĆA 6 21000 NOVI SAD
Реон/ПАК:
ПИБ/ЈМБГ: CP100724720
ЈБКЈС: 02256

Рачун за комуналне услуге

Износ за уплату 191.855,38

Елементи обрачуна			Разлика	Учешће (%)	За обрачун	Јед.	Цена		Обрачунато динара
Површина m2						m2		дин/m2	
...апирана снага kW	760,04				760,04	kW	229,48	дин/kW	174.413,9
...ториметар ТПВ Почетно		Завршно				kWh		дин/kWh	
...отрошена ТПВ Почетно		Завршно				m3		дин/m3	
...трошена енерг. Почетно		Завршно				kWh		дин/kWh	
...директна напл. Почетно		Завршно				kWh		дин/kWh	

(1)	Основица за обрачун	174.413,9
(2)	ПДВ 10%	17.441,4
(3)	Укупно фактурисано(1+2)	191.855,3
(4)	Закон.зат.кам. на плаћ. рач	
(5)	Аванс без ПДВ	
(6)	ПДВ по авансу	
(7)	Укупно(3+4-5-6)	191.855,3

НАПОМЕНА

Рок за плаћање 20.08.2018.

За неблаговремено плаћање обрачунава се законска затезна камата.
НАПОМЕНА: Рекламација се уважава у року од 8 (осам) дана и не одлаже плаћање

4212500

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
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Услуге по рачуну за ЈУЛ 2018.

РСД 191.855,38

105-800199-85

97 63-00056-020181055309

ЈАВНО КОМУНАЛНО ПРЕДУЗЕЋЕ
НОВОСАДСКА ТОПЛАНА
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Услуге по рачуну за ЈУЛ 2018.

РСД 191.855,38

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Кориснички центар: 0800 100 021 www.nstoplana.rs E-mail: osj@nstoplana.rs Q2.KO.02-22

Figure 4.21 The heating bill for the "Mašinski institut", July 2018.

The highest consumption in January corresponds to the fact that this month was the coldest in the entire year, while in the period from May to September there is no heat energy consumption at all. For the first heating substation, the cost for the power delivery defined by the contract is 365,332.16 RSD without VAT, i.e. 229.48 RSD/kWh for 1,592 kW. For the second substation, the same cost is 174,413.98 RSD without VAT, i.e. 229.48 RSD/kWh for 760 kW. This amount of money has to be paid whether the heating season is active or not. During the heating season, for the January 2018, for the heating of the part of an exemplary object connected to the second heating substation, the power in the amount of 102,930.00 kWh was consumed and regarding the price of 5.26 RSD/kWh the total cost is 541,411.80, without VAT. Therefore, the cost for the connection to the system takes about 30 % of the total cost of the heat energy, for the month characterized with the highest consumption.

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.

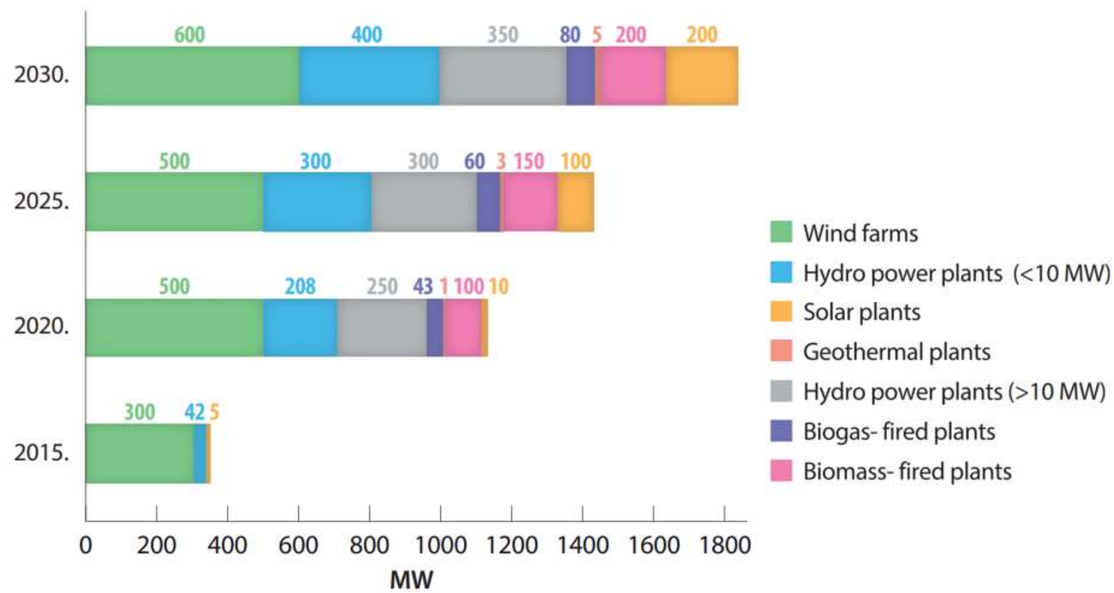

Figure 5.1 The projection of the construction of plants for electricity generation using RES until 2030 [19].

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].

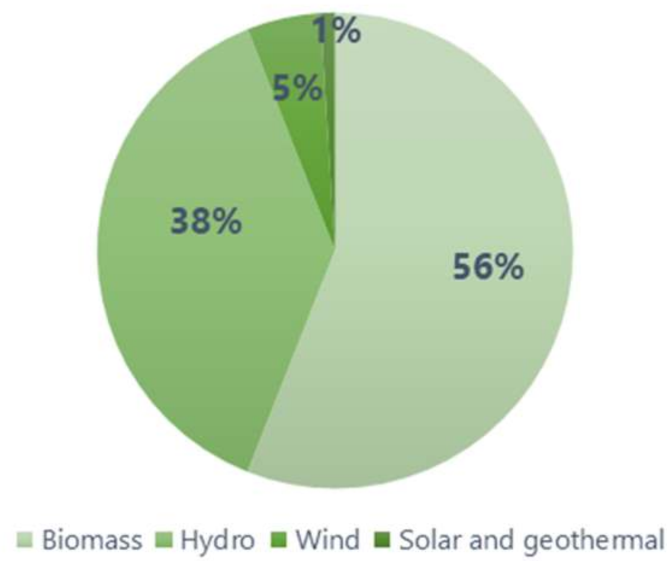

Figure 5.2 The total planned production of primary energy from individual RES for 2019.

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.

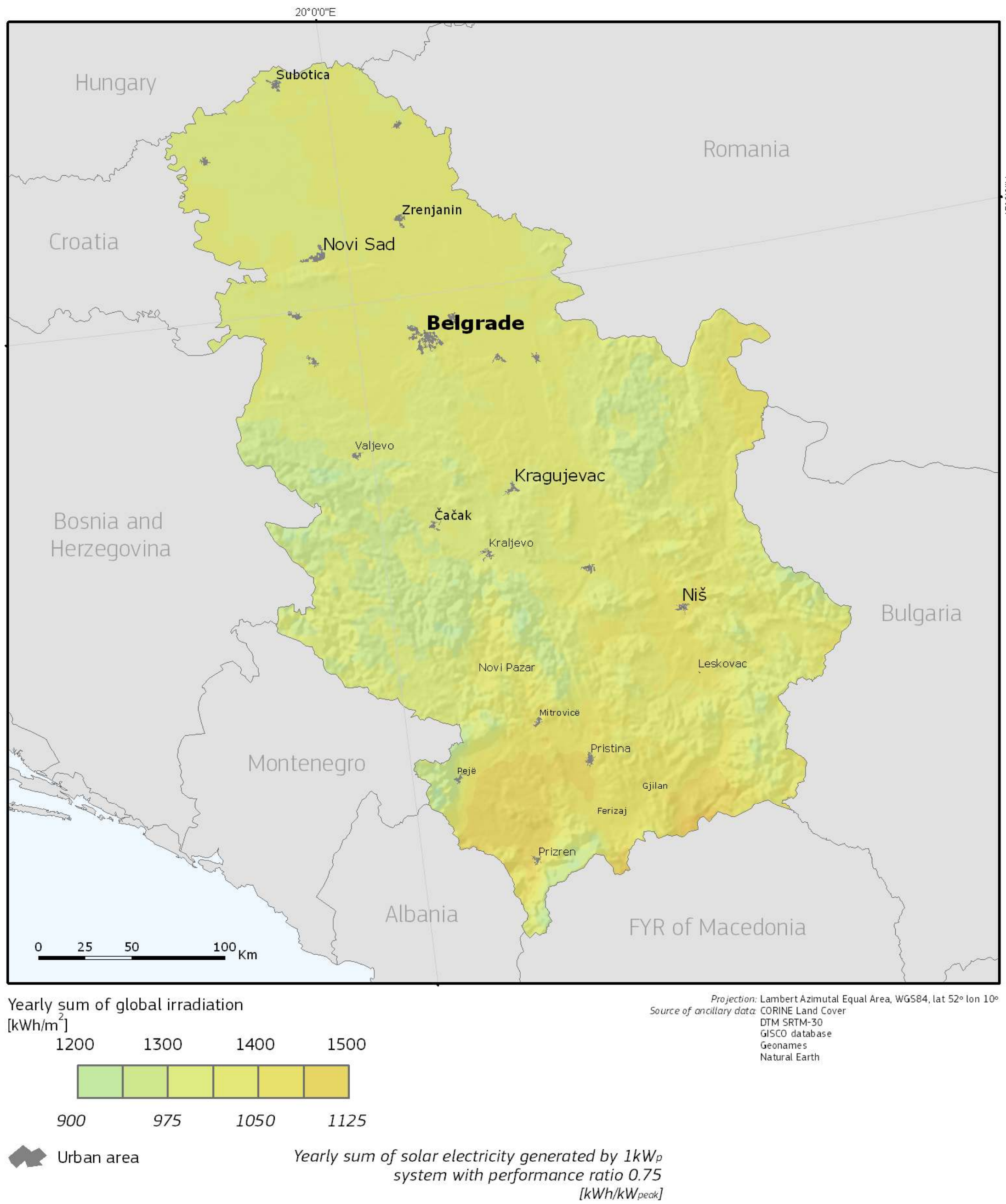

Figure 5.3 Global irradiation and solar electricity potential of the Republic of Serbia [22].

