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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 4: Clinical Hospital Center Osijek -

Osijek

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Title page

A study on energy demand, energy efficiency, available renewable energy sources and recommendation for optimal configuration of smart building energy management systems
- Case 3: Clinical Hospital Center -

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Abstract: This document presents a comprehensive study on energy demand and energy efficiency for the Clinical Hospital Center Osijek public buildings. Furthermore, the study describes the available renewable energy sources that could be used for energy generation in the near vicinity of the public building. After exploring the demand and the potential, the study proposes the optimal configuration of the renewable energy and the smart building energy management systems that would significantly increase the public building efficiency while reducing the energy demand, bringing the public building one step closer to near zero-energy building. This document also gives a short overview of the most important directives and national legislative supporting energy efficiency and renewable sources.

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Table of Contents

List of figures

List of tables

1. Introduction

Energy consumption is constantly increasing 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.

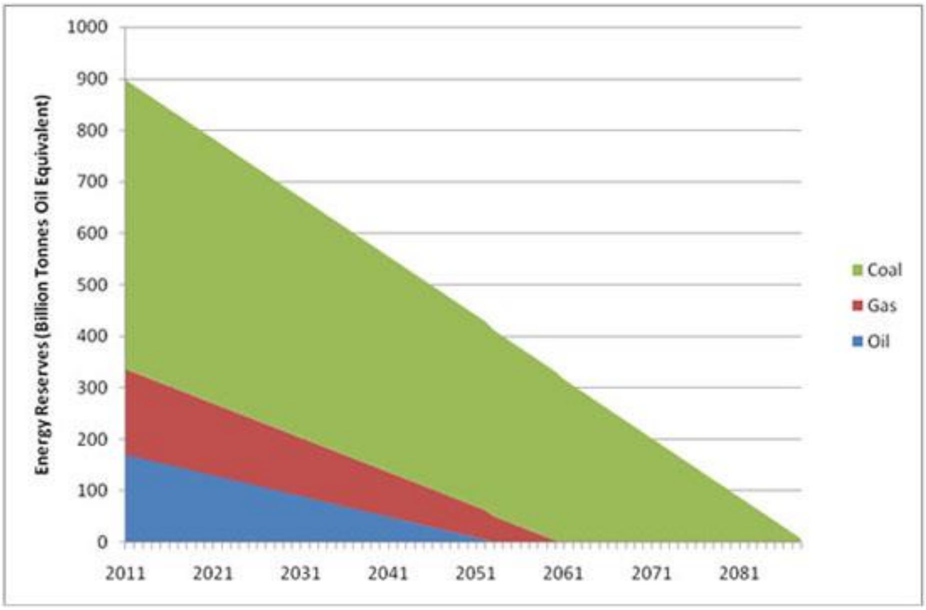

Figure 1.1 *The prediction of fossil fuel energy reserves [1].*

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.

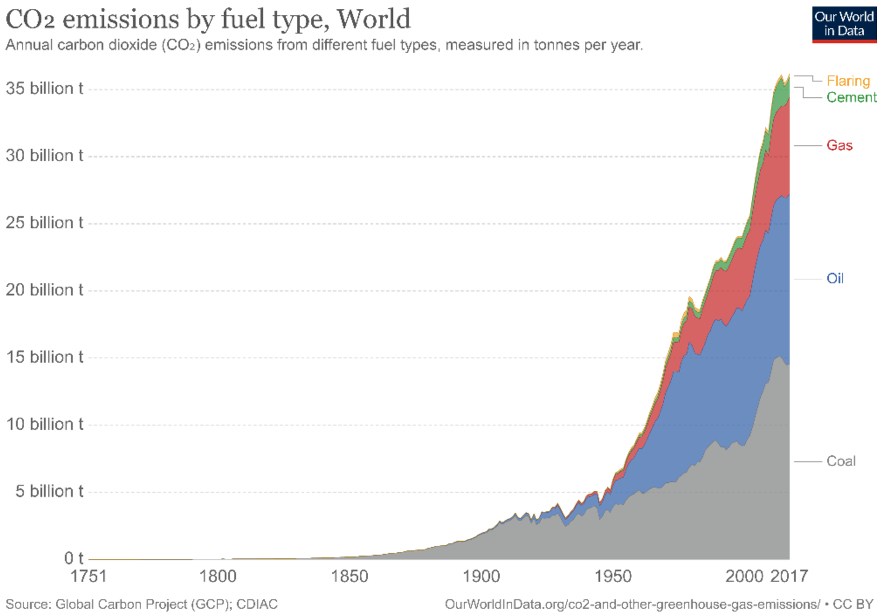

Figure 1.2 *Carbon dioxide (CO_2) emission by a specific type of fossil fuel [2].*

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.

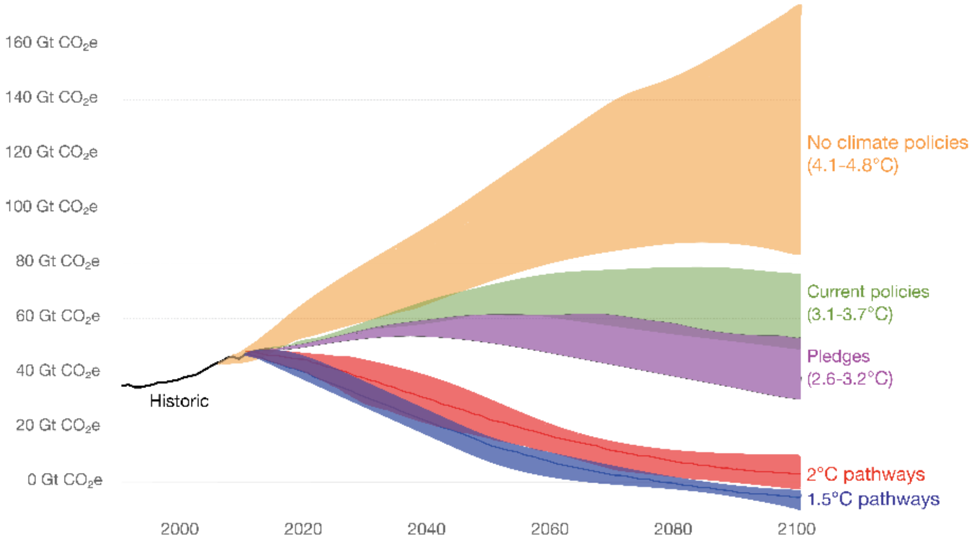

Figure 1.3 *The prediction of the CO_2 emission based on different scenarios [2].*

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 canters 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].

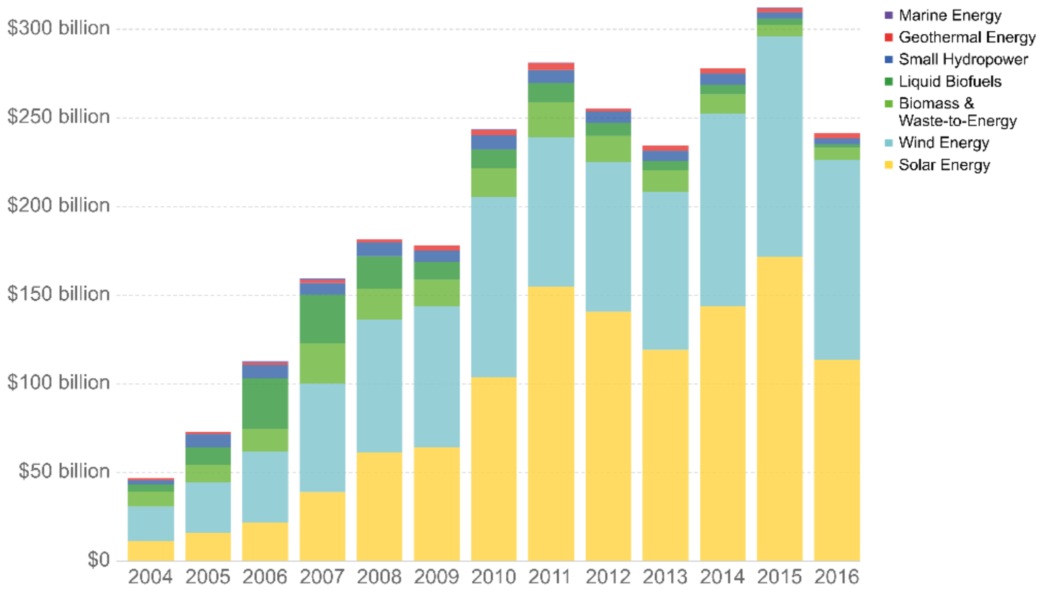

Figure 1.4 *Investment in different renewable energy technologies [6].*

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].

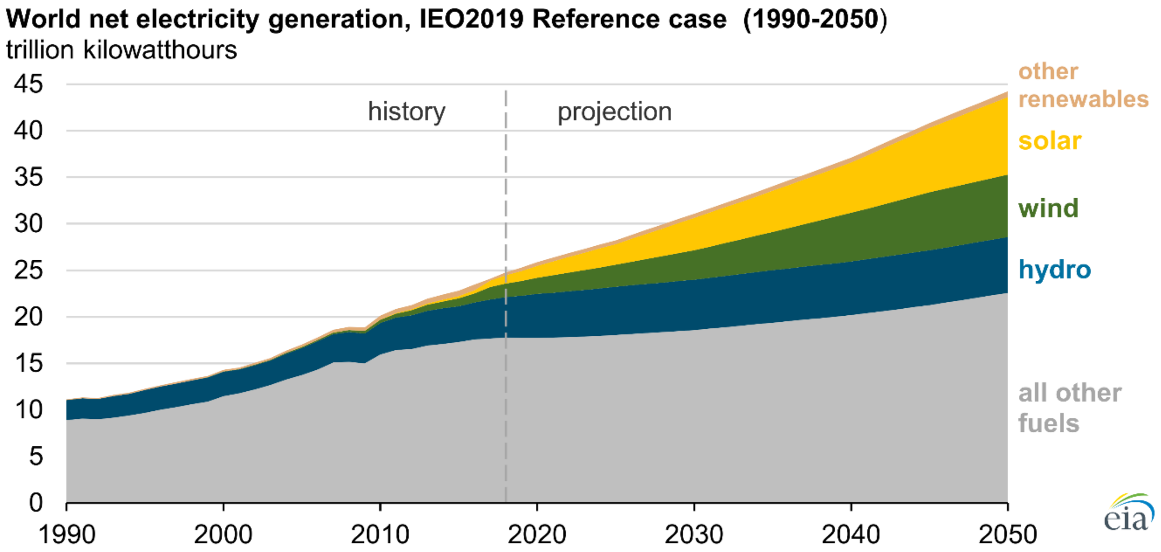

Figure 1.5 *World net electricity generation [8].*

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. 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 [9]. 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 [10]. The amending directive (2018/2002) [11] was agreed to update the policy framework to 2030 and beyond. The key element of the amended directive is an energy efficiency target for 2030 of at least 32.5%. The directive allows for a possible upward revision in the target in 2023, in case of substantial cost reductions due to economic or technological developments. It also includes an extension to the energy savings obligation in end-use, introduced in the 2012 directive. Under the amending directive, EU countries will have to achieve new energy savings of 0.8% each year of final energy consumption for the 2021-2030 period.

