Smart City Podgorica Study

Development of Energy Efficient Infrastructure and Services

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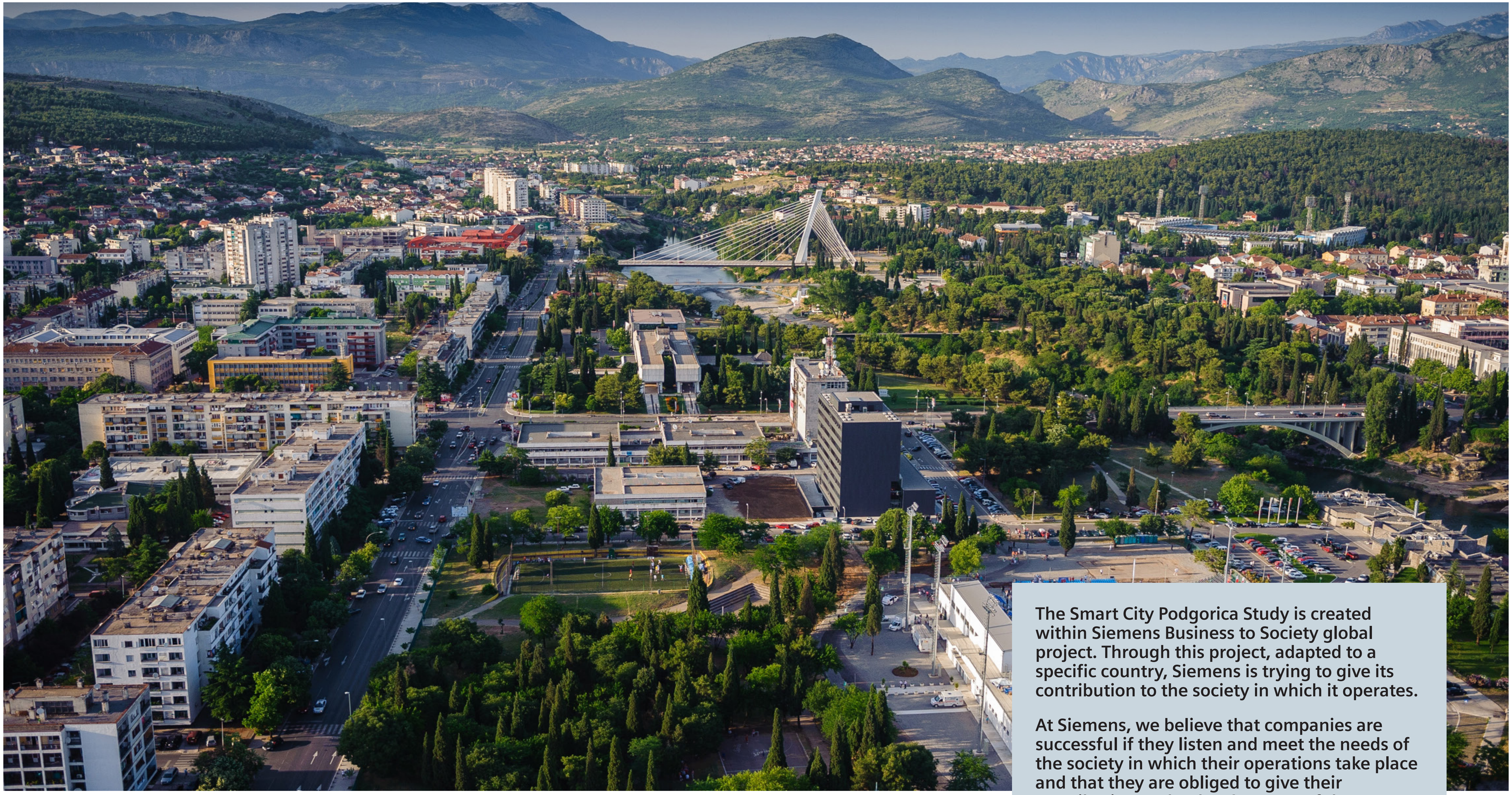

The Smart City Podgorica Study is created within Siemens Business to Society global project. Through this project, adapted to a specific country, Siemens is trying to give its contribution to the society in which it operates.

At Siemens, we believe that companies are successful if they listen and meet the needs of the society in which their operations take place and that they are obliged to give their contribution to the development of the environment by lasting values, investing and promoting. This implies expressing the success of a company in a wider sense, not just through profit.

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Introduction

1.1 About the “smart city” concept – in general

We are living in the convergence of two important phenomena in the history of mankind: accelerating the global urbanization and digital revolution. The UN points out that for the first time in history more than half of the population on the planet (54.6% or 3.6 billion) lives in cities. Also, UN predictions are that by 2050, urban dwellers will make up more than 70% of the world’s population (over 6 billion), 64.1% in developing countries and 85.9% in developed countries. With the Agenda 2030, UN has developed a framework for sustainable development (including goals for cities, energy, infrastructure, etc.) to which Montenegro has also committed[1]. The global reference for determining the value created for society is the United Nations’ 2030 Agenda for Sustainable Development. It sets out 17 Sustainable Development Goals (SDGs) to end poverty, to protect the planet and ensure prosperity for all.

Therefore, cities are the fastest growing form of settlement worldwide, which implies a growing growing space demand for buildings, infrastructure and the supply of food, water and energy. Around the world, especially developed, various initiatives are launched, as well as funds and legal regulations, so that modern cities can cope with these challenges, that is to become “smart cities”.

These challenges are great because cities were and will always be complex and permanent (and sometimes chaotic) growing entities. Each city has its own history, geography, population, and in particular local political circumstances. There are repeated patterns in every urban area in every urban area which, together with the new ICT technologies, form the basis for an entirely new scientific view of the city and the development of various urban simulation models.

The term “smart city” was only developed quite recently. As a reflection of the aforementioned tendencies, many new attributes of “cities” come into scientific terminology and political discourse in the last two decades, such as “sustainable”, “green”, “digital”, “smart”, “intelligent”, “eco”, “low carbon”, “knowledge cities”, etc. For conceptual confusion to be greater, even combinations such as “low carbon eco cities” and “ubiquitous eco cities” are used. By inspecting numerous texts, it can be concluded that since 2010 the term “sustainable city” is largely replaced by the word “smart city”.