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.

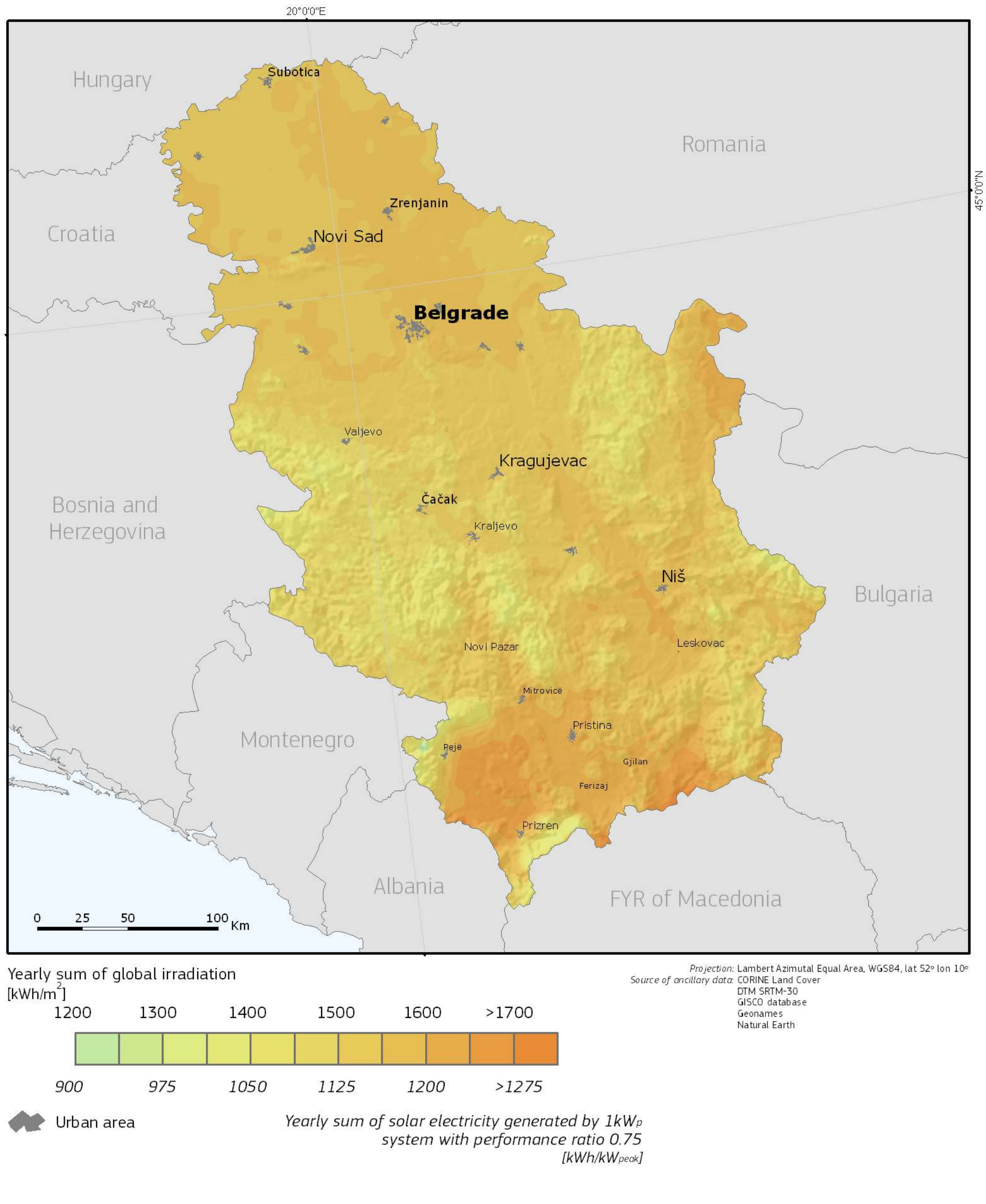

Figure 5.4 Global irradiation and solar electricity potential for the optimally-inclined photovoltaic modules of the Republic of Serbia [22].

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°.

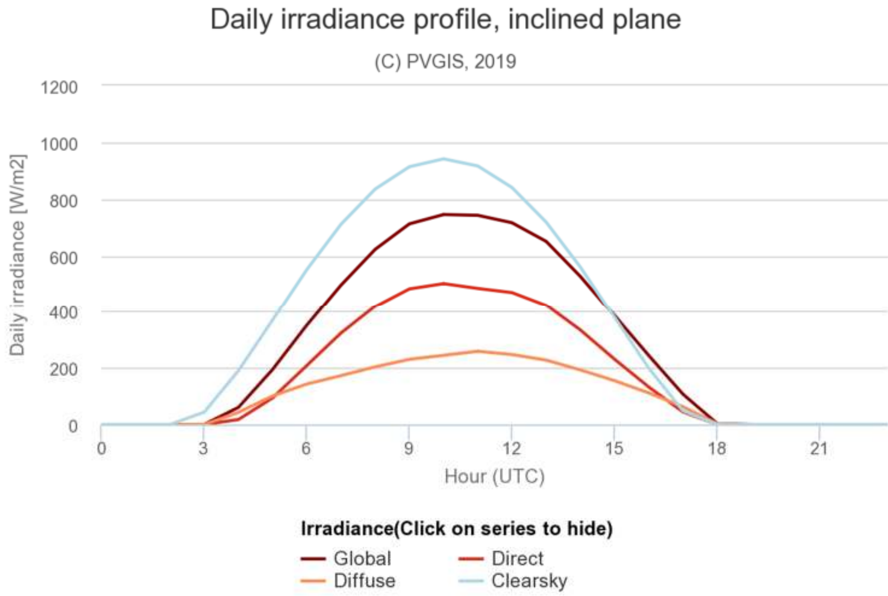

Figure 5.5 Daily average irradiance on the fixed plane with slope 0° and azimuth 0° for the month of July, city of Novi Sad [22].

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/m2]	Gb [W/m2]	Gd [W/m2]	Gcs [W/m2]
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

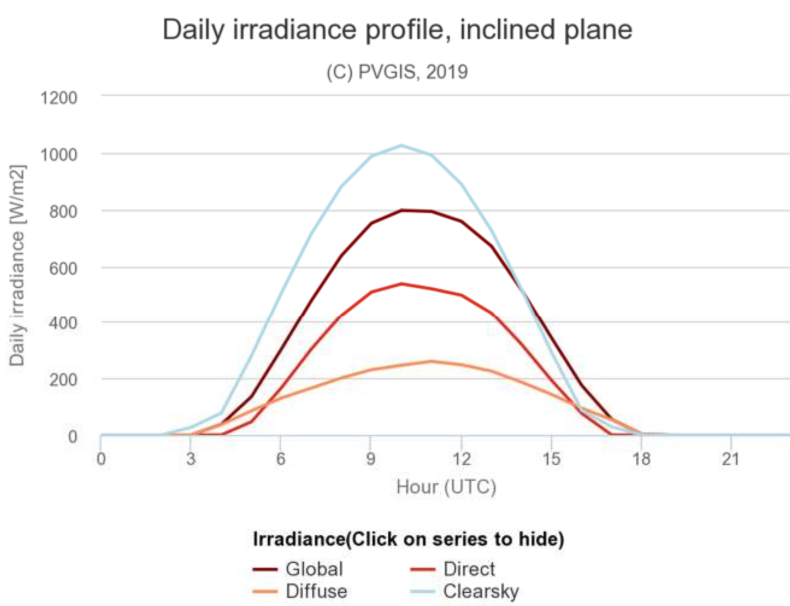

Figure 5.6 Daily average irradiance on the fixed plane with slope 35°, and azimuth 0° for the month of July, city of Novi Sad [22].

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

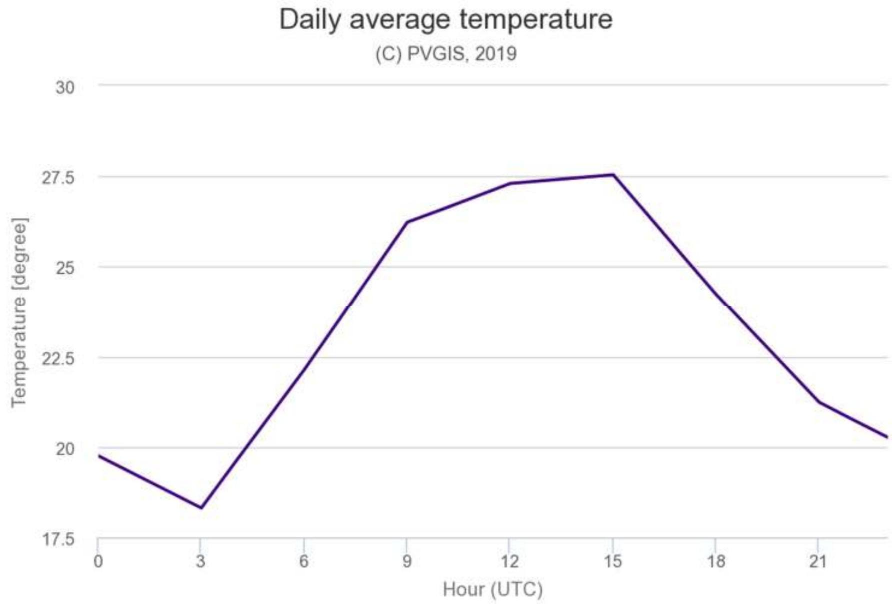

Figure 5.7 Daily average temperature for the month of July, city of Novi Sad [22].

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.