Another important directive is Directive 2010/31/EU on the energy performance of buildings [12]. This directive introduces a framework for improving the energy efficiency of buildings and proposes a plan in which all new buildings are nearly zero-energy buildings by 31 December 2020.

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. 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.

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 analyse 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 [13]. 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 [14].

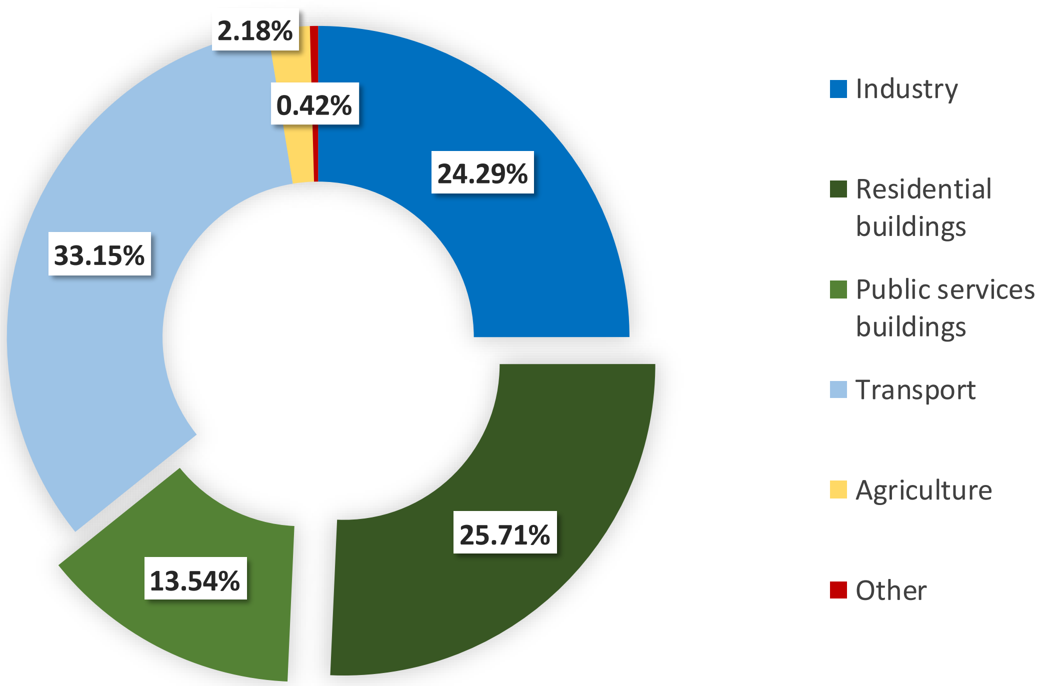

Figure 2.1 *Energy consumption by sector in the EU [15].*

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 [16].

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 [17]. 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 [18]. 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 decarbonization, 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 behavioral 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 mobilizing investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock. That strategy should address cost-effective deep renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance. Such deep renovations could also be carried out in stages."

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

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

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

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

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

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

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

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

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

Energy Efficiency Directive (2012/27/EU) Article 4 states: "Member States shall establish a long-term strategy for mobilizing 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 optimizing 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 [19]. Among others, directive states that the monitoring and automation of buildings have proven 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 decarbonized 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, split incentive 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 [9]. 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 [10]. The amending directive (2018/2002) [11] was agreed to update the policy framework to 2030 and beyond.

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

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

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

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

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

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

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

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

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

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

Energy Efficiency in Public Buildings in Croatia

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

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

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

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

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

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

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

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

3. The main features of the locations and the buildings for the exemplary facilities

Clinical Hospital Center Osijek (KBCO) started operation as a Clinical Hospital Osijek in 1874. During 20th century, hospital experiences massive expansion in spatial and personnel view. At the end of the 20th century, hospital turns into clincal-hospital center we know today. Currently, medically speaking, KBCO includes 26 organisational units, 17 clinics, 7 departments and 1 emergency center and 2 general purpose medical units (hospital pharmacy and central ordering).

KBCO occupies multiple locations in city of Osijek and its surroundings. KBCO functions in major clinical-hospital complex in Huttler street, Department of Eye Diseases which occupies 2 smaller facilities in Europske Avenije street and Department of Physical Medicine and Rehabilitation which occupies complex of building in Bizovac near Osijek. This study will focus only on clinical-hospital complex of buildings at the address Josipa Huttlera 4, Osijek. KBCO complex in Huttler street is located in the eastern part of Osijek in Slavonia-Baranja county. Geographical location of the complex is North latitude 45° 33′ 19.79′′, East longitude 18° 42′ 45.5′′.

KBCO complex in Huttler street is located on multiple cadastral parcels as shown in Figure 3.1. Near the complex, Josip Juraj Strossmayer University of Osijek campus is located, as well as building of the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek in Cara Hadrijana street.

In this study, building on which renewable energy systems will be installed will be in focus. These buildings represent central kitchen (red squared in Figure 3.1), building of Department of Oncology (blue squared in Figure 3.1) and building of Department of Diagnostical and Interventional Radiology (green squared in Figure 3.1).

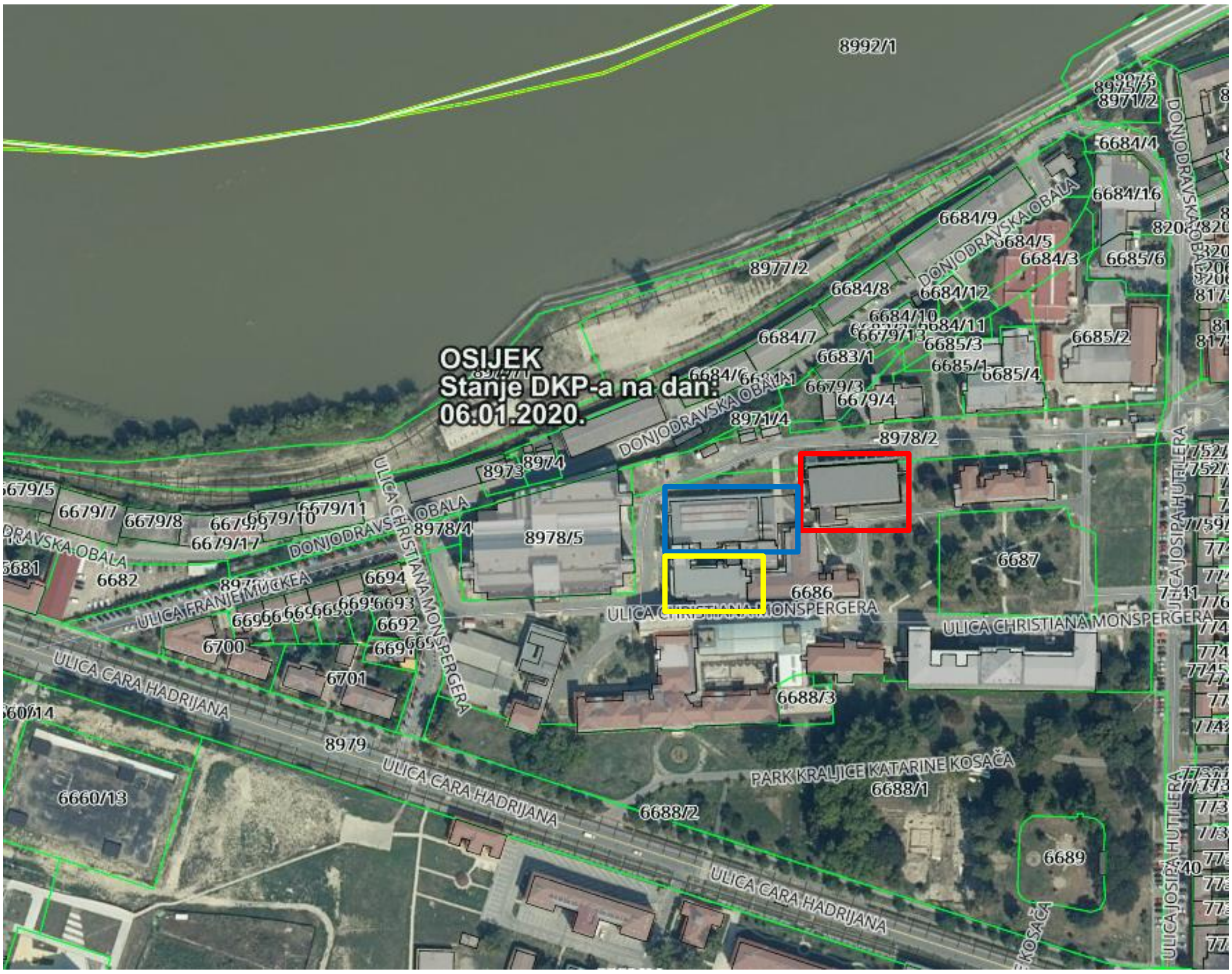

Figure 3.1 *Location of KBCO complex in Huttler street [20].*

Central kitchen is general-purpose facility used for preparation of food and diets of KBCO users. North side of the building in given in Figure 3.2. while its interior is given in Figure 3.3.

Figure 3.2 *North side of the central kitchen building.*

Figure 3.3 *Interior of the central kitchen facility*

The Department of Radiology and Oncology was established in 1932. The present building began to be built in 1968 and was commissioned in 1970 under the name "Department of Radiology and Oncology". At the end of 1973, the department was divided into: Department of Radiodiagnosis and Department of Oncology and Radiotherapy. Prior to becoming independent, the department integrated its activities in both the diagnostic treatment of patients and the implementation of therapeutic procedures in accordance with available equipment. By dividing the department into the diagnostic and therapeutic part, the equipment is rebuilt to extend the range of diagnostic procedures (ultrasound, computer tomography, magnetic resonance imaging, mammograms and specific therapeutic devices: CO bomb, linear accelerator, simulators for planning treatment procedures). West side of the building of Department of Oncology is given in Figure 3.4, while north side of the building of Department of Diagnostical and Interventional Radiology is given in Figure 3.5.

Figure 3.4 *East side of the building of Department of Oncology.*

Figure 3.5 *North side of the building of Department of Diagnostical Interventional Radiology*

Departments of Oncology and Diagnostical and Interventional Radiology consist mainly of clinic and control rooms for diagnostical treatments, infirmary rooms, hospital rooms and general-purpose rooms. Clinic rooms are used for devices that conduct diagnostic treatment of patients while control rooms are used for technicians and engineers that operate the devices. Infirmary rooms are used for examinations of patients by doctors (Figure 3.6). Hospital rooms are used for patients currently situated at the Department. Main engineer room in the Department of Diagnostical and Interventional Radiology is given in Figure 3.7.