There are more definitions for ‘smart city’. One of the more comprehensive definitions is the ITU Study Group on SSC:

“A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects”.

A shorter definition of a “smart city” is: it is a city that efficiently encompasses physical, digital and human systems to build an environment that would contribute to improving the lives of citizens.

Thanks to the advancement of ICT, the concept of “smart cities” has become a reality in highly developed countries. Advanced traffic management, buildings, electricity grid and waste disposal have allowed city authorities to influence energy savings and air pollution, and thus make life in cities better and more comfortable. If one looks at the list of cities with the best conditions for life, which is annually compiled by the Economist Intelligence Unit, a research division of The Economist, it can be seen that the “smart cities” strategy has already been successfully implemented in several cities: Vienna, Vancouver, Melbourne, Zurich... In the literature there are numerous illustrations of the concept of “smart city”, with the structure of key stakeholders and the possible positive effects in various urban functions. Figure 1.1.1[2] shows a more comprehensive presentation of this concept.

Finally, the “smart city” is the concept of thinking of city development in terms of sustainability and efficiency with the help of ICT. So, sustainability and efficiency are the key words to consider when developing a city, if the city administration wants the city to become truly “smart”.

The plan of each individual ‘smart city’ is differently focused on what “smart” or “smarter city” means and defines the goals and means of its further development on that concept. Recent experience shows that it is necessary to initiate as many initiatives as possible to contribute to the sustainability and efficiency of resource use. It is the task of all subjects; primarily the city administration, but also the business sector, non-governmental organizations and most of the citizens themselves.

From the organisational perspective, a differentiation of term “smart cities” was classified into the following two hierarchically counter-directed approaches:

- *Top-down smart cities* are usually initiated by city institutions, information and communication technology (ICT) and/or research facilities, and it is a straight forward planning concept;
- *Bottom-up smart cities* are usually modelled by local inhabitants, and an innovative potential, societal knowledge and networks is used by the cities themselves to design the city.

It is important to notice the key difference between these two approaches. Bottom-up approach is based on the development of the city, starting from the questions “What do people want?” instead of top-down approach: “What do city administration and companies think is best for them?” Optimal solution is reached in the combined application of both approaches, while the bottom-up approach assumes a very developed civil society.

Apart from the general observation of factual issues, it is the procedural setting which creates momentum in city development. Inside the functional framework, stakeholders can be identified as drivers in different institutions. Depending on their field of expertise, they have to deal with diverse contextual issues. In this relation, it is important to know which actor plays a role, to which extent and how he or she is influencing the whole system of a city.

Some of the terms and ideas which are currently used in this relation have been categorised:

- General improvement of urban energy and planning concepts;
- Environmental sustainability (sustainable resource use) ;
- Social sustainability (realising social inclusion of different kinds of urban residents in public services, citizen democratisation/cultural and societal empowerment) ;
- Higher quality of life through technical improvements in telecommunication infrastructure/administration/networks/living/mobility;
- Economic development/efficiency;
- Integrating private sector, business-oriented urban development;
- High-tech/creative industries in long-term growth;
- Social/relational capital in city development;
- Adaptivity.

The wide range of concepts and ideas that go with the concept of “smart city” is presently presented at the theoretical level and classified into six functions:

- Smart economy (competitiveness);
- Smart people (social and human capital);
- Smart governance (participation);
- Smart mobility (transport and ICT);
- Smart environment (natural resources);
- Smart living (quality of life).