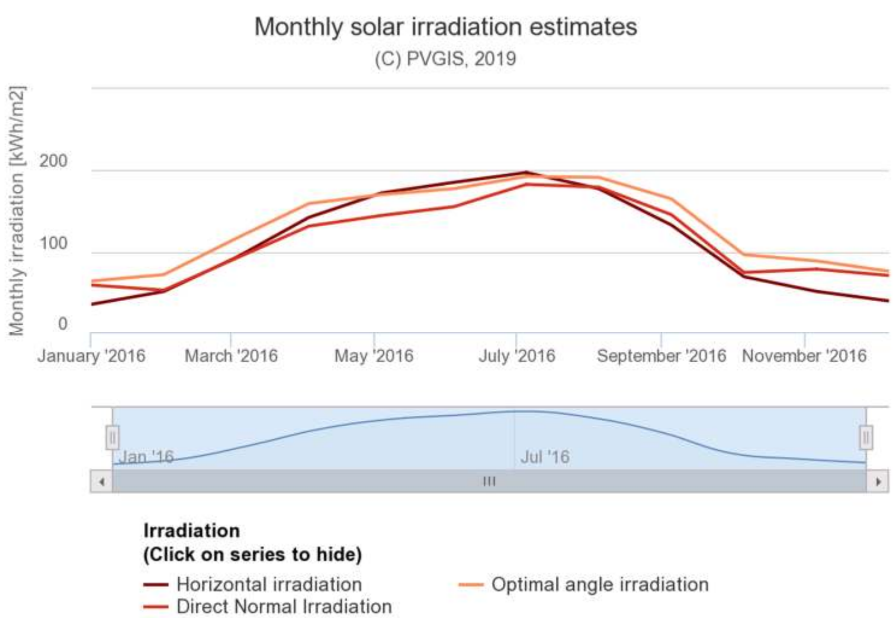

Figure 5.8 Monthly average irradiance on the fixed plane with slope 0°, and azimuth 0° for the year of 2016, city of Novi Sad [22].

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. Potential of the wind energy

In order to harness wind energy, one of the important factors is the existing road and railway structure and the accessibility of the terrain on which wind farms are planned. Also important is the existence and coverage of the territory with medium and high voltage power grid. Such infrastructure factors, necessary for successful connection of wind power plants, include the existence of suitable transformer stations and the possibility of connection to them. The territory of AP Vojvodina is mostly of plain character with a developed network of roads and tracks. An additional benefit is the existence of waterways and cargo ports, which enables the transportation of heavy and oversized cargo cheaper.

The Republic of Serbia has the potential to produce 4.89 million toe annually from renewable sources. In addition, there are suitable sites for the construction of wind turbines, which in perspective could be installed at about 1,300 MW of wind turbine production capacity and produce about 2,300 GWh of electricity annually [24].

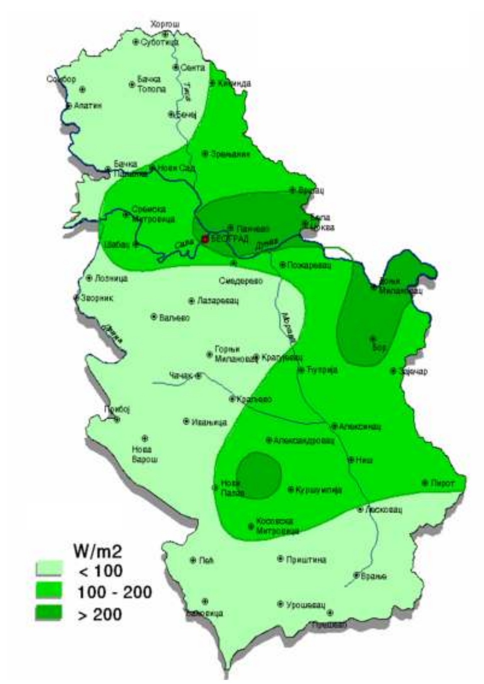

Figure 5.9 Average wind power at altitude of 100 m of the Republic of Serbia for the month of July [24].

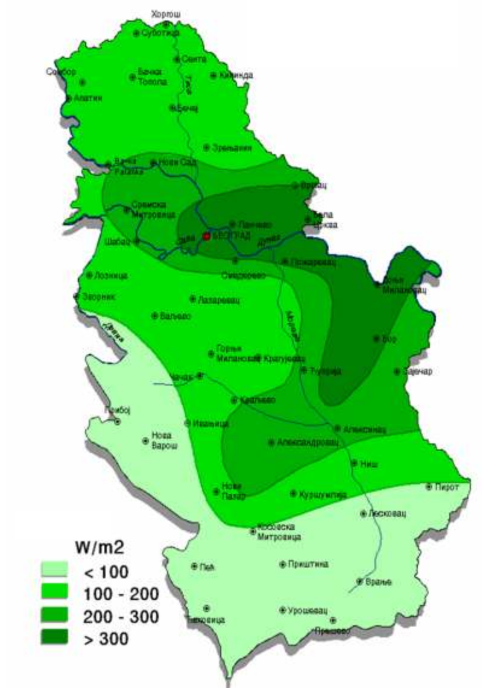

Figure 5.10 Average wind power at altitude of 100 m of the Republic of Serbia for the month of January [24].

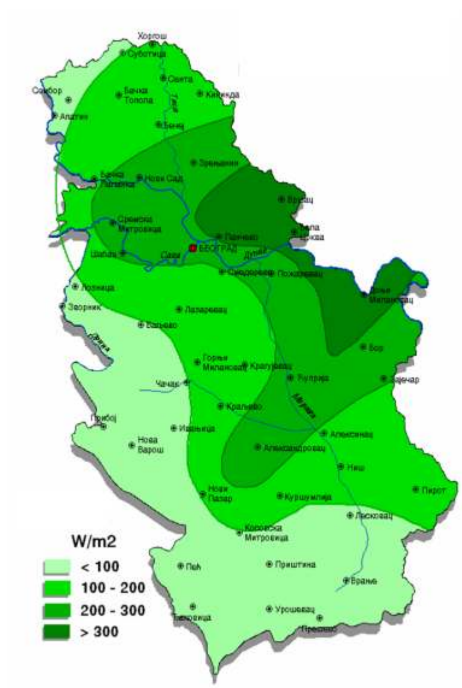

Figure 5.11 Yearly average wind power at altitude of 100 m of the Republic of Serbia [24].

The Autonomous province of Vojvodina is in the zone of the higher wind density, and yearly average wind power at altitude of 100 m is in the range of 200-300 W/m^2.

Project implemented within the National Energy Efficiency Program of the Ministry of Science and Environmental Protection of the Republic of Serbia in the year of 2005 provided maps of Serbia's wind energy potential [24]. The results of study show that the territory of Vojvodina is in the zone where the wind speed is 3.5 - 4.5 m/s. In some places (Fruška Gora, Vršački Breg, Southern Banat) wind speeds are 4.5 - 6 m/s, and two locations with velocities over 6 m/s are measured on Vršački Breg. It can be noted that the Pannonian Basin, eastern parts of Serbia, as well as mountainous areas are very suitable for the construction of wind farms. With the use of wind turbine technologies, which enable cost-effective operation at lower speeds, already above 3 m/s, it is possible to set up larger capacities, so it can be said that the potential of Vojvodina is significant.

Wind maps of the Autonomous Province of Vojvodina at 10 m, 25 m, 50 m, 100 m and 200 m above the surface are the result of data processing from 8 meteorological stations, which are obtained using the WAsP software package in the year of 2008. One of the 8 meteorological stations is located at Rimski Šančevi, Novi Sad municipality. Yearly average wind speed and density for the city of Novi Sad, which originates from the wind maps, are shown in the Table 5.5.

Table 5.5 Yearly average wind speed and density at 10 m, 25 m, 50 m, 100 m and 200 m above the surface above the surface for the city of Novi Sad.

Altitude [m]	Yearly average wind speed [m/s]	Yearly average wind density [W/m^2]
10	< 3,5	< 50
25	< 3,5	50 - 100
50	3.5 – 4.5	50 – 100
100	3.5 – 4.5	100 – 150
200	5 – 6	150 - 250

According to the data that were processed using the WAsP OWC Wizard program in the year of 2008, the average wind speed is 2.65 m/s, while the average wind density is 31.5 W/m^2.

According to the Global Wind Atlas, the average wind density at a height of 10 m is approximately 48 W/m^2 [25]. Figure 5.12 shows the average power density for the city of Novi Sad. It can be observed that the average wind density for 10% of the windiest parts of the city is 108 W/m^2.

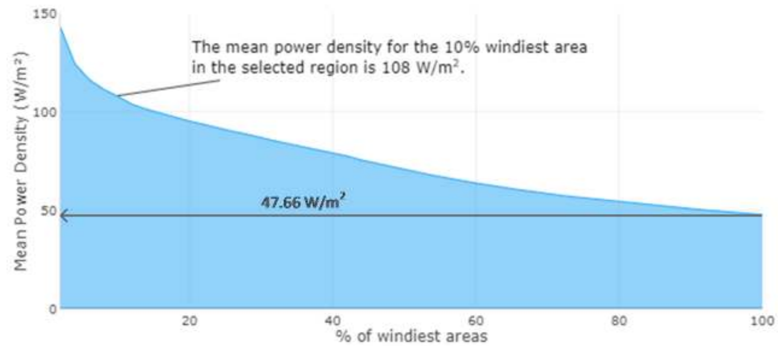

Figure 5.12 The average wind density at a height of 10 m for the city of Novi Sad [25].

The average wind speed at a height of 10 m is approximately 2.59 m/s. Figure 5.12 shows the average wind speed for the city of Novi Sad. It can be observed that the average for 10% of the windiest parts of the city is 108 W/m2.

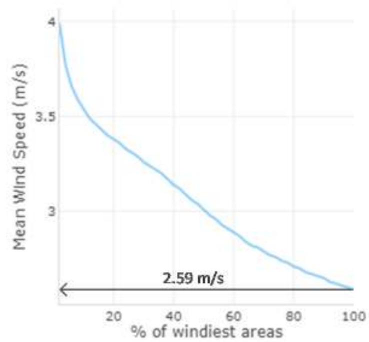

Figure 5.13 The average wind speed at a height of 10 m for the city of Novi Sad [25].

The Figure 5.14 shows the wind frequency, power and speed rose at 10 m, respectively. During the year, the most winds are in the west and northwest direction, and slightly less southeast. However, the highest power density occurs from the southeast. This should be considered for the position of the wind turbine blades.