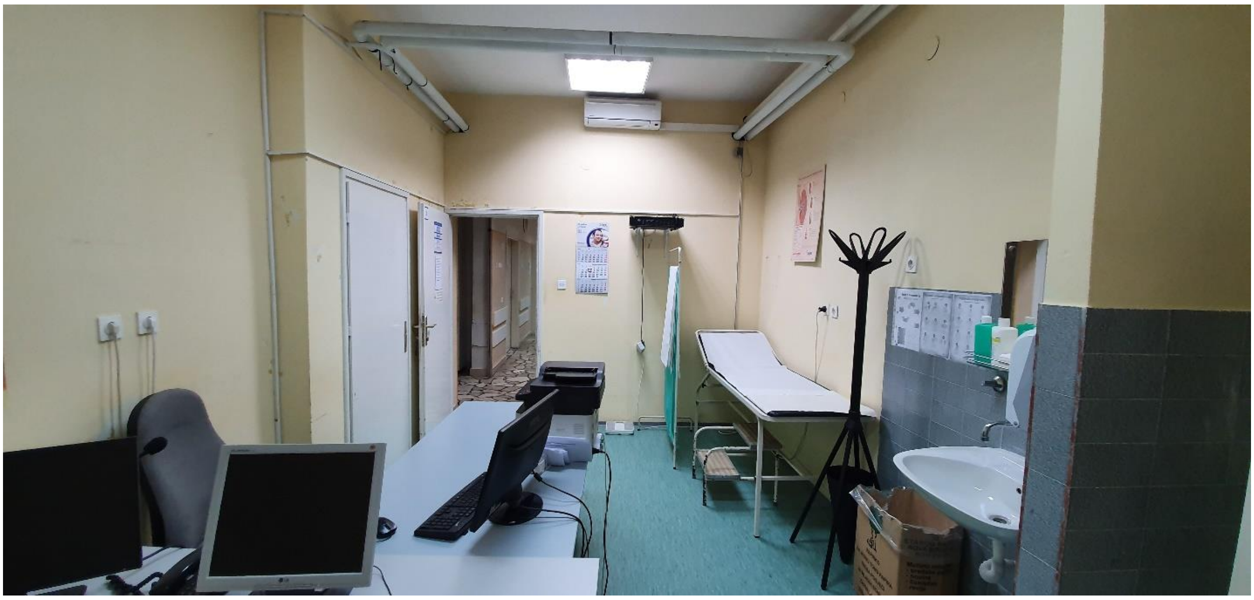

Figure 3.6 *Infirmary room at the Department of Oncology.*

Figure 3.7 *Main engineer room at the Department of Diagnostical and Interventional Radiology*

3.2. Climate conditions in the surrounding area

Continental Croatia is characterized by temperate continental climate and throughout the whole year it is marked by very variable atmospheric conditions because of circulation zone of mid-latitudes. Main feature of the climate is a diversity of weather situations with intense and frequent interchanges during the year caused by low or high air pressure moving complexes, usually like vortices hundreds and thousands of kilometers in diameter. Furthermore, continental Croatia climate is also modified by the Mediterranean maritime influence, which weakens by distancing towards the east. The next, more local than regional, factor that influences the climate is orography which, on the windward side of the orographic obstacle, makes easier the amplification of short-term heavy precipitation while on the leeward side generates appearance of precipitation shadow. Finally, these conditions also depend on the current season [21].

Stationary anticyclonic weather types with low clouds or fog and a very gentle air flow are beneficial for frost occurrence during the winter. On contrary, fast-moving cyclonic weather types (cyclone and trough) in spring result in frequent and unforeseen weather changes, varying from cold to warm, calm to windy or dry to rainy periods. During summer, small air pressure gradient results in a cooling night breeze blowing down mountain slopes interrupted by cold fronts passing through bringing fresh Atlantic air. Consequently, this results in strong air mixing, increased wind, thunder and showers from dense clouds with vertical development. Autumn is distinguished by intervals of calm anticyclonic weather, but there are also rainy days caused by passing cyclones. Autumn starts with warm and sunny days and fresh nights with much dew and low fog while at the ending conditions transform to cold, foggy, and gloomy [21].

Crucial source of information for Croatia's wind energy potential estimation is the wind atlas. Maps given in Figure 3.8 and Figure 3.9 show average wind speed (m/s) and mean wind power density (W/m^2) maps at 10 m and 80 m above ground. Given maps are a result of atmospheric numerical model and represent an average value in a grid cell of 2 km x 2 km [22].

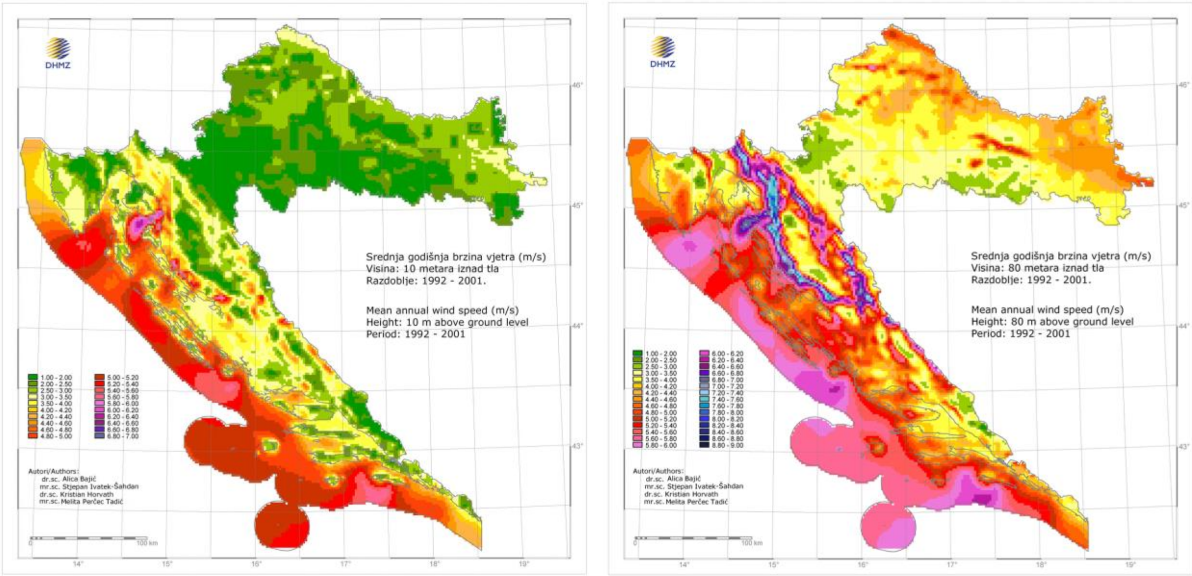

Figure 3.8 – *Mean annual wind speed in Croatia (m/s) [22].*

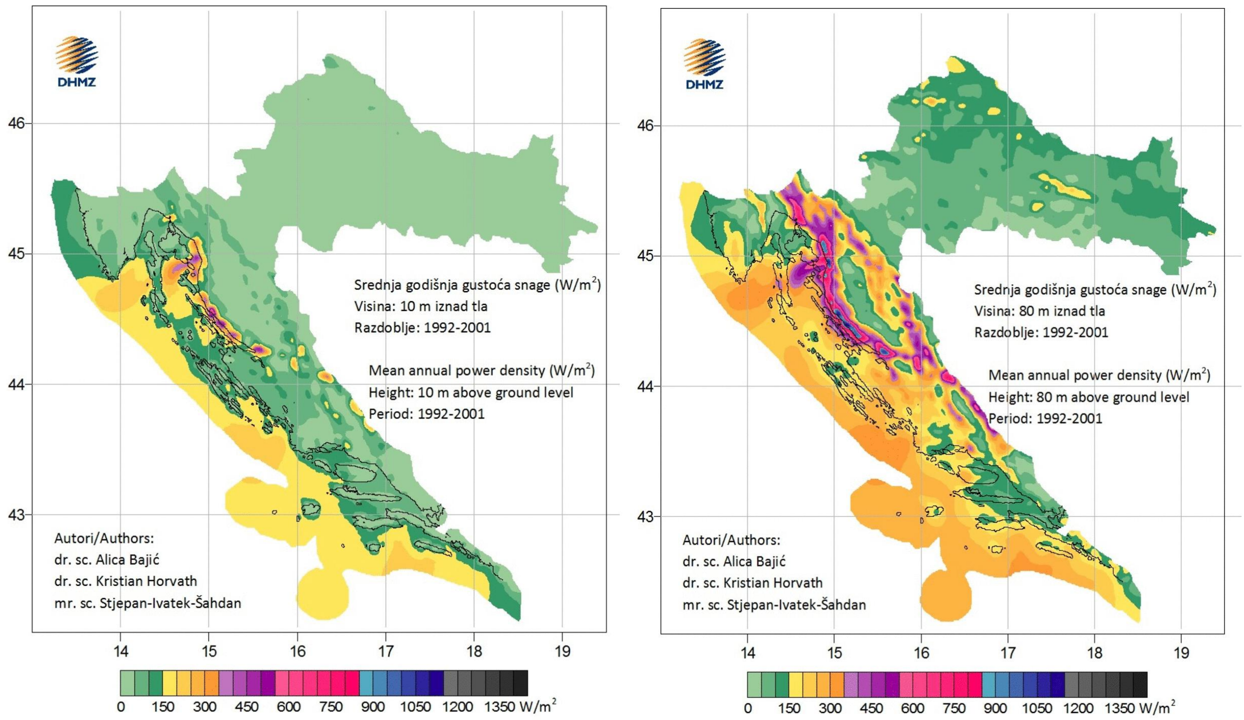

Figure 3.9 *Mean annual power density in Croatia (W/m^2) [22].*

Table 3.1 shows monthly mean and extreme values of climatological parameters in the period from 1999 to 2018 (according to data of the Croatian Meteorological and Hydrological Service). Osijek is at an average altitude of 90 m, with an average temperature of 11 ℃ during the year, and with an average temperature of -0.6 ℃ in January and 21.7 ℃ in July. The lowest measured temperature was -27.1 ℃ in July, while the highest measured temperature was 40.3 ℃ in August and September. The total annual average rainfall is 692.9 mm and the average number of days with snow cover is 23.

Table 3.1 Monthly mean and extreme values of climatological parameters for Osijek [23].