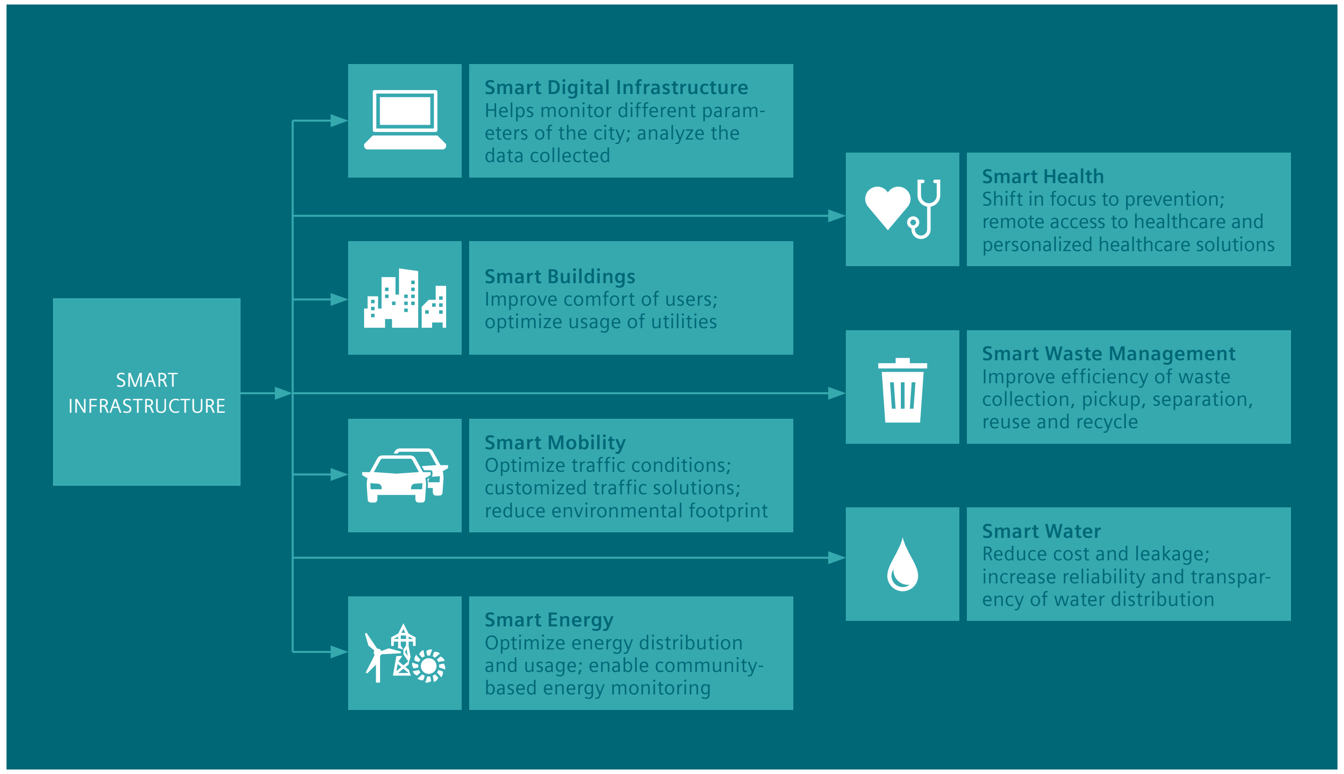


Figure 1.1.1 Concept, participants and possible effects of a “smart city”

[1] https://sustainabledevelopment.un.org/content/documents/10695Montenegro%20-%20HLPF%20Report.pdf

[2] Dong Wu: Smart Cities and Infrastructure, UNCTAD, May 2016

Also, in order to achieve a more comprehensive (holistic) approach, it is even defined as so-called smart city matrix that systematizes institutional categories, professional fields and keywords:

- Institutional category (public science, government, non-governmental organisation (NGO), private businesses, etc.);
- Field of expertise (spatial planning, architecture, urbanism, energy planning, mobility, climate research, social research, etc.);
- Keywords (energy standard, consumption, resources, renovation, insulation, networks, logistics, etc.).

In this respect, technological expansions of city infrastructure do not simultaneously imply improvements, neither regarding sustainability issues nor the reduction of energy demand and increase in quality of life, wealth and benefit for the whole community. There may be the risk that a "smart city" development is interpreted one-sidedly from a technical-business perspective only, and social and environmental requirements can be missed again. Smart city planners must not forget that just letting new businesses grow to produce smart technologies can have rebound effects, so that social and environmental requirements of a sustainable urban development can be missed again. Environmental savings and social justice can be outweighed by an additional implementation of technologies whose main goal is to increase quality of life.

1.2 Smart energy planning

Since energy systems are a key social infrastructure, they are also an important segment of spatial planning. The link between spatial planning and energy systems is mainly due to the fact that the provision of energy is guaranteed with the protection of the built environment, whether it is residential, commercial or industrial development. Ultimately, it is essential that the growing population density and the size of cities are accompanied by viable, "smart" energy systems.

Cities with a large population density have high demands for energy. Usually these requests exceed the availability of local resources. Individually developed options for covering energy requirements vary from place to place and can also be changed within the boundaries of the city. In the concept of European governance, cities are focused on energy savings, renewable sources (OIEs) and reduced dependence on imports of fossil fuels. There are many innovative concepts and technologies available to address these needs.

Planning and implementation of smart urban energy systems, however, involves a wide spectrum of stakeholders: from city administration to developers to energy providers to current as well as future inhabitants. The planning discourse between these stakeholders can be supported by reliable and comprehensive methods to design and evaluate complex energy systems. Such decision support methods:

- *Provide* answers to the different perceptions of the economic framework for the development of smart energy systems brought to the table by various stakeholders by creating reliable scenarios;
- *Allow* comparison of the scenarios by guaranteeing optimal energy systems generated by using different resource options and economic frameworks;
- *Provide* comprehensive ecological evaluation of the scenarios along with thorough economic and technical specification to enable a holistic planning process.

Energy planning that leads to 'smart' urban solutions requires integration of energy design into spatial planning and urban planning. This means that the design of new settlements, as well as the refurbishment of existing city quarters, requires an interdisciplinary planning approach that takes spatial and mobility planning, energy systems design, building and infrastructure design and the evaluation of ecological impacts into account.

The spatial plans set the framework for energy consumption, production and distribution, regardless of whether it is done with modern planning methods or randomly - often with negative effects on energy efficiency and the environment. Energy efficient housing structures lead to high quality of life and have several common opportunities such as decentralized concentration, multifunctionality, proximity within pedestrian and/or cycling distances.

Although the relationships between inhabited structures and energy demand are known, there is more and more real development that does not adhere to these relations. This leads to an increase in demand for energy, even in spite of energy efficient buildings, appliances and vehicles.

In addition to spatial organization, spatial planning decisions also affect energy demand by choosing a side with a certain topography and exposure, as well as construction of buildings according to already existing building patterns. Transformation and distribution of energy as well as its provision are subject to fewer or more land demand, especially in the case of bioenergy, wind energy, solar and similar resources. Requirements for the use of specific renewable sources in some cases may be in conflict with already defined urban land use planning for some more priority purposes - for example, for agriculture.

Electricity supply in urban areas has moved to the centre of debate on how to supply urban areas with renewable energy. Heat integration and heat storage, the integration of industrial waste heat and solar thermal energy in supply networks have also become major aspects of smart city development. The development of a 'smart' energy system contributes to an increase in the production of electricity from the OIE. This is at the same time part of the decarbonisation strategy of cities that play a key role in mitigating climate change.

Modern mathematically oriented software can be used to determine the optimal choice of energy balance structure, technology networks, as well as ecological and socio-economic evaluation of various options for future city plans and projects. One of the more efficient optimization approaches, successfully applied to a case study for a few 'smart cities', is briefly presented below.

The aim of this methodological framework is to provide information about optimal technology networks and the ecological and socio-economic evaluation of different options for future city developments. It consists of the Process Network Synthesis (PNS) and, inter alia, the tool Energetic Long-term Assessment of Settlement Structures (ELAS), the tool applying the Sustainable Process Index (SPI). In order to achieve the research goals raised in the framework plan to find smart and sustainable energy systems for cities, the PNS was chosen. With this method, it is possible to model complex systems and find optimal energy systems before studying the relevant matters in depth with the help of a modelling or design process. On the other hand, ELAS and SPI can deal with interdisciplinary issues of complex settlement structures and a comprehensive ecological evaluation. Process cycles of various energy systems can so be ecologically evaluated and provide usable information and a practical model for a stakeholder process.