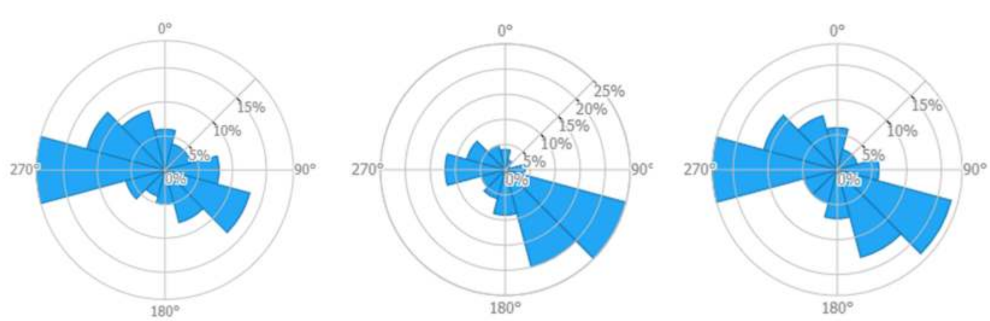

Figure 5.14 Wind frequency, power, speed rose at 10 m, respectively for the city of Novi Sad [25].

The Figure 5.15 shows the hourly and monthly radar plot for the city of Novi Sad.

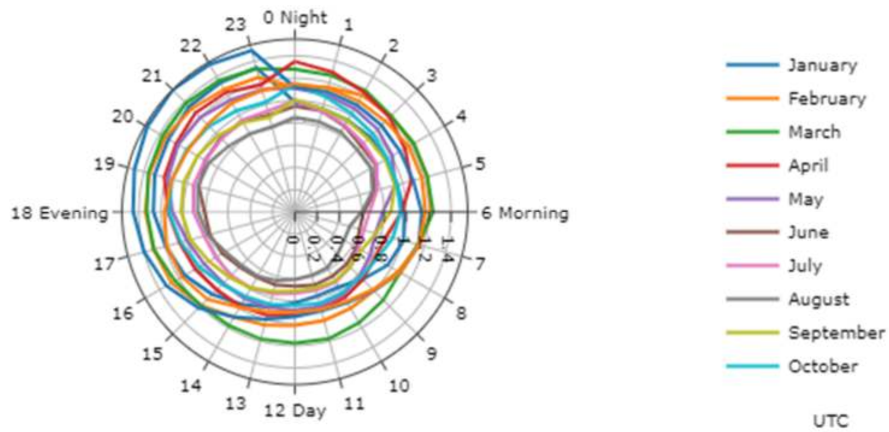

Figure 5.15 Hourly and monthly radar plot for the city of Novi Sad [25].

5.4. The potential of geothermal energy

The Republic of Serbia has significant potential of geothermal energy. For now extremely low geothermal energy is used, even though the Republic of Serbia is among countries with the highest potential. The results of the previous research show that the use of geothermal energy in Serbia for energy purposes can be significant in the energy balance of the country. The first estimates of the energy potential of geothermal resources show that an intensive geothermal exploitation program by 2030 could replace at least 500 000 t of imported liquid fuels on an annual basis, and with direct use by geothermal heat pumps, the electricity consumption of at least 1200 MW could be reduced [26].

The geothermal density flow in most of the areas in country is 60 mW/m^2, which is higher than the average value for Continental Europe. The total average flow of all geothermal sources in country is 4000 l/s. In the Republic of Serbia, geothermal energy is mainly used for room heating and spas [27].

The Pannonian basin, southern and central Serbia have geothermal density flow over 100 mW/m^2. The total average flow of 62 geothermal drill holes in the Autonomous Province of Vojvodina is approximately 550 l/s, and the heat output power is 50 MW. The most common water flow is 10-20 l/s, with a water temperature of around 82 °C. The shallowest drill hole is in the city of Novi Sad, at 305 m and with water temperature around 25 °C. In Figure 5.16, the hydrothermal drills map of the Autonomous Province of Vojvodina is shown, while in Figure 5.17 the map of the temperature at the depth of 500 m is presented. The total potential of geothermal energy in the Autonomous Province of Vojvodina is 22 ktoe/year [28].

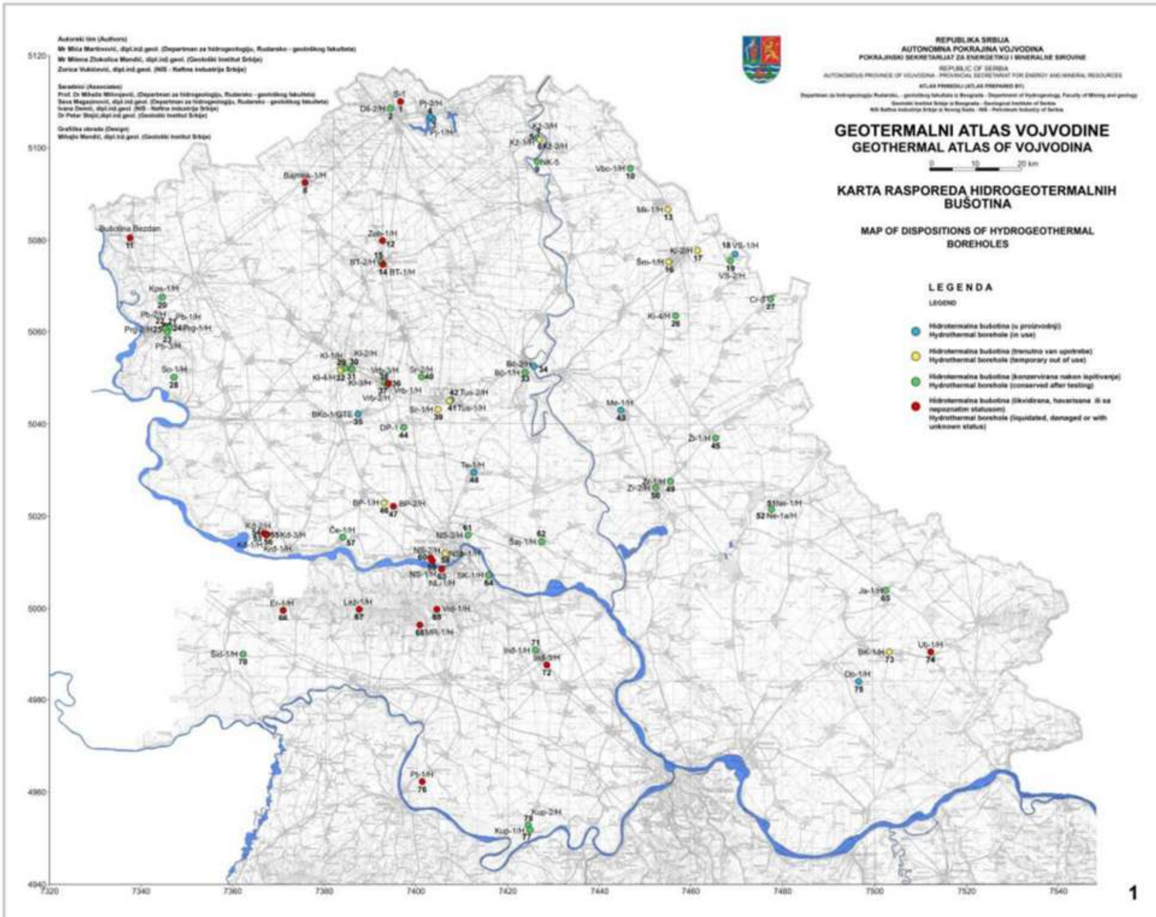

Figure 5.16 Hydrothermal drills map of the Autonomous Province of Vojvodina [28].

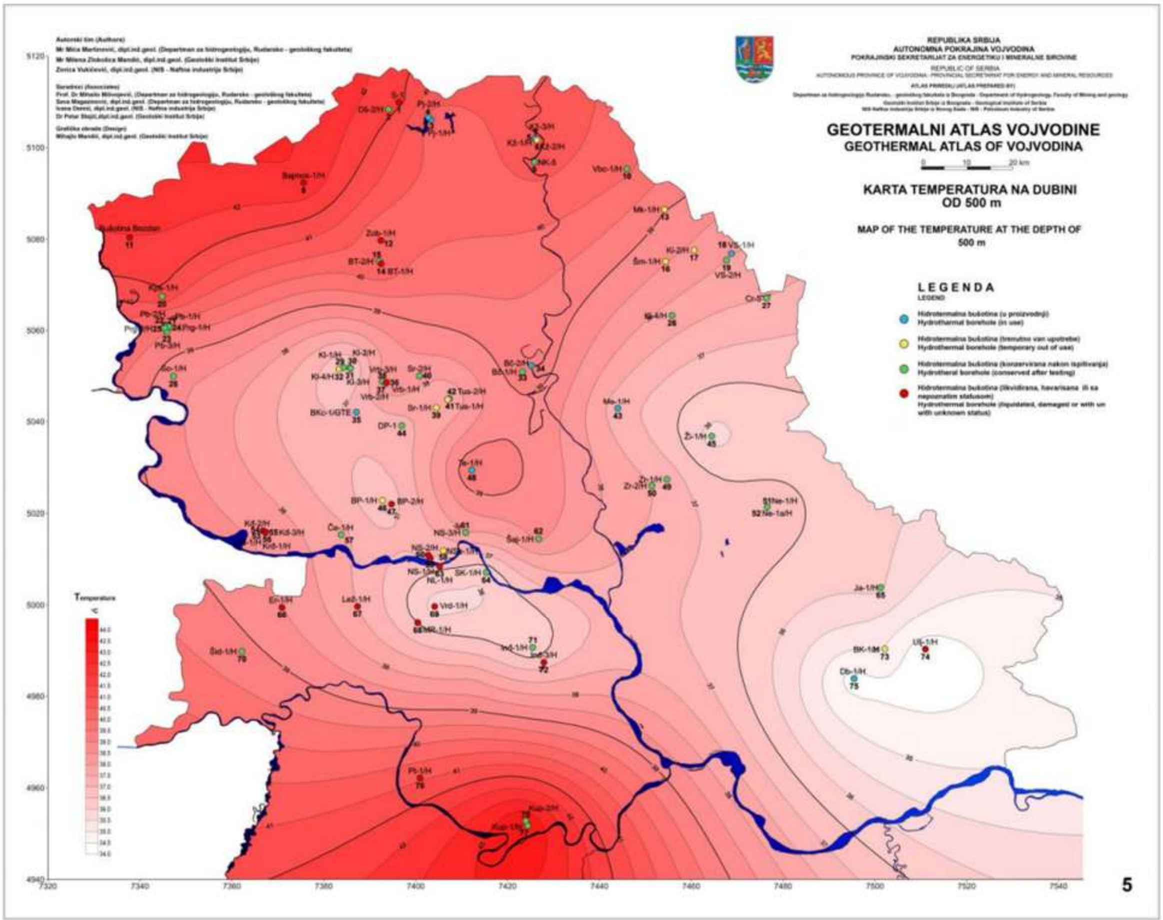

Figure 5.17 Map of the temperature at the depth of 500 m of the Autonomous Province of Vojvodina [28].