	Jan	Feb	Mar	Apr	May	Jun	Jul	Avg	Sept	Oct	Nov	Dec
Temperature [°C]												
Mean	-0.6	1.3	6.3	11.6	16.6	19.8	21.7	20.9	16.7	11.3	5.8	1.3
Absolute maximum	19	23	26.9	30.9	36	39.6	40.3	40.3	37.4	30.5	25.8	21.3
Absolute minimum	-27.1	-26.4	-21.0	-6.8	-3.0	1.0	4.7	5.1	-1.2	-8.6	-15.7	-23.2
Daylight hours [h]												
Total	59.7	86.3	142.9	182.1	226.5	247.1	276.3	261.6	191.8	150.4	75.1	52.0
Rainfall												
Volume [mm]	45.4	42.7	45.7	57.8	70.3	82.4	61.3	58.8	55.5	59.5	59.8	53.7
Maximum snow height [m]	52	93	49	22	-	-	-	-	-	-	40	60
Number of days												
Clear	3	4	5	5	5	6	9	11	9	7	3	2
Foggy	6	4	2	1	0	0	1	1	2	4	6	7
Rainy	7	7	10	12	13	12	10	9	9	10	11	10
With frost	7	7	7	2	0	0	0	0	0	3	6	8
With snow	6	6	3	1	0	0	0	0	0	0	2	5
Icy day (t_{min} ≤ -10°C)	4	3	0	0	0	0	0	0	0	0	0	2
Frosty day (t_{min} < 0°C)	9	4	1	0	0	0	0	0	0	0	1	6
Cold day (t_{min} < 0°C)	23	18	11	2	0	0	0	0	0	2	8	19
Warm day (t_{max} ≥ 25°C)	0	0	0	2	11	18	24	23	12	2	0	0
Hot day (t_{max} ≥ 30°C)	0	0	0	0	2	6	11	10	3	0	0	0

4. Current energy demand overview for the public building

In order to implement different strategies for the increase of energy efficiency, it is necessary to analyze the major consumers and the consumption of electrical energy in the exemplary objects.

Here, buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology in KBCO complex in Huttler street will be referred to as Department.

4.1. Description and classification of the consumers in the objects

One of the diagnostic procedures that Department performs are magnetic resonance imaging (MRI). MRI is a diagnostic radiological method that uses a strong magnetic field and radio waves to get an image of tissues and organs inside human body. It is standard that body imaging is done by segments such as the brain, pituitary, orbits, cervical spine, thoracic spine, loin spine, joints (shoulder, knee, hip...), etc. Most MRI scanners have a tunnel-like housing into which the body is to be analyzed using an automated examination table.

Currently, the Department uses Siemens Magnetom Avanto 1.5T MRI and the Siemens Magnetom Skyra 3T MRI scanner (Figure 4.1). Control room of the Siemens Magnetom Skyra 3T MRI scanner, where engineers and technicians supervise the procedures is given in Figure 4.2.

Figure 4.1 *Skyra 3T Siemens Magnet*

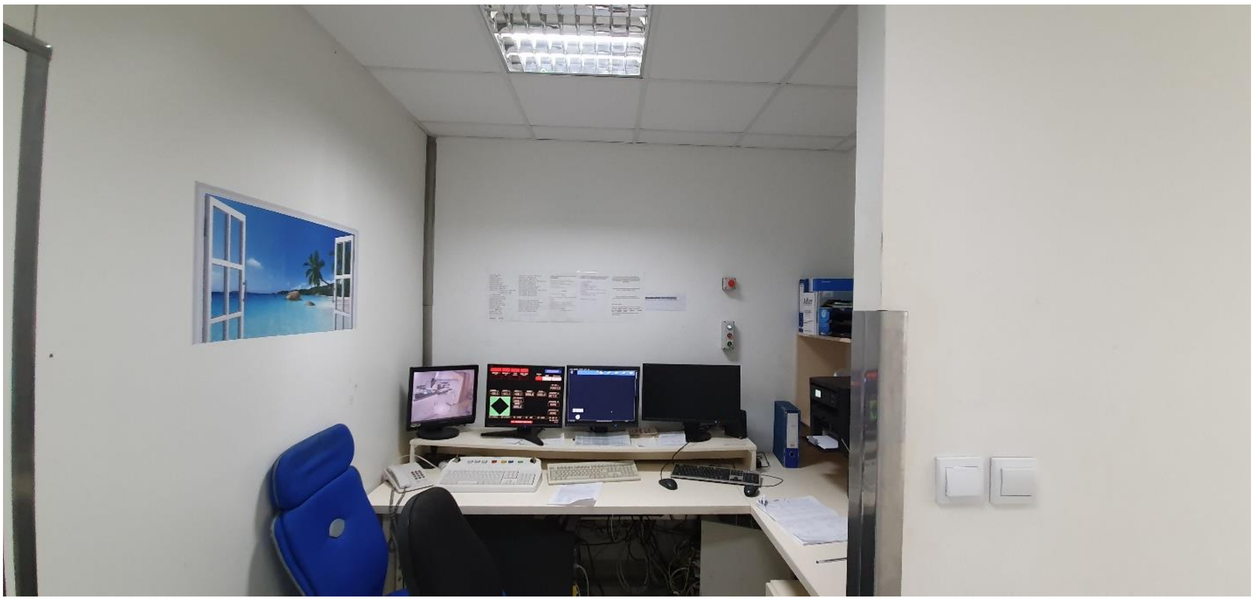

Figure 4.2 *Control room of Siemens Magnetom Skyra 3T MRI scanner*

Furthermore, Department provides computer tomography (CT) diagnostic procedures. CT is now an indispensable method in the diagnosis of brain, spine, and chest diseases, including the lungs and midbrain, then in the diagnosis of abdominal organs, excluding the stomach and intestines. The main advantage of computed tomography over classical radiological methods is the ability to measure the density of a particular pathological process, to accurately estimate the size and relationship with adjacent anatomical structures. Using contrast media, blood vessels in a human body can also be displayed. Currently, Department uses Siemens Definition AS CT scanner, given in Figure 4.3.

Figure 4.3 *Siemens Definition AS CT scanner*

With MR and CT, one of the more important devices in the department is the Varian Edge linear accelerator, given in Figure 4.4. Radiation therapy uses focused energy beam to damage cancerous cells and at the same time have minimal impact on healthy tissue. The radiation damages the DNA of the cancerous cells which consequently impairs their ability to spread, destroying them and reducing the tumor. Healthy cells can more easily recover from radiation exposure. The treatment is done with the help of a machine called a linear accelerator. It creates a high-energy beam that directs the tumor from many different angles to fully encompass the tumor with the required amount of radiation. The overall treatment takes five days a week for several weeks.

Figure 4.4 *Linear accelerator Varian Edge*

The air conditioning of the buildings is realized with combination of split air conditioners and cooling towers. The total installed power of the air conditioners is approximately 50kW and the cooling towers around 60 kW.

4.2. Analysis of the energy consumption of the complex

In order to establish appropriate measures for the enhancement of energy efficiency, it is necessary to analyze the energy consumption in the exemplary objects. 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 year, calendar year and all seasons. During the analysis, all relevant parameters for the energy consumption were taken from the electricity bills for all KBCO facilities. Electricity consumption of the KBCO complex in Huttler street is measured at PCC at the 10 kV feeder.

Figure 4.5 depicts parameters of electricity consumption in December 2018 for all KBCO facilities at different adresses. KBCO complex in Huttler street and facility in Europske Avenije street use HEP PRO model (red squared in Figure 4.5) for electricity consumption.

Datum računa: 30.11.2018
Mjesto izdavanja: ZAGREB
Datum dospijeća: 05.02.2019
R-1

036300

OIB: 63073332379
HEP-OPSKRBA d.o.o.
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IBAN: HR9823400091110112928

Podaci o kupcu:
Šifra kupca: 10000887
Kupac: KLINIČKI BOLNIČKI CENTAR OSIJE
Ulica i kbr.: JOSIPA HUTTLERA 4
Mjesto: OSIJEK
OIB: 89819375646

Broj obračuna po mjernim mjestima: 4

R
10000 Zagreb
KLINIČKI BOLNIČKI CENTAR OSIJEK
JOSIPA HUTTLERA 4
31000 OSIJEK

Račun: 0010000887-181120-4 za električnu energiju, razdoblje 11/2018

Opis	Jed.mjere	Količina	Jed.cijena	Iznos kn
HEP MAX				
Radna energija po jedinstvenoj dnevnoj tarifi	kWh	1287	0,4859	625,35
Naknada za poticanje proizvodnje iz obnovljivih izvora	kWh	1287	0,1050	135,14
Trošarine za neposlovnu uporabu električne energije	kWh	1287	0,00750	9,65
HEP OPTI				
Radna energija po višoj dnevnoj tarifi	kWh	26328	0,5080	13.374,62
Radna energija po nižoj dnevnoj tarifi	kWh	15683	0,3391	5.318,11
Naknada za poticanje proizvodnje iz obnovljivih izvora	kWh	42011	0,1050	4.411,16
Trošarine za neposlovnu uporabu električne energije	kWh	42011	0,00750	315,08
HEP PRO				
Radna energija po višoj dnevnoj tarifi	kWh	492832	0,4667	230.004,69
Radna energija po nižoj dnevnoj tarifi	kWh	251575	0,2569	64.629,62
Naknada za poticanje proizvodnje iz obnovljivih izvora	kWh	744407	0,1050	78.162,74
Trošarine za neposlovnu uporabu električne energije	kWh	744407	0,00750	5.583,06
Porezna osnovica				402.569,22
PDV 13%				52.334,00
UKUPAN IZNOS RAČUNA				454.903,22

Figure 4.5 *The electricity bill of the KBCO (summarized bill for electricity consumption of all facilities).*

One electricity bill with the most important parameters is given in Figure 4.6. The bill is split into several segments, one segment for each facility of KBCO at different addresses. The red squared segment shows the total parameters taken from the electricity meter of KBCO complex in Huttler street. It is visible that the metering is double tariff for active power (RVT and RNT items). In the electricity bill, there are calculated active power consumption for the month, considering the consumption in the lower and higher tariff, expressed in kWh. It can be seen that the electricity contract price for the higher tariff is 0.4667 HRK/kWh and for the lower tariff is 0.2569 HRK/kWh. Lower tariff is charged in the period 10 pm to 8 am during the summertime or between 9 pm until 7 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. Also, cost of the incentives for the renewable energy sources (to cover feed-in tariffs) of

0.105 HRK/kWh and cost for non-business usage of electricity: 0.0075 HRK/kWh are presented.

KLINIČKI BOLNIČKI CENTAR OSIJEK OSIJEK, JOSIPA HUTTLERA 4
Broj obračunskog mjesta: 0808002215 Model: HEP PRO Brojilo: 42736364 Obr.: 1

OBRAČUN OPSKRBE		tar.stavka		konstanta	potrošak	jed.cijena	iznos kn
01.11.2018	01.12.2018	RVT	Radna energija po višoj dnevnoj tarifi	3000	482484	0,4667	225.175,28
		RNT	Radna energija po nižoj dnevnoj tarifi	3000	246162	0,2569	63.239,02
		OIE	Naknada za poticanje proizvodnje iz obnovljivih izvora		728646	0,1050	76.507,83
01.11.2018	01.12.2018	TRNP	Trošarine za neposlovnu uporabu električne energije		728646	0,00750	5.464,85
UKUPAN IZNOS OPSKRBE							370.386,98

KLINIČKI BOLNIČKI CENTAR OSIJEK BIZOVAC, SUNČANA 37/A
Broj obračunskog mjesta: 0808003234 Model: HEP OPTI Brojilo: 42736351 Obr.: 2