One method in particular that has proven its worth in planning tasks like integrated spatial and energy planning is PNS. This method has been developed in the framework of process technology. It uses a directed bipartite graph (p-graph or process-graph) method to describe process networks and employs combinatorial rules to find all feasible network solutions using all possible resources, intermediates and products as well as all relevant technologies processing these mass and energy flows (superstructure). All data concerning flows and cost of technologies, pipes and transport can be provided in predefined material and operating units input tables of PNS Studio. Moreover, parameters like the required and maximum flows, lower bound and upper bound of capacity constraints for operating units can be set. Flows are split into resources, intermediates and products. Flows can then be set as input and output flows in the operating units to display conversion and production interdependencies between the technologies considered.

Using the PNS network enables optimization of energy systems using various energy sources for heating, storage and cooling. The method is interesting as it combines on-site energy sources (e.g. solar heat and photovoltaic) with nearby industrial waste heat and cooling at different temperatures and grid-based resources such as existing district heating, natural gas, and electricity. The case study also includes the competition between centralised technologies (e.g. large scale combined heat and power and heat pumps with district heating grids) and decentralised technologies (e.g. small scale combined heat and power, single building gas boilers, solar collectors, etc. in buildings). Ecological assessment with the ELAS calculator provides an evaluation of the ecological impact of the developed energy systems.

The result of the optimal structure of PNS obtained for a particular set of economic boundary conditions (a scenario) is used as input for ELAS evaluation. Amounts of resources (in this case, energy flows for the supply of the city quarter) resulting from PNS are one input for the assessment with ELAS calculator. In addition, the input parameters for ELAS are the site-specific data, building standards, infrastructure, induced mobility and energy, construction and mobility costs. Results are the ecological footprint (SPI), energy demand and CO_2. The total sequence proceeds as shown in Figure 1.2.1.

ELAS was developed to analyze urban structures ranging from single houses to whole settlement structures regarding their energy situation and in particular their ecological performance. The calculator allows the evaluation of single buildings as well as

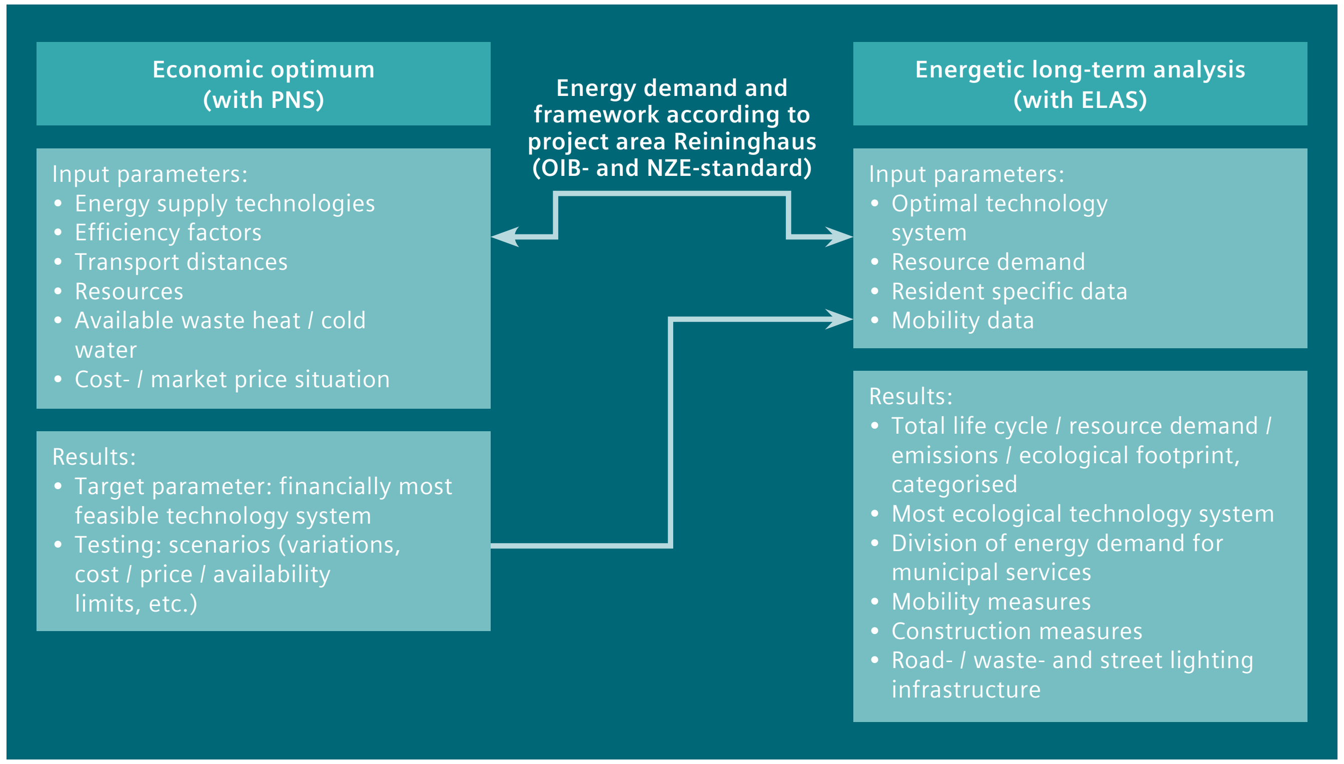


Figure 1.2.1 Software package for the optimization of energy systems

whole settlements. It can be applied to existing structures as well as planning tasks and also allows the evaluation of refurbishing and extension plans to existing settlements.

The calculator takes site-specific data of residential settlements into account. This consists of energy consumption and supply, mobility induced by the location of the settlement as well as the distances to service provision. It uses a life cycle approach to the evaluation and accounts for the ecological impact of construction, use and disposal of all buildings and energy infrastructure in a settlement, such as roads, wastewater drains and lighting of public space.