Heat energy potentials for the heat pump based HVAC are based on microclimatic conditions (air temperature, relative humidity, wind velocity, sun irradiation) in the area of Novi Sad. During the winter and summertime stable functionality of the heat pump provides up to maximum thermal power with high efficiency (COP). The average low air temperature is -3°C and the average maximum outdoor air temperature in summer is +29°C. The lower and higher outside air temperatures have a rare frequency and their cumulative values are in a short period of time. During that period COP decrease, but the rated power of the heat pump remains constant.

6. The optimal renewable energy system topology and building energy management system for the exemplary facility

In this section, considering the features of the location and building for the exemplary object and considering conducted 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.

6.1. Optimal configuration of a renewable energy system

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 reduced. Furthermore, the reduction in the energy provided by the power grid would leave to 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 object, the following systems are going to be constituted:

- Photovoltaic system;
- Photovoltaic based bike and assistive device charging station;
- Photovoltaic based electric vehicle charging station;
- Renewable energy storage/supply system;
- Wind energy system;
- Heating, ventilation and air conditioning (HVAC) system.

6.1.1. Photovoltaic system

Since the conditions for the utilization of solar energy are exceptional, the photovoltaic (PV) power plant is going to be constructed on the rooftop of the exemplary object. The precise location is depicted in Figure 6.1. The exemplary object is divided into three sectors and the PV plant is going to be placed on the rooftop on one of the sectors.

Figure 6.1 The location for the PV plant construction.

The installed power of the PV plant is 50 kW. The block diagram of the PV system is given in Figure 6.2.

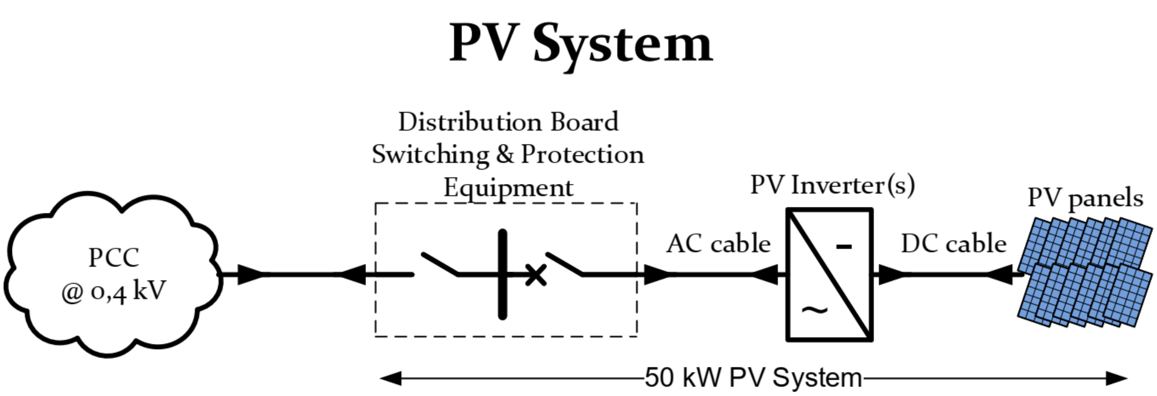

Figure 6.2 Block diagram of the PV plant.

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. Other electrical equipment such as protective and switching 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 production of electrical energy of the PV plant monthly and is depicted in Figure 6.3. The total estimated value of the energy produced annually is 54.44 MWh.

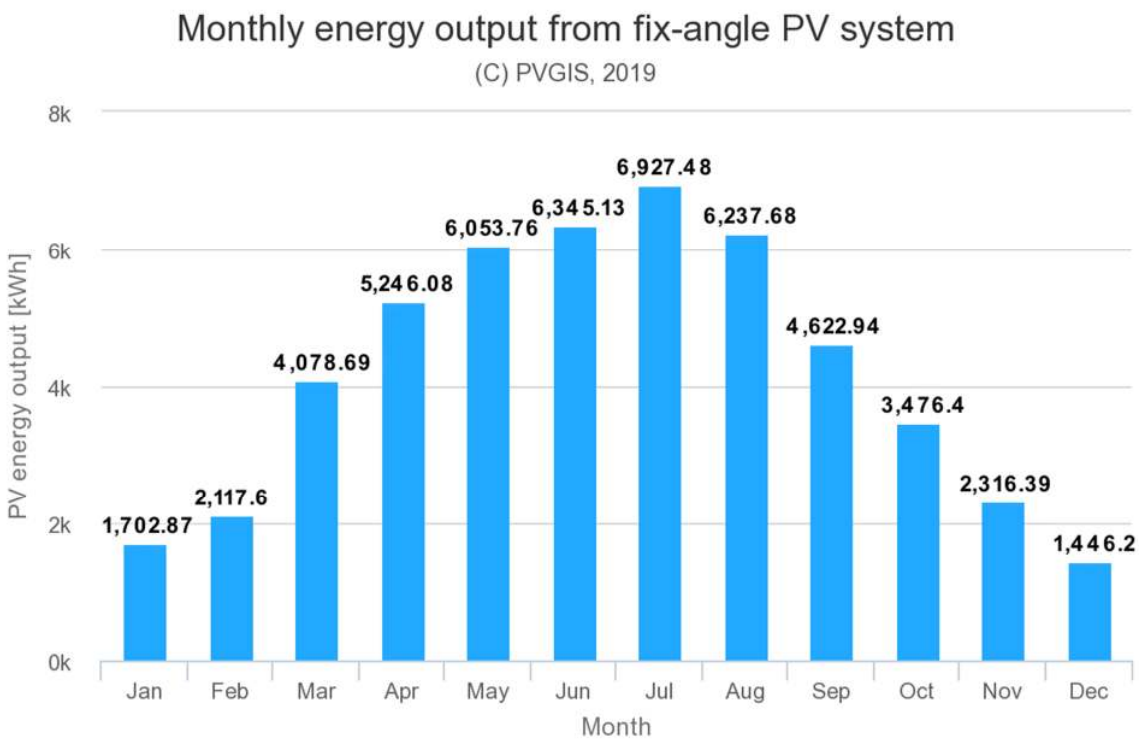

Figure 6.3 Estimated electrical energy production of the PV plant, located at the exemplary object.

6.1.2. Photovoltaic based bike and assistive device charging station

The global e-bike market is expected to grow at a CAGR of 6.39%, during the forecast period 2019-2024, according to [29]. Apart from the growing consumer preference toward recreational and adventure activities, the adoption of e-bike applications in several sectors, like logistics and e-bike rental services, is expected to drive the market studied during the forecast period. This is affordable and efficient transportation to the masses. Assuming that the number of electric bicycles is going to grow and considering that there is a large number of students and employees at the Faculty that may use this attractive

technology, electric bike and assistive device (such as mobile phone) charging station is going to be constructed. This charging station is powered with solar energy and therefore eco-friendly.

The e-bike and assistive device charging station is going to be located at the "Mašinski institut", between two building sectors. Solar panels are going to be placed on a solar tree since it is aesthetically attractive, enhances the landscape and architecture and yet behaves as a functional power generator.

The installed power of the photovoltaic based bike and assistive device charging station is 2 kW. The block diagram of this system is depicted in Figure 6.4.

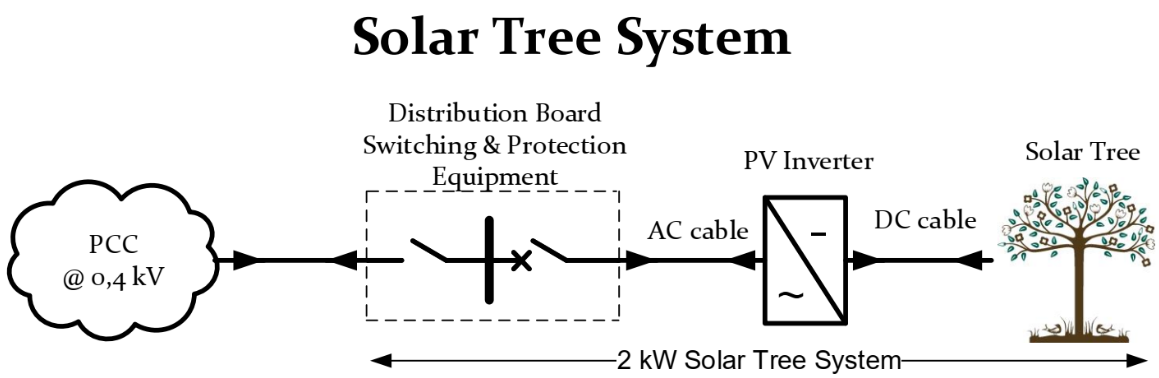

Figure 6.4 Block diagram of the solar tree system used as a generator for e-bike and assistive device charging station.

The solar tree is directly connected to the inverter unit that transforms the DC voltage from the output of PV panels placed on the solar tree to AC voltage. Electrical equipment such as protective and switching devices is placed inside the distribution board. The voltage level in the PCC is 0.4 kV.

Using the PVGIS software tool, it is possible to predict the total production of electrical energy of the solar tree monthly, which is depicted in Figure 6.5. The total estimated value of the energy produced annually is 2.18 MWh.