OBRAČUN OPSKRBE		tar.stavka		konstanta	potrošak	jed.cijena	iznos kn
01.11.2018	01.12.2018	RVT	Radna energija po višoj dnevnoj tarifi	400	26328	0,5080	13.374,62
		RNT	Radna energija po nižoj dnevnoj tarifi	400	15683	0,3391	5.318,11
		OIE	Naknada za poticanje proizvodnje iz obnovljivih izvora		42011	0,1050	4.411,16
01.11.2018	01.12.2018	TRNP	Trošarine za neposlovnu uporabu električne energije		42011	0,00750	315,08
UKUPAN IZNOS OPSKRBE							23.418,97

KLINIČKI BOLNIČKI CENTAR OSIJEK OSIJEK, EUROPSKE AVENIJE 16
Broj obračunskog mjesta: 0808076758 Model: HEP MAX Brojilo: 10336743 Obr.: 3

OBRAČUN OPSKRBE		tar.stavka		konstanta	potrošak	jed.cijena	iznos kn
20.10.2018	22.11.2018	RJT	Radna energija po jedinstvenoj dnevnoj tarifi	1	1287	0,4859	625,35
		OIE	Naknada za poticanje proizvodnje iz obnovljivih izvora		1287	0,1050	135,14
20.10.2018	22.11.2018	TRNP	Trošarine za neposlovnu uporabu električne energije		1287	0,00750	9,65
UKUPAN IZNOS OPSKRBE							770,14

KLINIČKI BOLNIČKI CENTAR OSIJEK OSIJEK, EUROPSKE AVENIJE 14
Broj obračunskog mjesta: 0808083010 Model: HEP PRO Brojilo: 40974165 Obr.: 4

OBRAČUN OPSKRBE		tar.stavka		konstanta	potrošak	jed.cijena	iznos kn
01.11.2018	01.12.2018	RVT	Radna energija po višoj dnevnoj tarifi	80	10348	0,4667	4.829,41
		RNT	Radna energija po nižoj dnevnoj tarifi	80	5413	0,2569	1.390,60
		OIE	Naknada za poticanje proizvodnje iz obnovljivih izvora		15761	0,1050	1.654,91
01.11.2018	01.12.2018	TRNP	Trošarine za neposlovnu uporabu električne energije		15761	0,00750	118,21
UKUPAN IZNOS OPSKRBE							7.993,13

Figure 4.6 *The electricity bill of the KBCO.*

Figure 4.7 shows the KBCO bill for December 2018 from the distribution system operator. The blue squared segment of the bill is dedicated to the costs for the connection of KBCO complex in Huttler street to the transmission and distribution power network (measurement at 10 kV middle-voltage network), charged active power in both tariffs (RVT and RNT) and monthly cost for measurement registration and calculation of the bill 66.00 HRK. The electricity contract price for the higher tariff is 0.17 HRK/kWh and for the lower tariff is 0.08 HRK/kWh. Furthermore, the contracted power, the amount of 29.50 HRK per kW of the active power has to be additionally paid.

HEP **Operator distribucijskog sustava d.o.o.**

036605

Datum računa: 30.11.2018.
Mjesto izdavanja: Osijek
Datum dospijeća: 20.12.2018.
R-1

Matični broj: 1643991
OIB: 46830600751
HEP - Operator distribucijskog sustava d.o.o.
Elektroslavonija Osijek
Šetalište K. F. Šepera 1a, 31000 Osijek
TEL: 031/244-105
FAX: 031/244-029
RAČUN: HR3723900011500101780

114
KLINIČKI BOLNIČKI CENTAR OSIJEK
P.P. 362
31000 OSIJEK

Podaci o kupcu:
Šifra kupca: 8582985
Kupac: KLINIČKI BOLNIČKI CENTAR OSIJE
Ulica i kbr.: P.P. 362
Mjesto: OSIJEK
Porezni broj: 3018822
OIB: 89819375646
Broj obračuna po mjernim mjestima: 2

Račun: 0808582985-181120-9 za mrežarinu, razdoblje 11/2018

Opis	Jed.mjere	Količina	Jed.cijena	Iznos kn
SREDNJI NAPON BIJELI 10 KV (20 KV)				
Električna energija viša dnevna tarifna stavka	kWh	482484	0,17	82.022,28
Električna energija niža dnevna tarifna stavka	kWh	246162	0,08	19.692,96
Angažirana snaga u doba više tarife	kW	1529	29,50	45.105,50
Naknada za obračunsko mjerno mjesto	mjesec	1,00	66,00	66,00
NISKI NAPON CRVENI				
Električna energija viša dnevna tarifna stavka	kWh	10348	0,25	2.587,00
Električna energija niža dnevna tarifna stavka	kWh	5413	0,12	649,56
Angažirana snaga u doba više tarife	kW	56	44,50	2.492,00
Naknada za obračunsko mjerno mjesto	mjesec	1,00	41,30	41,30
Porezna osnovica				152.656,60
PDV 13% (osnovica: 152.656,60)				19.845,36
UKUPAN IZNOS RAČUNA				**172.501,96**

Figure 4.7 *The bill for the KBCO from the distribution system operator*

Table 4.1 shows an overview of the electricity consumption and electricity cost from January to December 2018 for all KBCO facilities. Most of the total electricity is consumed by KBCO complex in Hutller street where renewable energy sources systems will be installed. It is expected that all produced electricity (described in section 6) is going to be consumed directly by consumption of the KBCO complex buildings so there is no need for additional energy storage systems.

Table 4.1 – Electrical energy consumption of all KBCO facilities during 2018.

	Total consumption [MWh]	**Total cost [HRK]**
Jan 2018	715.392	508,213.00
Feb 2018	662.873	479,547.00
Mar 2018	716.018	506.647.00
Apr 2018	698.288	507,260.00
May 2018	795.443	583,280.00
Jun 2018	933.263	694,318.00
Jul 2018	1043.97	760,847.00
Aug 2018	976.59	15,436.00
Sep 2018	702.008	548,075.00
Oct 2018	747.278	562,559.00
Nov 2018	729.128	562,702.00
Dec 2018	714.75	562,702.00
Total	9435.001	5,784,939.00

Table 4.1 shows variable electricity consumption during the year for all KBCO facilities. Consumption increase is visible during the summer months (June to August) during the hot weather conditions. Analyzing the annual electricity bills, total electricity consumption of all KBCO facilities is 9435.001 MWh with the total cost of 5,784,939.00 HRK.

Graphical interpretation of the electricity consumption of all KBCO facilities in 2018 is depicted in Figure 4.8.

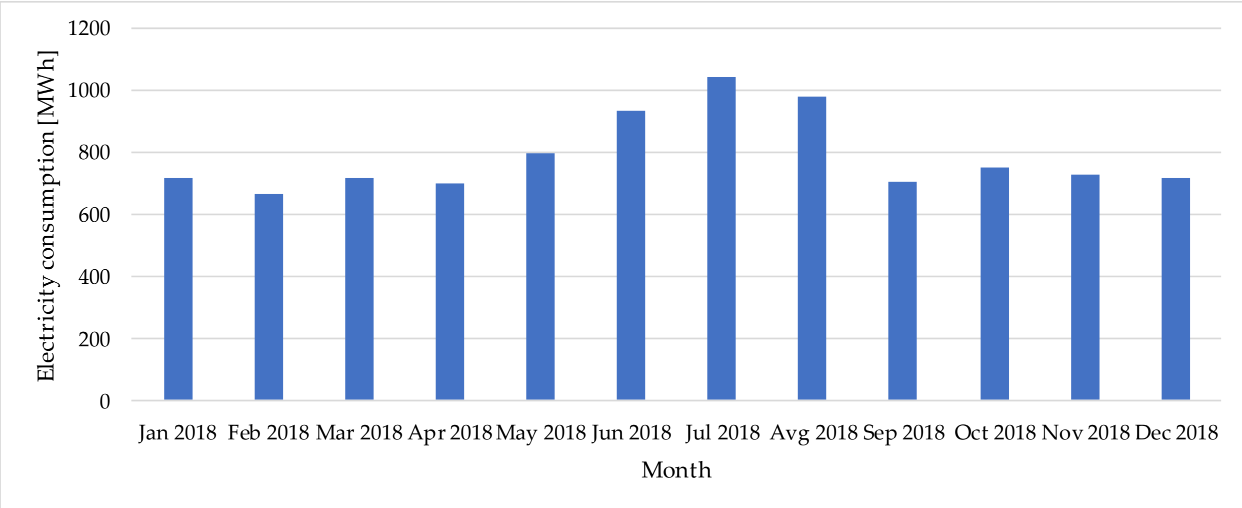

Figure 4.8 *Electricity consumption per month of all KBCO facilities during 2018.*

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

5.1. Solar energy

Because of its favourable geographical location, Republic of Croatia has large solar energy potential. Annual global solar irradiation on horizontal surface is given in Figure 5.1. Global irradiation and solar electricity potential for the optimally inclined photovoltaic modules of the Republic of Croatia are shown in Figure 5.2. It is visible that continental areas have slightly lower annual solar irradiated energy. Nevertheless, continental part, in which Osijek is situated has great solar energy potential.