Results of the ELAS calculator contain accumulated energy demand, ecological footprint (calculated with the SPI method), CO_2 life cycle emissions and regional economic impact (turn over, value added, imports, jobs created or lost) of the settlements. The Sustainable Process Index is an ecological footprint method. The SPI has been applied in several fields such as ecological evaluation of agricultural products or collectively shown in the evaluation of energy technology systems based on renewable resources. The ELAS calculator is an online tool that runs SPI evaluations in the background (along with other technical parameters and statistical variables). The ELAS calculator allows users to provide specific data via a GUI (graphical user interface).

ELAS provides municipalities a basis for sustainable energy supply and appropriate policy decisions or gives an overview of individual energy consumption and its economic and ecological effects. The tool is freely available online.

This model may be used to develop consistent optimised scenarios for different economic framework configurations and evaluates them economically and ecologically. The scenarios serve as a solid basis for negotiations between the various stakeholders, whose interactions will shape the district's future smart energy system. The goal of using this model is to provide stakeholders and decision makers with a factual basis for a discourse on the development and implementation of a smart energy system in their action plans.

1.3 General data about the capital city

Podgorica is the capital city of Montenegro with certain international functions and it is the largest urban agglomeration of the country. In Podgorica, numerous administrative, cultural, educational and health centers are concentrated, as well as large economic capacities. However, the intensive expansion and the socio-economic consequences of the multiannual transition have led to urban imbalance and unplanned expansion of settlements, which has become the main threat to the sustainable development of the capital city. Considerable aggravating circumstances may include the poor state of the economy, the large spread of informal construction, energy inefficiency and insufficient construction of transport and communal-technical infrastructure.

Podgorica occupies an area of 1,492 km² or 10.7% of the territory of Montenegro. Municipalities of Tuzi and Golubovci also form part of the Capital City of Podgorica. According to the official 2011 census, the number of inhabitants of Podgorica is 185,937, although due to developments and other trends it is estimated that this number is higher. The number of inhabitants per household is 3.27, which is close to Montenegrin average of 3.22 inhabitants per household. According to the data from the Statistical Office (2011), the absolute number of dwellings is 73,033 and the number of households is 57,045.

According to spatial-demographic analysis, the capital city belongs to the type of high concentration area with a population density of 129 inh./ km² in 2011, which is significantly higher than the national average (44.9 inh./km²). Observed by individual areas, this indicator drastically differs: urban areas 1,209.5 inh./km², Podgorica 1,786.4 inh./km², suburbs 21.2 inh./ km², Plain area 81, 9 inh./ km², Eastern hills 5,6 inh./ km², North hills 4,9 inh./km² and West hills 8,0 inh./ km². According to the number of inhabitants, the most populated area is in the area of GUP Podgorica, which is home to about 82% of the population. The share of the population in other planned areas is as follows:

- Plain area 13.28%
- Eastern hills 1.71%
- North hills 1.20%
- West hills 1.74%

Podgorica's climate is classified as a Mediterranean climate with dry summers and cold winters, which is conditioned by the vicinity of the sea as well as the proximity of the Dinaric Alps in the north. Temperature exceeds 25 °C in about 135 days a year, while the average annual number of tropical days (max. temperature above 30 °C) is 50 to 70. Podgorica is especially known for exceptionally warm summers, with the highest recorded temperature being 44.8 °C. The number of rainy days is about 115, while with strong wind it is about 60 days. The strong north wind is common in the city and affects the climate in winter.

According to estimates from the Spatial Urbanistic Plan, the total GDP in 2011 in Podgorica is estimated at 1.47 billion euros, which makes 46% of Montenegro's total GDP. The territory of the capital city is covered by all the most important traffic flows, except maritime navigation, in Montenegro, starting from the international airport, railroads to Belgrade, Skadar, Bar and Nikšić, to main and regional roads, as well as the routes of future highways: the Adriatic-Ionian and Bar-Boljare-Belgrade.

The organizational scheme of the capital city is very complex due to the wide field of activity. Administrative bodies are organized through: secretariats, administrations and directorates. For performing professional and other tasks for the Mayor, Chief Administrator, managers and administrative bodies, professional services have been established. For the performance of tasks requiring special professional knowledge and autonomy in work, the Mayor may form an Agency by the special decision. The capital city is the founder of 12 companies that deal with activities of interest for the normal functioning and development of the city and city infrastructure, as well as 9 public institutions active in the field of culture and social activities.

Within this Study, an analysis was made of the possibility of applying modern solutions from the aspect of energy efficient infrastructure and services in the capital city. In order to examine the benefits that can be expected by implementing these solutions, a breakdown of the existing situation in the capital city is given, followed by measures and possibilities for improvement of the existing situation in order to achieve the desired effects in terms of energy efficient infrastructure and services.

Smart technologies application in energy sector

2.1 Energy management system

Energy management is a process of continuous improvement of energy performance. Energy performance of an object is defined by its energy consumption, the manner energy and available energy resources are used and the degree of achieved energy efficiency. In order to successfully perform energy management, the energy performance has to be monitored. Therefore, a quantification of energy performance is needed. It is achieved through adoption of energy performance indicators. These indicators may be general, like energy consumption or degree of energy efficiency, but in order to thoroughly define energy performance of an object some specially designed indicators are used (indicators that correlate energy consumption/supply with the degree of activity of an object, like number of employees, production quantity, etc.). When there is a basis for energy performance monitoring, the continuous improvement of energy performance is achieved through planning process, implementation of adopted plans and monitoring of their realization. The plans are formulated as the set of actions that have to be done within the defined timeframe in order to achieve the adopted goal, i.e. improvement of energy performance (lower energy consumption, sustainable energy supply, fuel substitution, renewable energy usage, etc.).

In order to establish an energy management system there are two main prerequisites:

- Reliable monitoring of energy consumption (as well as other parameters of interest for energy consumption)
- Availability of qualified staff (technical education).

Without reliable monitoring of energy consumption, as the basic energy performance indicator, there is no energy performance monitoring. Therefore, the efficiency of measures from energy related plans cannot be evaluated, which may lead to selection of inappropriate measures with poor impact on energy performance and the budget (high investment with low return).