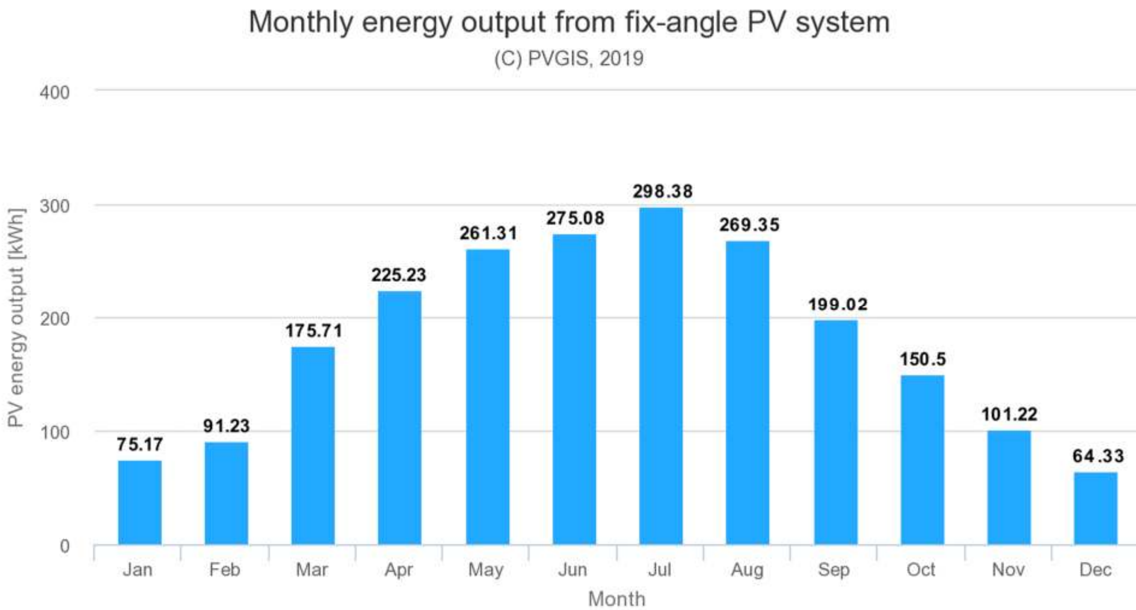

Figure 6.5 Estimated electrical energy production of the solar tree used as an e-bike charging station, located at the exemplary object.

6.1.3. Photovoltaic based electric vehicle charging station

According to [30], in the EU, the European Commission has evaluated that battery-electric vehicles (BEVs) and fuel cell vehicles (FCEVs) will represent more than 90% of the vehicle stock by 2050 in a net-zero scenario. Due to technology improvements and investments, electric vehicles are becoming more affordable and increasingly present in daily life.

Solar energy is the ideal candidate to fuel green, electric mobility since it provides CO_2 -free electricity that can be used to drive electric vehicles. Looking at the physics, solar is complementary to electric mobility, particularly in certain use cases like day charging at workplaces or combined with battery capacity at home. By maximizing self-consumption ratios of solar electricity generated on-site, the EV owner reduces the need to consume energy from the grid, saving on their electricity bill while also reducing grid congestion. This is reinforced by additional regulatory measures, such as a tax or fee exemption on the self-consumed electricity. The concept of solar-powered mobility is depicted in Figure 6.6. The charging station is powered by a PV system that may be placed on the rooftop of the nearby building or even integrated into the station. Smart meters are used to measure the power and other electrical parameters that are significant and collected data are forwarded to the energy management system that optimizes the performance of the entire system.

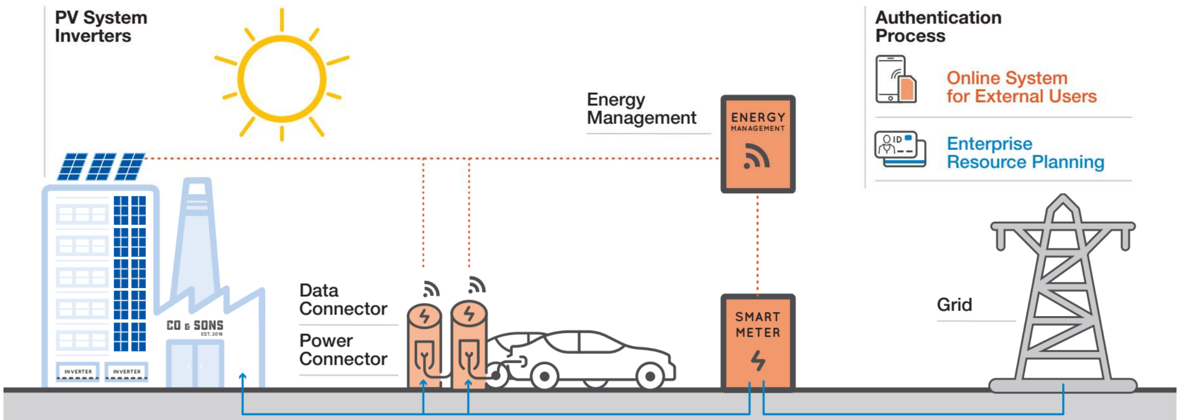

Figure 6.6 Solar-powered mobility concept [31].

Regarding the importance of the integration of electric vehicles, as well as the significance of clean mobility with solar energy as a cost-competitive and scalable candidate, a photovoltaic based electric vehicle charging station is going to be constructed in the exemplary object. It will be located in front of the main entrance of the "Mašinski institut". The installed power of the EV charging station is 3 kW. The block diagram of this PV system used to produce power for EV charging is illustrated in Figure 6.7.

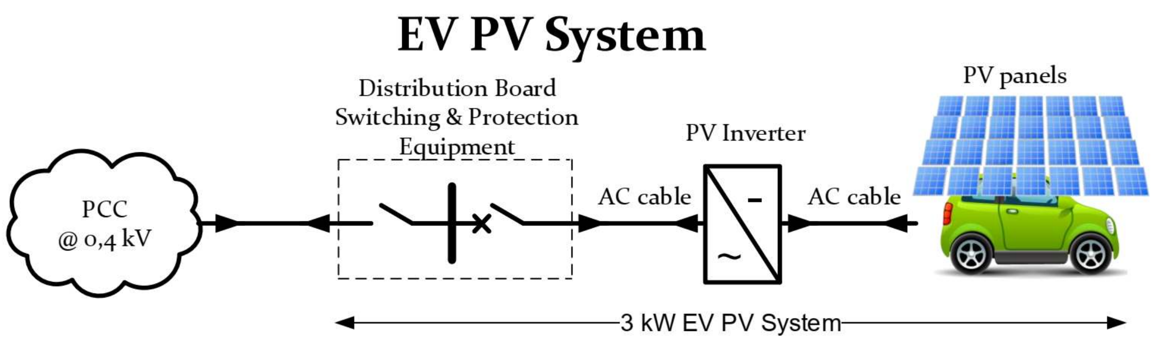

Figure 6.7 Block diagram of the photovoltaic system for the electric vehicle charging power production.

PV system used to power an electric vehicle is directly connected to the inverter unit that transforms the DC voltage from the output of the charging station to AC voltage. Electrical equipment such as protective and switching devices is placed inside the distribution board. The voltage level in the PCC is 0.4 kV.

Using the PVGIS software tool, it is possible to predict the total production of electrical energy of the PV based system that can be used for charging monthly, which is depicted in Figure 6.8. The total estimated value of the energy produced annually is 3.28 MWh.

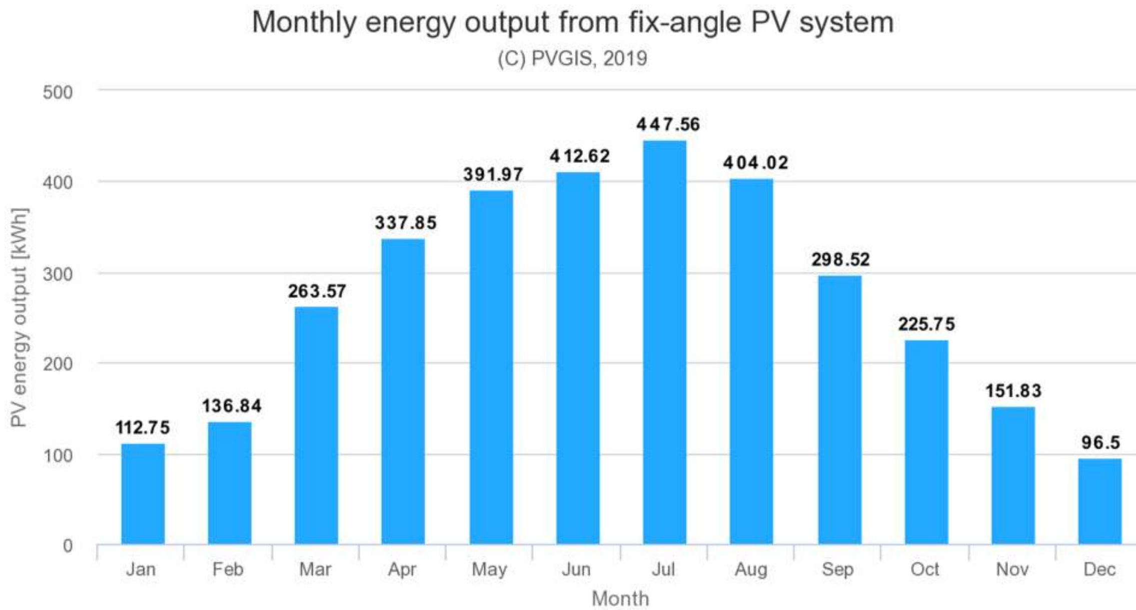

Figure 6.8 Estimated electrical energy production of the PV based system used to charge electric vehicles, located at the exemplary object.

6.1.4. Renewable energy storage/supply system

Energy storage/supply technologies are used in modern grids in order to enhance the reliability of renewable energy sources, improve the resilience of the grid and resolve its issues, as well as realize the benefits of smart grids and optimizing generation to suit demand. They are usually accompanied by renewable energy sources. Due to the highly intermittent nature of the renewables, sometimes it is possible that consumers do not need all the energy produced by the source or there is not enough energy as required. Therefore, energy storage/supply systems can be used to store energy when the amount generated exceeds the demand and inject power into the system during shortages. Furthermore, they can be used for the peak shaving application, i.e. to cover the peak load.