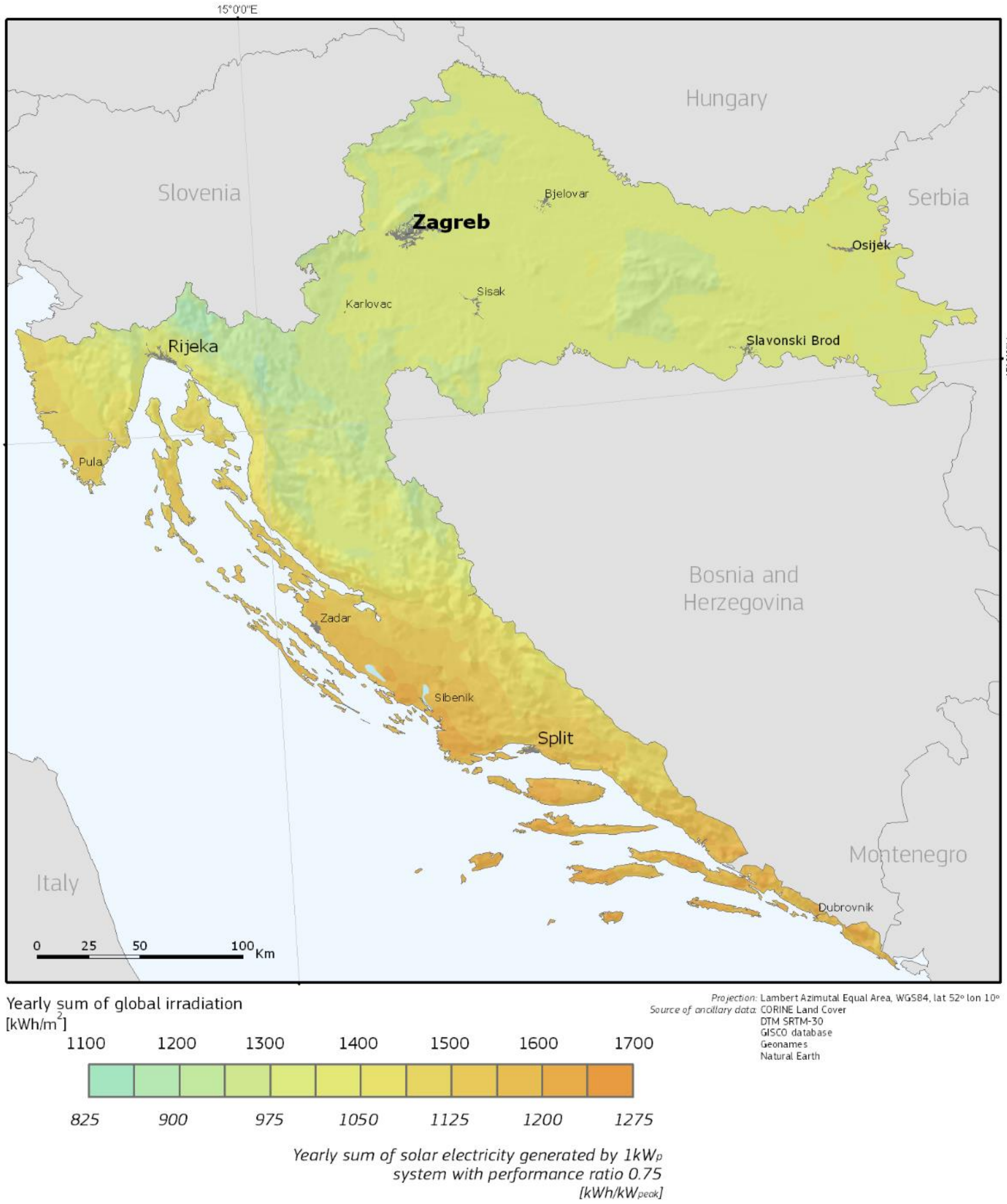

Figure 5.1 – *Annual global solar irradiation on horizontal surface in Republic of Croatia [24].*

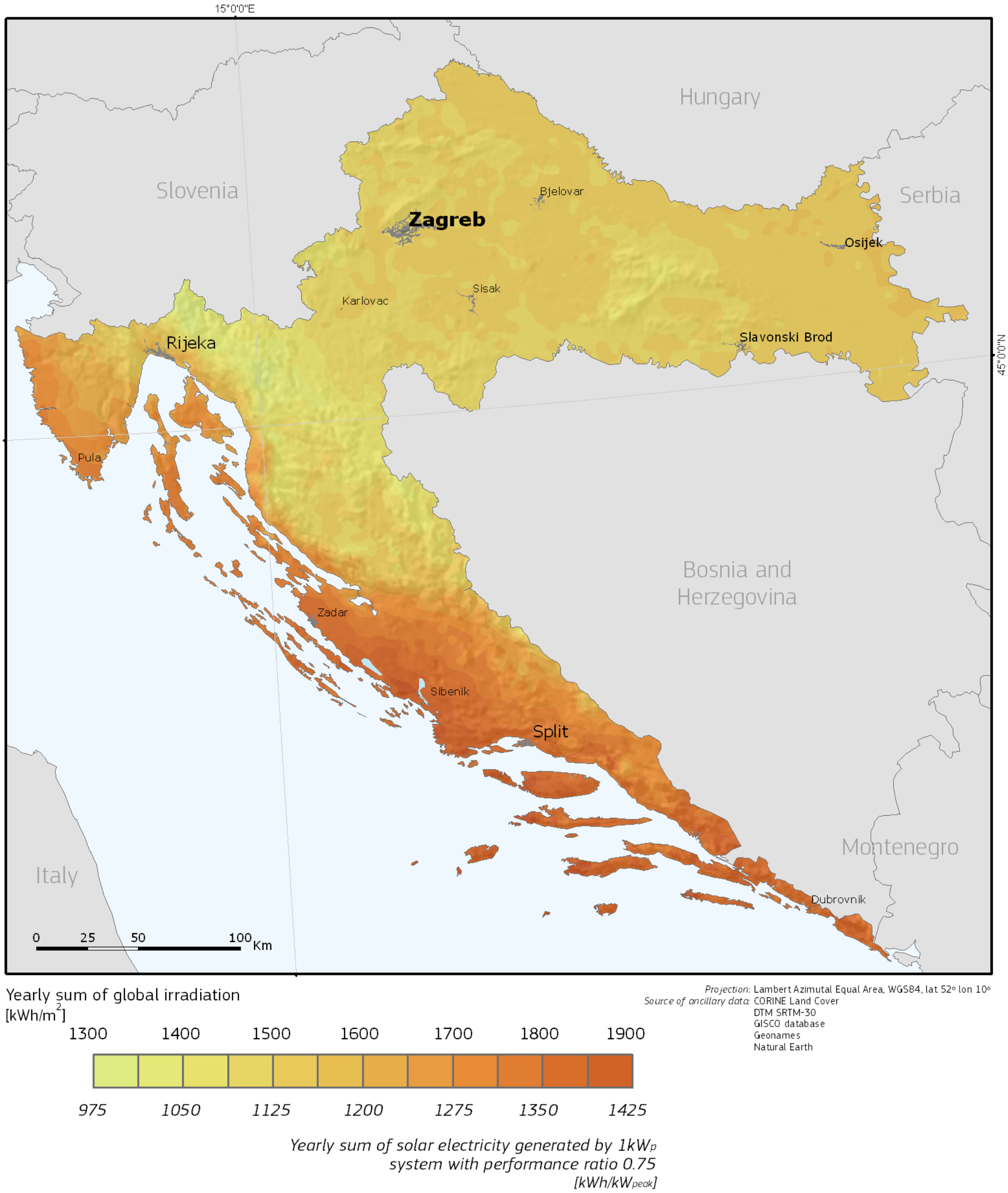

Figure 5.2 – *Annual global solar irradiation on optimally inclined surface in Republic of Croatia [24].*

Average annual solar irradiation on horizontal plane in Osijek region is around 1282 kWh/m2 while annual optimal inclination angle of photovoltaic modules and solar thermal collectors is 34° [24]. Highest solar irradiation occurs in summer months (June – August) while the lowest occur in winter months (November - January). Distribution of global solar irradiation for every month and annual solar irradiation for Osijek is given in Table 5.1.

Table 5.1 – Global monthly and annual solar irradiation for Osijek [24].

Month	Global
	kWh/m²
January	40.8
February	41.78
March	90.86
April	133.58
Max	172.2
June	198.09
July	187.46
August	138.18
September	116.22
October	92.04
November	42.67
December	28.21
Total	1,282.09

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°.

5.2. Waste and biofuels

5.2.1. Solid waste biomass

Solid waste biomass is considered as biodegradable part of municipal waste, food industry and other related industries. Furthermore, solid waste biomass can origin from wood industry. Theoretical annual energy potential of solid waste biomass for Osijek-baranja county is given in 0 [25].

Table 5.2 Theoretical annual energy potential of solid waste biomass for Osijek-baranja county [25]

Raw material type	Available waste [t/year]*	Theoretical energy potential [MWh/year]	Theoretical energy potential [TJ/year]
Slaughterhouse waste	4,651	23,255	84.7**
Wood industry waste	321	1,509	5.4
Biodegradable part of municipal waste	39,210	26,467	95.3**

*source: Waste logs for period of 2008-2010 (Agency for environmental protection), ** Registri otpada za razdoblje 2008-2010. (Agencija za zaštitu okoliša), ** obtained by biogas production technology

5.2.2. Liquid biofuels

Liquid biofuels bioethanol and biodiesel can are produced by hydrolysis and esterification of vegetable oils with alcohol. In Osijek-Baranja county, corn and sugar beet can be used for production of bioethanol while rapeseed and soy can be used for biodiesel production.

Apart from agriculture crops, there are other ways of biodiesel production. There is a growing trend of organized collection and collection of edible waste oils used for food preparation in large public facilities. They can be easily used for biodiesel production. There are also certain capacities for the treatment of oil emulsions by ultrafiltration and the subsequent disposal of the resulting oil concentrate by solidification. Cement plants have the capacity to use waste oils for energy purposes.

Theoretical annual energy potential of bioethanol production from corn and sugar beet and biodiesel production from rapeseed and soy is given in 0 for Osijek-Baranja county [25].

Table 5.3 Annual theoretical energy potential of liquid biofuels production in Osijek-Baranja county [25]

Raw material type	Raw material mass [t/year]*	Biofuel quantity [t/year]	Lower heating value [GJ/t]	Theoretical energy potential [GWh/year]
Bioethanol				
Corn (a.v.)**	1,100,032	330,962	27	2,482
Sugar beet	8,048,159	623,887	27	4,679
Biodiesel				
Rapeseed	463,911	189,351	37	1,946
Soy	421,738	79,874	37	821

* Calculation is based on average yield of agriculture culture from Statistical anniversaries of Republic of Croatia for the period 2006 to 2008 and data of available agriculture land for cultivation of energy crops;

** a.v. – average value between dry milling and wet milling process

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

In this section, regarding the features of the location and building for the exemplary objects 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 objects of KBCO, the following systems are going to be constituted:

- 110 kW photovoltaic (PV) system on the roof of central kitchen;
- 120 kW PV system on the roofs of Department of Oncology and Department of Diagnostical and Interventional Radiology;
- 125 kW biodiesel generator and biodiesel production system for additional 125 kW;

6.1.1. Photovoltaic systems on the buildings roofs

PV systems utilize solar irradiation for direct conversion of solar energy into electricity. There are two basic elements of PV systems, PV array and inverter on which PV modules are connected.

PV array consists of series-parallel connected PV modules which topology depends on the size of the array and inverter characteristics. Since output of the PV modules is DC electricity, in order to integrate PV systems into AC power grid, converter unit is necessary. This unit is called inverter which is power electronics device that converts DC electricity into AC electricity suitable for the power grid. The DC cables that connect PV strings with the inverters are planned for external mounting. 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.

Proposed PV systems for KBCO project partner have nominal power of 230 kW. This power will be distributed on three KBCO buildings roofs located in Huttler street. Preliminary design of the systems proposed that system with nominal power of around 110 kW will be installed on building central kitchen and around 120 kW on buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology.

110 kW PV system on building of central kitchen

110 kW PV system is planned to be installed on horizontal roof surface. Azimuth of the building is 3 ° to East (South is reference). PV modules will be installed under optimal annual inclination angle of 35°. Block diagram of the PV system is given in Figure 6.1 while 3D model of the system is given in Figure 6.2.