Also, since the data regarding energy performance have to be analyzed in order to evaluate some of the applied measures or energy management decisions, there should be available qualified staff designated for the task. In addition, as a result of the energy performance analysis the staff should propose measures for further improvement in form of an action plan which is the basic tool for energy management. These tasks can be performed only by staff qualified in the technical field (engineering).

When there are available qualified staff and established reliable system for energy consumption monitoring, the following actions should be performed in order to establish an energy management system:

- Identification of responsibility hierarchy for realization and operation of energy management system;
- Defining of procedures for establishing and operation of the energy management system;
- Defining of energy performance indicators basing on the monitored dynamic and available static data;
- Defining of procedures for monitoring of the energy management system efficiency, i.e. form and frequency of reporting (energy related data).

The expected results of energy management system operation are:

- Higher productivity for the same amount of energy consumed;
- Lower specific costs of energy usage;
- Increase of energy supply independence and security;
- Higher diversification of energy resources;
- Leaving energy resources that have bad impact on environment;
- Increasing use of renewable energy resources;
- Awareness rising regarding positive impacts of EE, RES and energy demand management;
- Important contribution towards achieving of national policy goals in the field of energy and environment;
- Sustainable usage of available energy resources;
- Positive impact on the budget.

2.1.1 Present state

Energy management related activities defined by ISO 50001 are not performed by the designated energy team as it is the custom for complex organizations with large energy consumption. A part of the activities that are related to the energy management are performed by the Secretariat for Planning and Spatial Regulation and Environment, Sector for Environment and Sustainable Development. Within the sector, the Energy Management Office and Info Center with 2 employees were established in 2010 (2014[3]). Its activities are: collecting energy consumption data on municipality level, energy consumption data analysis and proposing measures for energy efficiency improvement; work on local, national and international projects in energy field; organization of the event "Energy Days of Podgorica" which promotes energy efficiency, its importance and environmental protection.

[3] The office was established in 2010 as a part of the project, but since 2014 it has operated as a part of the Sector for Environment and Sustainable Development.

The Sector for Environment and Sustainable Development performs certain energy planning activities which have resulted in the preparation of SEAP (Sustainable Energy Action Plan, 2011) and LEP (Local Energy Plan 2015-2020, 2015). The preparation of the mentioned documents included participation of extern experts. Both of the documents point out the challenge of reliable energy consumption data collection. Energy balances used for the analysis are often estimated basing on the scarce available data which significantly limits the evaluation and monitoring of selected measures (Action Plan).

There is no reliable energy information system established. However, some basic procedures for energy consumption data collection are established. They require a lot of manual data collection from hard copy materials (especially for the energy carriers other than electricity). These procedures are time demanding and there is a lot of potential for increasing their efficiency and effectiveness through implementation of available ICT solutions. A first step could be custom made software solutions for data collection and processing. In order to enable more reliable energy management, modern hardware and software solutions for energy information system (and control) should be considered for implementation. However, these solutions are much more financially demanding, so a cost/benefit analysis should be performed to select the appropriate solution for modern energy management system for the capital city. The benefits of a modern energy management system directly depend on the energy intensity of all processes within the municipality. The costs depend on the number of monitored objects, selected hardware (monitoring and control) and software (visualization, archiving, data processing) functionalities. Without reliable energy supply/demand monitoring, there is no reliable energy balance preparation.

2.1.2 Energy balance

The first step in analysis of energy performance is creation of energy balance for an object, or, in this case, municipality. With energy information system available (monitoring of energy consumption/supply and other relevant parameters), the process of energy balance creation is straight forward. In order to achieve reliable overview of the energy performance, energy balance should be prepared for several levels:

- Municipality level - includes all sectors (commercial, service, residential, industrial and transport);
- Buildings and utility companies owned by the municipality management;
- Single building or utility company.

The energy balance for municipality level is necessary prerequisite for creation of energy plans that target the development of the whole municipality. Preparation of the energy balance for municipality level is very demanding due to the number of consumers and energy suppliers that possess the necessary information for the balance creation. Although some energy resources are reliably monitored (like electricity), that is not the case for all of them. Main energy resources used in Montenegro are: fuel wood, electricity, coal and oil derivatives. There is only one supplier for electricity, so it is rather easy to obtain the electricity consumption per sector or per single consumer. As for coal and oil derivatives, there are more suppliers with various development level of information system that monitors quantity of supplied fuel. Collecting information from these suppliers is rather demanding but it can be performed with the acceptable reliability. Fuel wood is very important energy resource in Montenegro. There is a large number of suppliers and majority of them with very poorly developed information systems, which makes difficult to estimate fuel wood consumption even on the sectorial level. Also, great number of consumers use own fuel wood (owned forests) which is very difficult to monitor on the regular basis. Therefore, as the main option for monitoring fuel wood consumption, there are periodical inquiries or the data collected by the Statistical Office of Montenegro (Monstat).

The mentioned problems of collecting data necessary for energy balance creation are applicable for all levels, but when the number of observed consumers is small, the main source of information are consumers. Therefore, when preparing energy balances on the level of buildings and companies operated (owned) by the capital city, all data regarding energy consumption have to be obtained from consumers. Since energy information system is often unavailable, the main source of information are bills for fuels used. Availability of bills for greater time period (large number of billing intervals) is questionable if there is no established form of energy consumption monitoring within the building/company. Similarly as mentioned earlier, electricity consumption per consumer can be accessed through the supplier's database which contains data for long period (necessary for reliable energy consumption analyses). However, this is not the case for other fuels whose consumption monitoring can be performed only by the consumer itself.

Single object consumption monitoring can be very simple even in case of unavailability of modern energy information system. In order to achieve it, the energy consumption monitoring procedures should be defined (archiving of the fuel bills, reporting of the energy and financial quantities, etc.). However, it demands greater number of employees with respect to the ITC based energy information system (modern BMS systems) when greater number of objects is included in energy consumption monitoring.

Creation of energy balances on a single object or group of objects level is better suited for analyzing object specific measures which enables more reliable planning. Combining balances created for single or group of objects enables bottom-up principle of energy balance creation for the municipality level. However, it should be taken into account that due to the low availability of specific energy data, creation of energy balance for municipality is more often a top-down procedure.