Therefore, a renewable energy based storage/supply system is going to be installed at the exemplary object in order to provide stabilizing the power output while also enhancing the reliability of the system. The block diagram of the energy storage/supply system is given in Figure 6.9. The bi-directional power converter is used as an interface between the storage/supply system and the grid. Switching and protection equipment is placed in the distribution board. The installed power of the bi-directional converter used in the system is 35 kW. The storage/supply system comprises the battery storage system, as well as the supercapacitor system. Batteries present an advanced technique for storing electrical energy in electrochemical form and have a wide range of use. Supercapacitors have a high energy storage capacity due to their high power ability and since the stored

energy has to be used very quickly, they are able to provide peak shaving and thus improve the power profile.

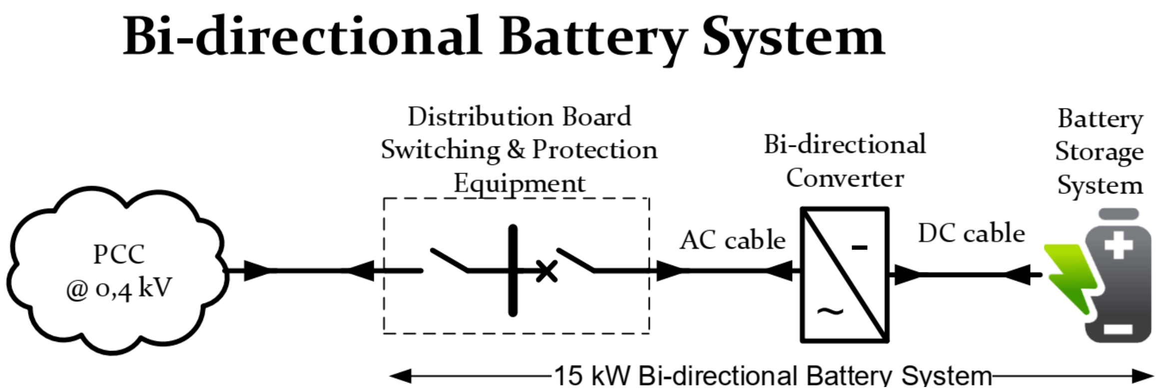

Figure 6.9 Block diagram of the energy storage/supply system.

The battery of the electric vehicles can also be used as a storage/supply unit and can enable different grid support functionalities. This is a state-of-art concept that is very interesting to the researches and certainly could become a new tool for electric utilities in the next decade.

6.1.5. Wind energy system

The exemplary public building is located in the region with good potential for wind energy development, especially in higher height levels. However, since the area is urbanized, there are limited options when it comes to wind energy due to the surrounding buildings, trees and other obstacles. Another important issue is the size of the wind turbine. Wind turbines can be noisy and require consistent, non-turbulent winds of certain speeds that are uncharacteristic of urban environments. However, due to the technology improvements wind turbines should be self-starting, ultra-quiet, provide smooth torque, and be highly efficient so usable energy can be delivered at modest wind speeds.

Therefore, a small wind power system is planned to be constructed on the rooftop of the “Mašinski institut”. Rooftops are elevated above the ground, where it is windier and the electricity is generated right where it is needed. The installed power of the system is 2kW. The block diagram of the wind power system is given in Figure 6.10.

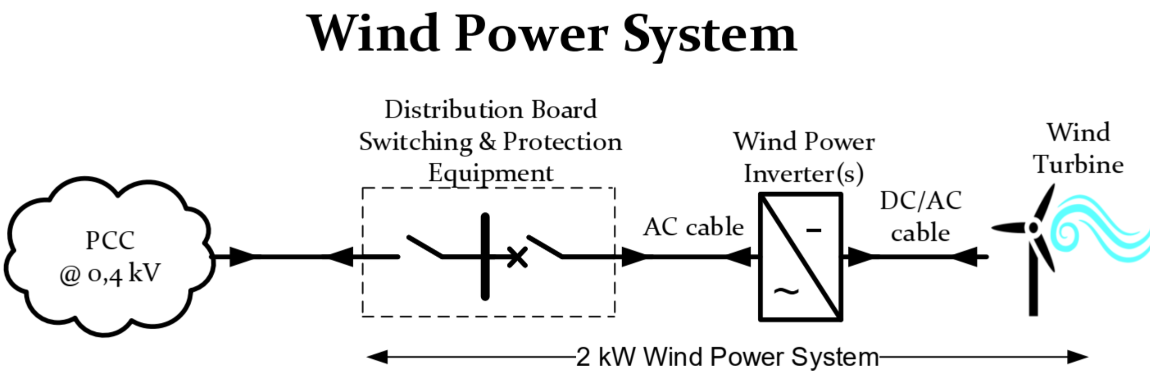

Figure 6.10 Block diagram of the wind power system.

The wind turbine is directly connected to the three-phase inverter unit(s) which transform the DC voltage from the output of wind turbine to AC voltage. Protective and switching devices are placed inside the distribution board. The voltage level in the PCC is 0.4 kV.

A free online tool from REUK.co.uk is used to estimate the amount of electricity that can be generated by a wind turbine with a known rotor diameter, in a location with a particular average wind speed. The prediction is that the energy produced annually is 1.06 MWh and estimated monthly output of the system is depicted in Figure 6.11.

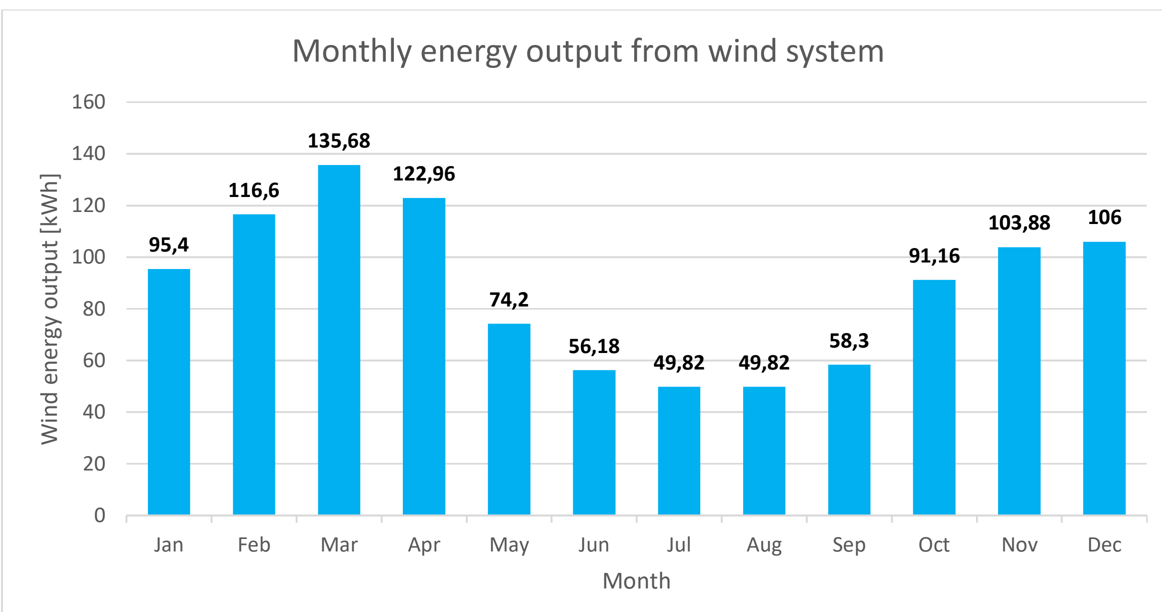

Figure 6.11 Estimated electrical energy production of the wind based system.

6.1.6. Heating, ventilation and air conditioning (HVAC) system

The exemplary object is primarily dedicated to research and teaching activities of a large number of employees and students. All parts of the building are at disposal almost the entire day, and thus thermal comfort and acceptable indoor air quality are extremely important. Moreover, considering the cost of the heating energy that is consumed in the object, the reduction of the heating bill price is beneficial. Therefore, heating, ventilation, and air conditioning system (HVAC) is an adequate solution to this problem. HVAC systems provide significant energy-saving benefits, have a positive environmental impact, can improve air quality by constantly exchanging the indoor air with fresh, offer superior humidity control and a variety of other options.

Therefore, the HVAC system is going to be installed in the exemplary object. The system is dedicated to the air conditioning of several laboratories. It is intended to provide better insulation of that part of the building in order to achieve greater system efficiency. Energy-efficient windows and doors should provide insulation for the winter, decrease air conditioning use in the summer, and eliminate overall uneven heating and cooling.

The installed power of the HVAC system is 55 kW. The efficiency of its components depends on the relation between HVAC size and facility size, local climate, operation time and the type of the fuel HVAC uses. It is decided that the central HVAC system, based on air heat pump, with fan coils units. Thus, the volume of this combined system is reduced, and the outdoor ventilation is produced to properly condition the desired zone. The appropriate thermal medium is responsible for carrying the thermal load in a building by 80–90 %, while air medium conditions the remainder.

The coefficient of performance or COP of HVAC system is a ratio of useful heating or cooling provided to work required. Higher COPs equate to lower operating costs. It is expected that a HVAC system with the installed power of 55 kW has a COP ratio value of approximately 3.5, considering the operating conditions, for example the difference between the sink and system temperatures. Also, at least 50 % of the heat pump capacity should be accessible. The worst operating conditions are present when the outside temperature is low, while the required sink temperature is high. For example, if the outside temperature is about -10°C and the sink temperature is about 60°C, heating capacity should be approximately 40 kW, and the electrical energy consumption should be about 25 kW. On the other hand, the best operating conditions are present when the outside temperature is high, while the required sink temperature is low. For example, if the outside temperature is about 7°C and the sink temperature is about 35°C, heating capacity should be approximately 75 kW, and the electrical energy consumption should be about 15 kW.

The block diagram the HVAC system connection to the grid is depicted in Figure 6.12. The system is directly connected to the PCC point at voltage level 0.4 kV, and complete equipment dedicated to the switching and protection is placed inside a distribution board. The HVAC system uses the thermal energy from different mediums – air, water, etc. If that thermal energy is not enough to fulfill all requirements, the remaining energy for heating/cooling process is taken from the grid.