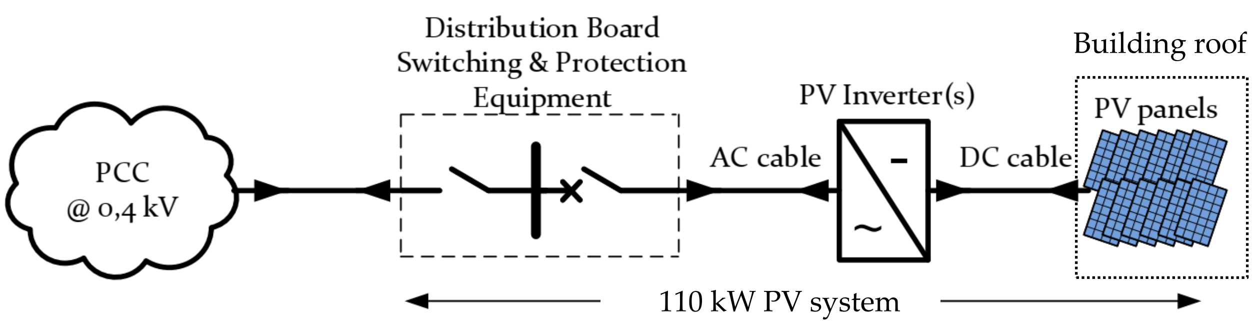

Figure 6.1 *Block diagram of the PV systems on building of central kitchen*

Figure 6.2 – *3D model of PV system on building of central kitchen*

If we assume to use monocrystalline silicon modules SUNCECO SEM 300W-HE, which technical characteristics are given in Table 6.1., for the PV modules of the system, PV array will consists of around 367 PV modules with nominal power of 300 W which results in total output power of 110.1 kW at the DC side of the system.

Table 6.1 – Technical characteristics of PV modules [26].

SUNCECO SEM 300W-HE			
Nominal power	P_{max}	300	W
Maximum power point voltage	U_{MPP}	32.9	V
Maximum power point current	U_{MPP}	9.12	A
Short-circuit current	U_{OC}	9.58	A
Open-circuit voltage	I_{SC}	39.7	V
Efficiency	η	18.3	%
Maximum system voltage		1000	V
Dimensions		1650 x 992 x 35	mm
Weight		18,5	kg
Operating temperature		-40 do +85	°C
Number of cells		60	pcs.

Based on Solar energy potential described in section 5.1. for Osijek, monthly forecast of electricity production for the proposed PV system is determined using PVSOL Premium software package and given in Figure 6.3. Total annual production of the PV system is around 117 MWh.

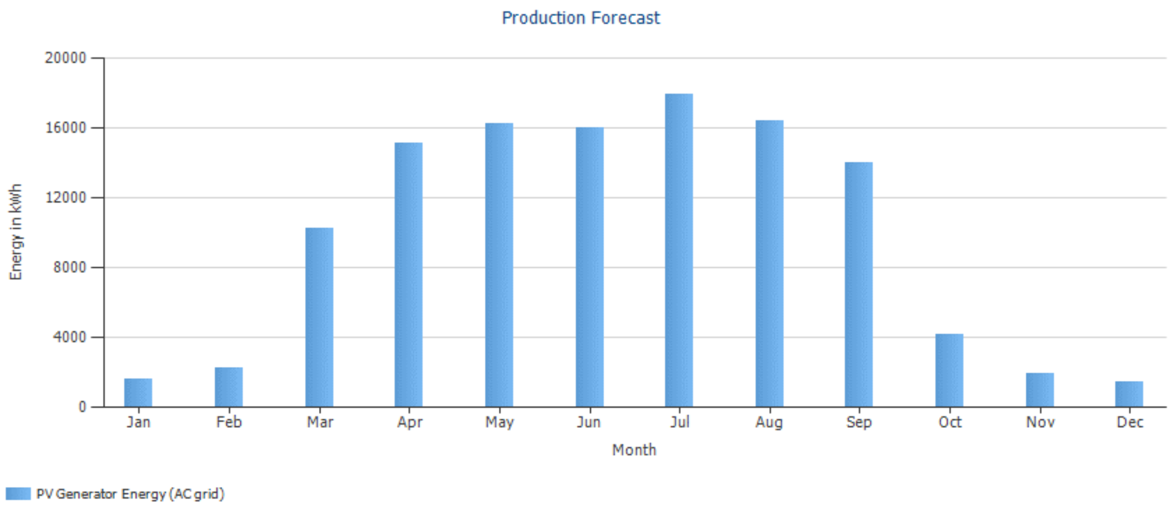

Figure 6.3 – *Estimated electricity production of 110 kW PV system of central kitchen*

120 kW PV system on buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology

120 kW PV system is planned to be installed on roof surfaces on different angles, depending on the roof section. First part of photovoltaic array will be installed on horizontal surface of building of Department of Oncology under optimal inclination angle of 34 °. Azimuth of the building is 1 ° to the West (South is reference). Second part of photovoltaic array will be installed on horizontal and tilted surfaces of building of Department of Diagnostical and Interventional Radiology under various tilt angles. Part of the photovoltaic array will be installed on horizontal surface under optimal tilt angle of 34 ° while the rest will be installed on tilted roof surfaces under 32 ° tilt angle. Azimuth of the building is 2 ° to the West (South is reference). Block diagram of the PV system is given in Figure 6.4 while 3D model of the system is given in Figure 6.5.

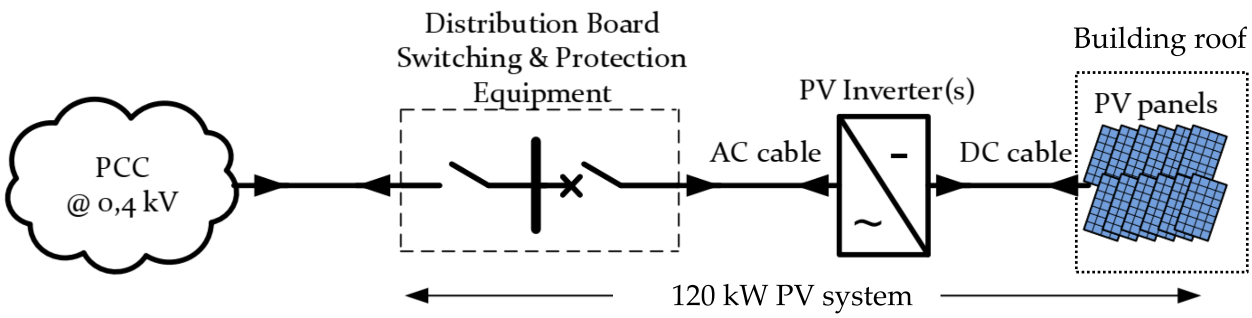

Figure 6.4 *Block diagram of the PV system on buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology*

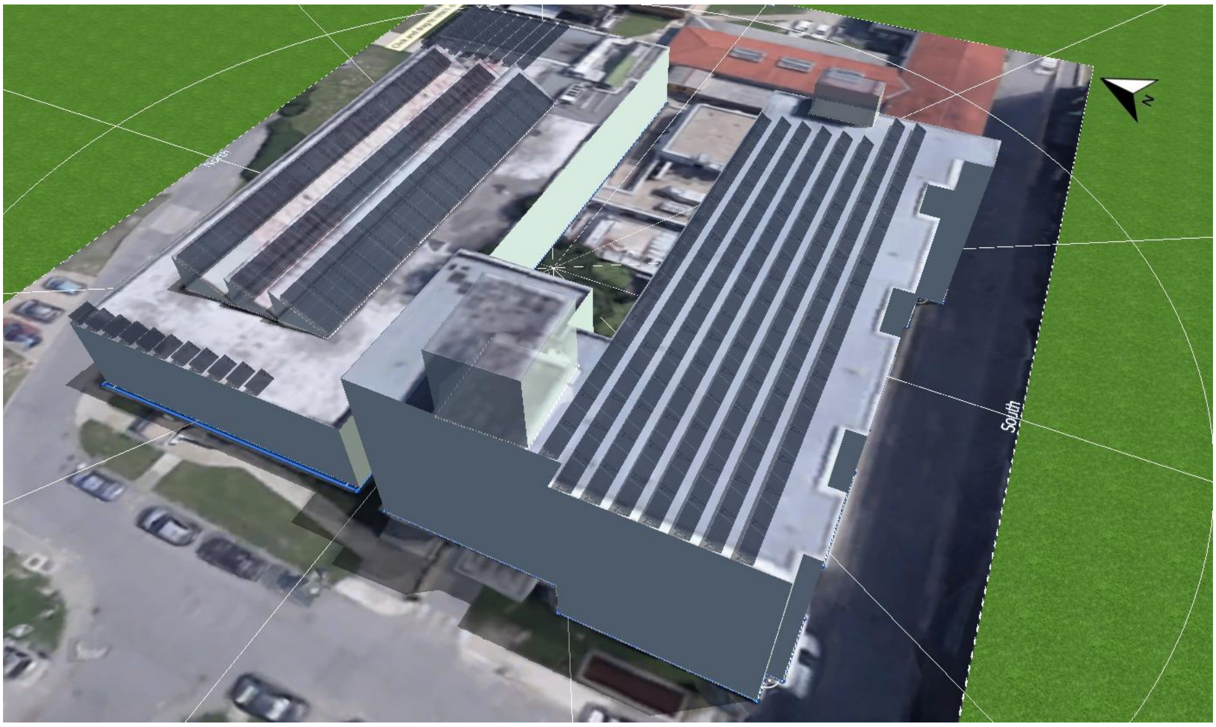

Figure 6.5 – *3D model of PV system on buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology*

If we assume to use monocrystalline silicon modules SUNCECO SEM 300W-HE, which technical characteristics are given in Table 6.1., for the PV modules of the system, PV array will consists of 400 PV modules with nominal power of 300 W which results in total output power of 120 kW at the DC side of the system.

Based on Solar energy potential described in section 5.1. for Osijek, monthly forecast of electricity production for the proposed photovoltaic system is determined using PVSOL Premium software package and given in Figure 6.6. Total annual production of the photovoltaic system is around 130 MWh.

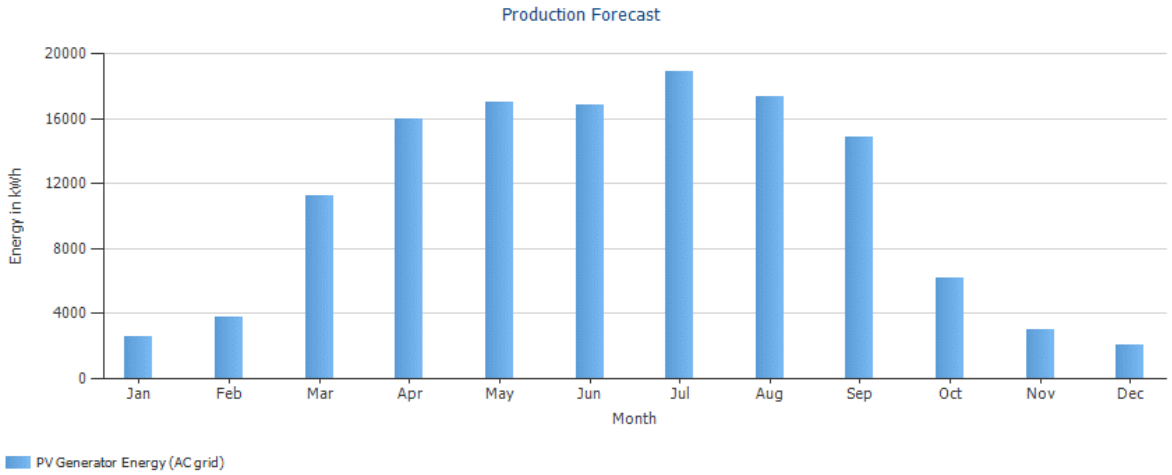

Figure 6.6 – *Estimated electricity production of PV system on building in Cara Hadrijana street*

6.1.2. Biodiesel generator and biodiesel production system

As previously described, waste oil is one of the waste products of KBCO central kitchen operation. Proper environmentally friendly disposal of the waste oil is expensive and relatively complicated, therefore, a system that enables the waste oil recycling and reusing is completely justified. The principal scheme of the waste oil processing system is shown in Figure 6.7. It employs standard industrial waste oil processor that is available on the market and as a result of a biodiesel fuel is obtained. This biodiesel fuel can be used either for vehicles like emergency vans or for diesel and biodiesel generators in KBCO complex that operate during partial of complete blackout of electric power supply.