In the following text various energy balance related data for the capital city will be presented[4]. Fuels used in the capital city are: electricity, fuel wood and oil derivatives (diesel, petrol and LPG). Electricity and oil derivatives have the dominant shares in the total final energy consumption, which are around 40% (Figure 2.1.1). Within oil derivatives the share of diesel is around 85%. The rest of final energy consumption corresponds to fuel wood which participates with 18% share. All needs for oil derivatives, as it is the case for the whole country, are satisfied through import performed by several major and various small companies that act as suppliers. Therefore, reliability of oil derivatives supply is good. On the other hand, the needs for fuel wood are fully satisfied by local and suppliers from northern municipalities. As for electricity, as mentioned earlier, there is only one electricity supplier in the capital city, i.e. public electricity supplier (EPCG). There are no significant distributed energy resources, although there are plans for solar power potential utilization. Although there is a single electricity supplier, the supply reliability is acceptable due to the following facts:

[4] Due to unavailability of the energy information system, various sources for data were used: previous studies, urban plans, local energy plan, SEAP, National energy strategy and electricity data measured by supplier.

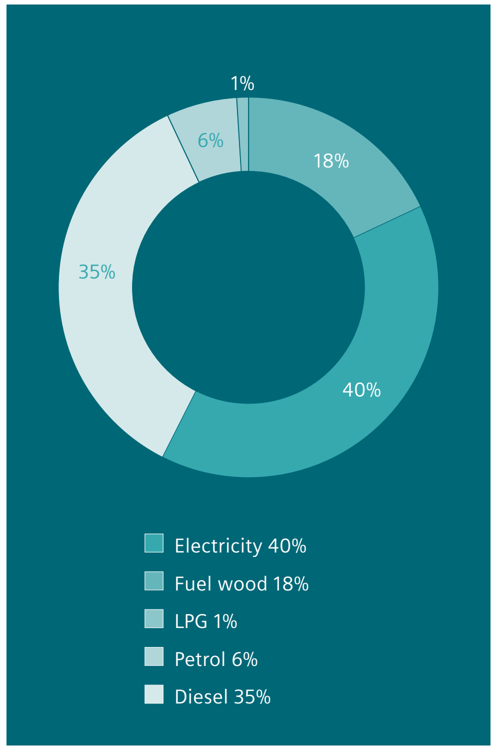


Figure 2.1.1 Final energy consumption structure for the capital city in 2012

- Small country electricity import dependence[5];
- Reliable grid infrastructure characterized by 4 supply points (substations connected to the transmission grid) and medium voltage cable grid with the reserves in capacity;
- The most important 400 kV substation is located in the capital city.

The final energy consumption structure per sector (commercial, service, residential, industry and transport) for the capital city is very demanding for creation due to the unavailability of the energy consumption monitoring, as well as due to the great number of consumers that have to be monitored. However, it can be stated that approximately the total share of oil derivatives is consumed within the transport sector. Negligible share is used for heating purposes in service sector. Fuel wood is used mainly in residential sector, but a small part of it is used in commercial and service sectors. Electricity, as the most versatile energy resource is used in all mentioned sectors[6]. Since the data regarding electricity consumption are the most reliable (and easily available through communication with the supplier), and the electricity is the most important energy resource, an additional analysis of the available electricity consumption data follows.

The trend in electricity consumption for the past several years is a soft decrease (Figure 2.1.2). Although the number of consumers is slightly increased, the total electricity consumed is lower or at the same level. This trend can be confirmed through the change in power demand over the same period (Figure 2.1.3). With respect to the power demand, the capital city has the share of about 33% of the country power demand.

In order to better understand the electricity consumption, a comparison of the two selected years with similar consumption is made (Figure 2.1.4). The comparison is performed on monthly base. The selected years are: 2012 and 2015. Although both years are characterized with similar annual consumption, there are significant differences that should be noted with respect to the consumption on the monthly level. These differences are important for selection of measures that could increase energy performance. On the other hand, there are similarities that characterize the strong seasonal dependence of electricity consumption, i.e. "V-shape" curve.

The fact that larger electricity consumption corresponds to the winter months suggests that the electricity is greatly used for fulfilling of the heating needs. Also, a slight increase in the electricity consumption in July and August points to the greater need for electricity consumed by air conditioning. The differences between monthly electricity consumptions corresponding to the observed years arise because of different weather characteristics of the respective years.

More than 70% of the total electricity consumption of the capital city corresponds to the residential sector. The remaining share corresponds to service and commercial sector. Therefore, with respect to the amount of electricity consumed it is obvious that measures aimed at the residential sector will provide the best overall results, but these measures are often difficult to implement thoroughly. On the other hand, service sector has shown better potential for implementation of measures due to clear management structure, and due to this is often the main target of energy plans. This is especially the case for buildings and companies owned by municipality. Also, it should be taken into account that national policy through plans and strategic documents strongly promotes and even demands implementation of measures for energy performance improvement in public buildings. In order to define appropriate measures for the mentioned sectors, the corresponding energy balances should be created.

[5] About 10% of the total country electricity consumption is imported. This share may increase in the years with long droughts due to the dependence of hydro power plants.

[6] It is not calculated with the electricity consumed by national railroad companies, since it is not managed by the capital city.