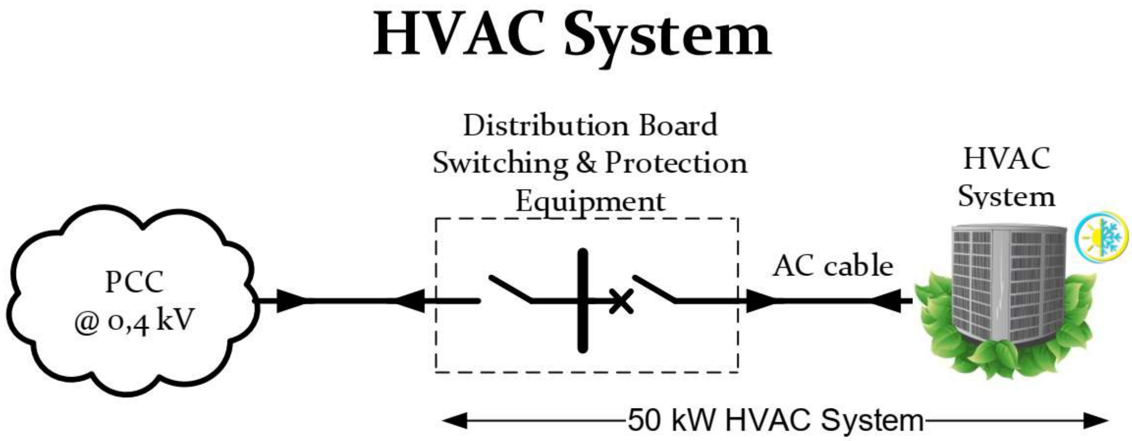

Figure 6.12 Block diagram of the HVAC system.

6.2. Optimal configuration of the smart building energy 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 [32].

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 heterogeneous sensory and actuator devices. Sensing 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 devoted 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 system, PV based bike and assistive device charging station, PV based EV charging station, renewable energy storage/supply system, wind energy system and HVAC system, as depicted in Figure 6.13. Red and green arrows indicate possible directions of the power flow.

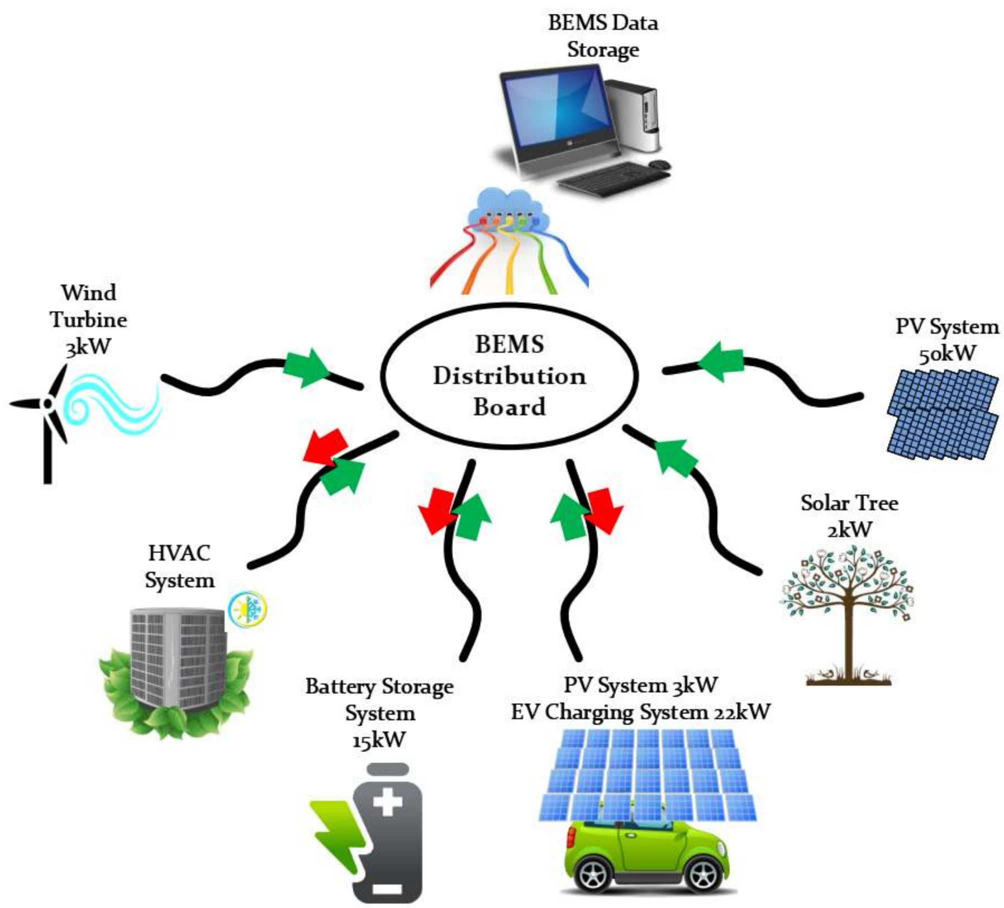

Figure 6.13 BEMS system configuration.

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 highest 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 otherwise) 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/m^2 to 300 W/m^2. 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.

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 Faculty of Technical Sciences

public building, and according to the available potential, there are several systems planned for installation. First and foremost, the PV power plant of 50 kW will be installed on the roof top of the building. Additionally, 2 smaller PV plants of 2 kW and 3 kW will be installed on the solar tree and EV charging stations. The latter will make full use of the natural synergy between the renewable energy sources and EVs, providing the vehicle with the free RES based energy for transport and daily activities of the project (and Faculty) staff. Additionally, to further diversify the energy mix the installation of the 2 kW wind power plant is proposed. All of these renewable energy sources have a very well-known intermittency issues. To compensate for these, a 35 kW bi-directional RES based storage/supply system will be installed. The system will offer peak load leveling operation, providing the clean energy to the facility through the day. Since the significant amount of energy is used for heating and ventilation a heat pump based HVAC of 55 kW will be used to provide the thermal energy for the laboratories and offices within the public building. 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 RES systems during the year is created. It can be observed in Figure 7.1 that the PV plant has the highest production, which is expected given the installed capacities of the systems. However, it is necessary to notice that the installed capacities of the rest systems are chosen for their purposes. For example, the PV system that will be used as an electric vehicle charging station has enough production during the year for reducing the travel costs. The total estimated electrical energy production has the highest production during the summer.

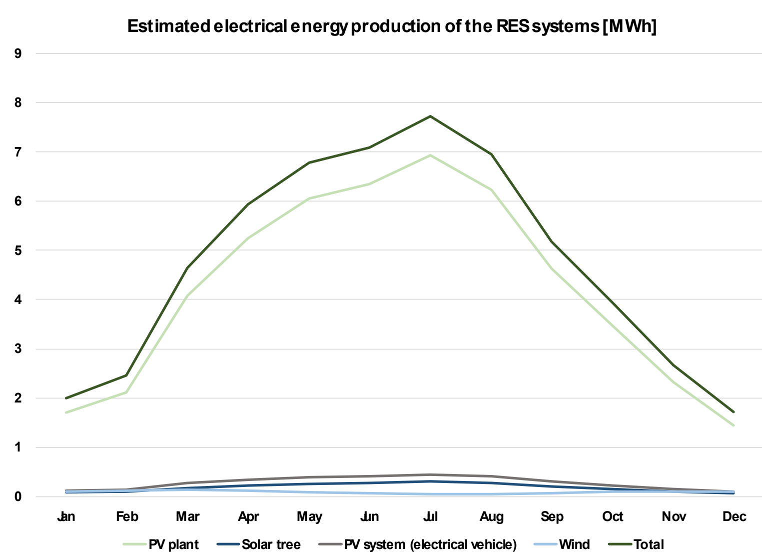

Figure 7.1 Estimated electrical energy production of the RES systems.

In Figure 7.2, a comparison of the total consumption for 2018 and the estimated values of PV and wind systems in MWh, is shown. PV systems have a significantly higher

production capacity compared to the wind system, which is expected given the installed capacity of the systems. Considerably reduced consumption is observed from April to September. The highest share of the RES systems in final consumption is for the month of July, approximately 35%, while the lowest is during the month of December, approximately 5%.

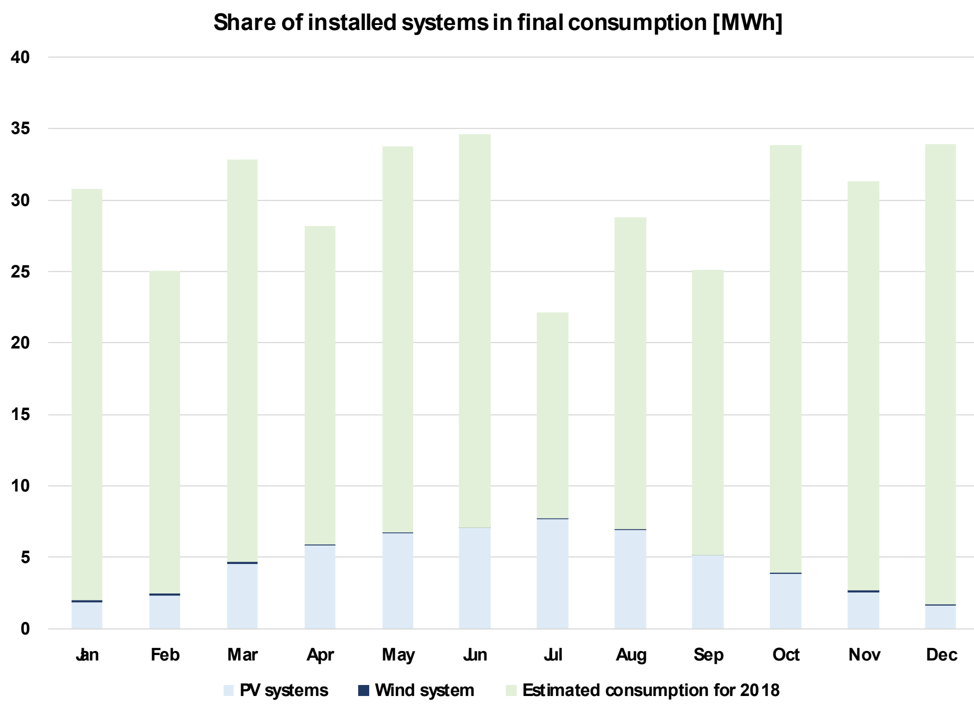

Figure 7.2 Share of installed systems in final consumption for 2018.

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