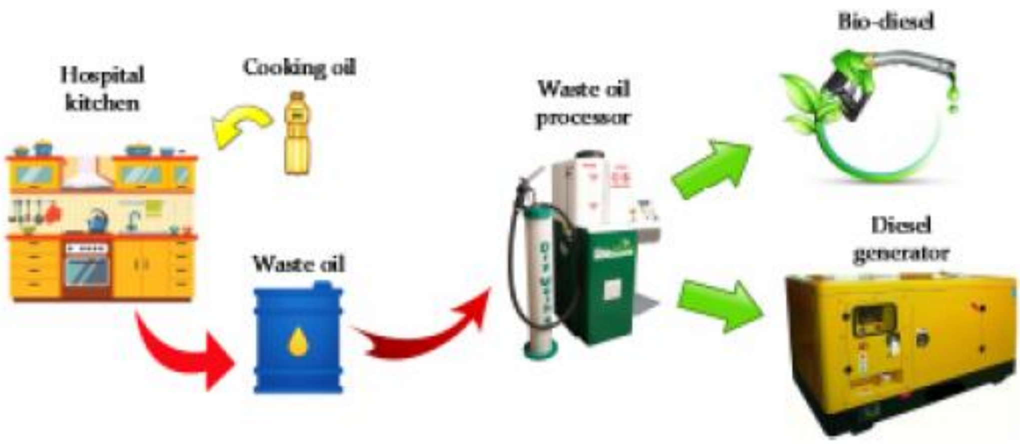

Figure 6.7 *Principal schematic of system for biodiesel production from waste oil*

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

By analyzing the consumption of cooking oil used by KBCO central kitchen, it has been found out that 1000 liters of waste oil is generated on an annual basis. At the same time, this is roughly the amount of the waste oil that is generated on monthly basis that is not recycled and must be properly stored or disposed. Therefore, recycling of the waste oil and converting it to biodiesel has twofold positive impact which is elimination of necessity for storage of expensive and complicated disposal procedures and replacing the regular diesel fuel that is used on daily basis in KBCO with more environmentally friendly biodiesel fuel.

Furthermore, new 125 kW biodiesel generator will be installed in order to fully utilize biodiesel production potential. Generator will serve as a backup electricity supply during partial or total blackouts. Block diagram of the PV system is given in Figure 6.8.

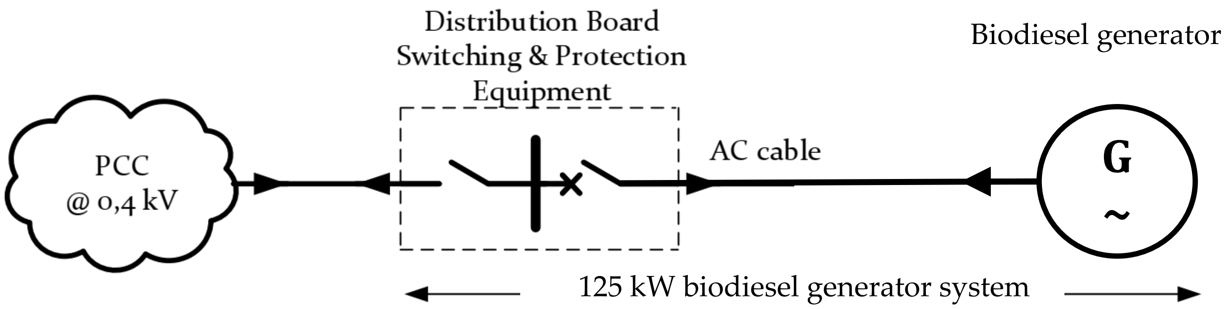

Figure 6.8 *Block diagram of biodiesel generator system*

6.2. Optimal configuration of the smart building energy system

Building energy management system represents superior control and management system for sources of electricity alongside with electric loads into one fully controllable unit. This is realised with Supervisory Control and Data Acquisition System (SCADA) which is computer-based system for control and management of processes. In our case, sources of electricity are renewable energy-based while the electric loads represent building loads. In the area of electrical engineering, this unit represents microgrid which is an emerging concept while its SCADA system represents its superior control and management system.

SCADA system consists of fully coordinated ICT systems that supervise and control every element in the microgrid. Basic block diagram of building energy management system for building in Trpimirova street and its basic elements is given in Figure 6.9.

At the PCC point of all 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 irradiance, temperature, humidity, air speed and direction, etc. This data is sent to the BEMS system and processed. Based on all inputs, BEMS provides outputs – control signals for controllers so that the automation of all ongoing processes is possible regarding the energy efficiency maximization.

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

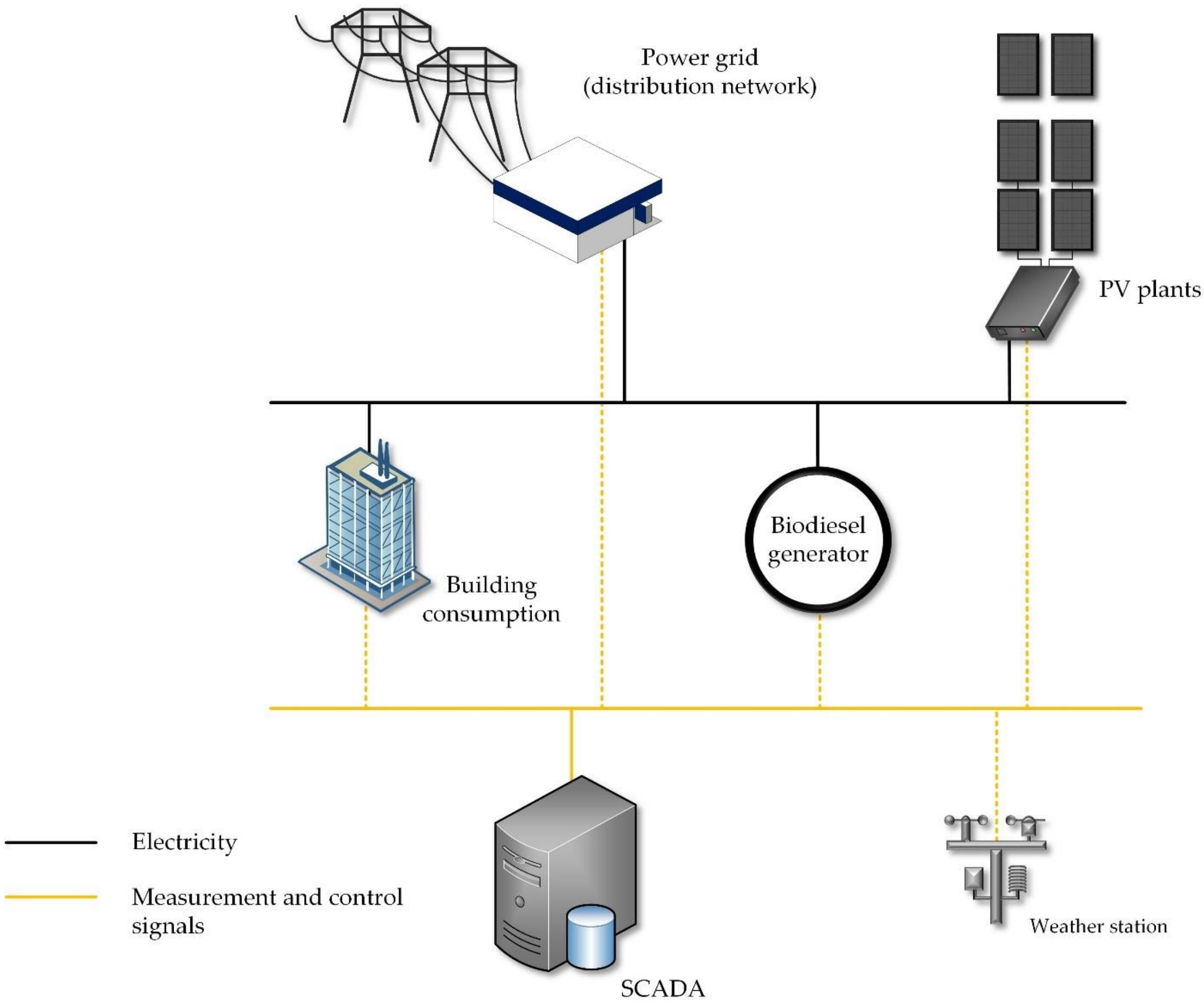

Figure 6.9 – *Basic block diagram of KBCO building energy management system*

7. Conclusion

Annual electricity consumption of all KBCO buildings, including one in Europske Avenije street and complex of buildings in Bizovac near Osijek, is 9 435.001 MWh which results in total cost of 5,784,939.00 HRK for 2018. Since Osijek, situated in the eastern part of Republic of Croatia, has large solar, certain part of consumed electricity can be supplied by systems which utilize renewable energy sources.

In this study, after thorough analysis of exemplary object in Huttler street and its energy demand, potential of renewable energy sources (solar energy and waste and biofuels) for the microlocation, the following systems are proposed to be integrated into existing power system of KBCO: 110 kW PV system on the roof of central kitchen and 120 kW PV system on the roofs of Department of Oncology and Department of Diagnostical and Interventional Radiology.

By analysing the consumption of cooking oil used by KBCO central kitchen, it has been found out that 1000 liters of waste oil is generated on an annual basis. Therefore, biodiesel production system and a new 125 kW biodiesel generator will also be installed to fully utilize the potential.

If we observe each PV system that are planned to be installed within the project by itself, 110 kW PV system on central kitchen building will produce around 117 MWh while 120 kW PV system on buildings of Department of Oncology and Department of Diagnostical and Interventional Radiology will produce around 130 MWh annually. Since the annual electricity consumption of KBCO is around 9 435 MWh, it can be expected that installed systems will supply around 2.6 % of the annual electricity consumption.

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