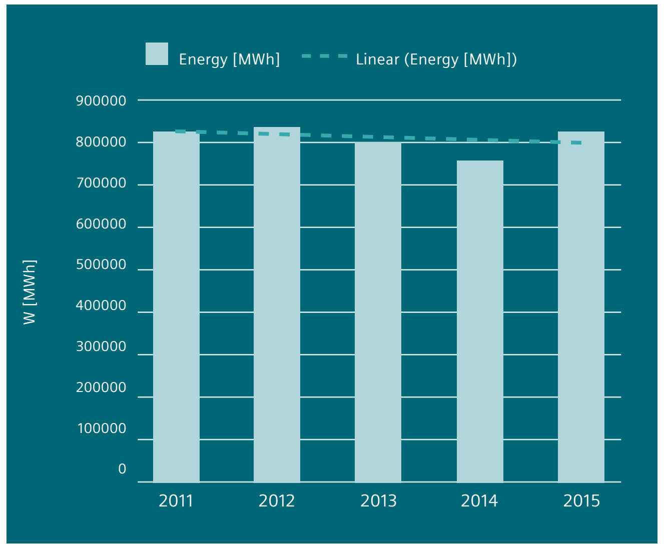


Figure 2.1.2 Total metered annual electricity consumption for all supply nodes of Podgorica in the period 2011-2015

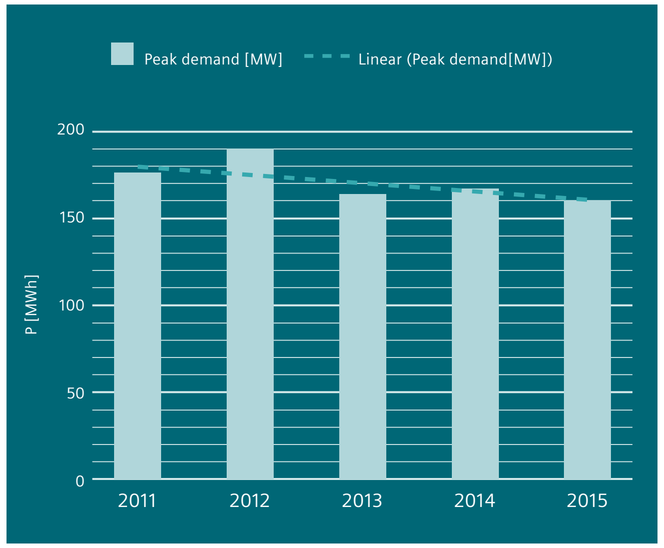


Figure 2.1.3 Total metered annual peak demand for all supply nodes of Podgorica in the period 2011-2015

Since the data regarding household consumption in the capital city is not systematically monitored, energy balance preparation is very challenging because of the need for time demanding data collection process. The household energy balance data which are reliable and based on surveys conducted by licensed organization are available only for a typical Montenegrin household, or household sector as a whole. Mentioned data are available in publications of the Statistical Office of Montenegro, and raw survey data used for preparation of Montenegrin strategy Strategy for Development of Energy Sector until 2030. It should be pointed out that the data from Strategy for Development of Energy Sector are for year 2008 (base year in the Strategy), and the data from the Statistical Office of Montenegro are for year 2012. The structure of needs for energy as well as for what purposes the fuels are used is similar for the capital city as on the country level due to the dominant share of the capital city in the total country consumption[7]. The share of energy carriers used in household sector are presented in the following figure.

As it can be seen from Figure 2.1.5, there are 6 energy carriers in use in a typical Montenegrin household:

- **Electricity**
  - The most dominant energy carrier in household sector is electricity. Although its dominance can be expected due to the versatility of its usage, it should be pointed out that its usage for heating is great, especially in central and southern region of Montenegro, which is recognized as a great potential for energy efficiency.
- **Fuel wood**
  - Fuel wood as an energy carrier is mostly used in Montenegrin areas characterized by cold winters, which is the case for the north of the country. Also, the energy balance of households in the central region of Montenegro (Podgorica, Nikšić and Cetinje) includes a significant share of fuel wood.
- **Coal**
  - Due to the great availability of lignite from the local mine, coal is used by households in Pljevlja.

[7] Approximately 40% of Montenegro population is located in the capital city.

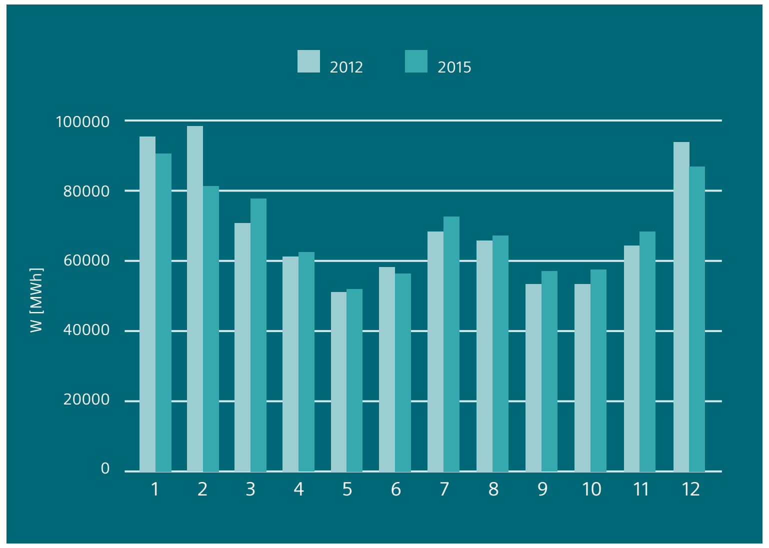


Figure 2.1.4 Total metered monthly electricity consumption for all supply nodes of Podgorica (2012 and 2015)

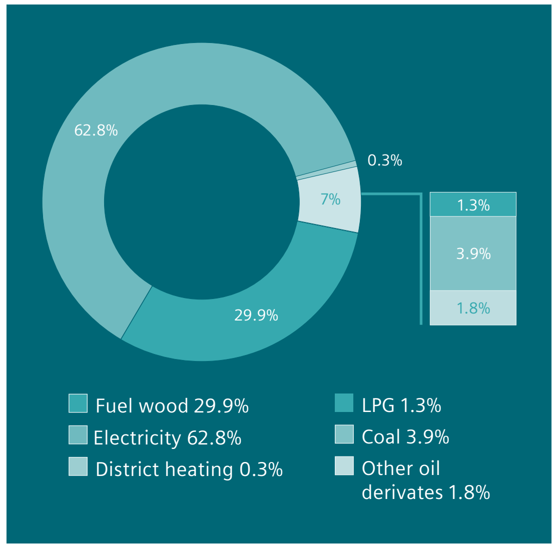


Figure 2.1.5 Final energy consumption structure per fuel for household sector in Montenegro [1]

- **District heating**
  - District heating in Montenegro exists in a very limited amount. It is not developed or well researched in spite of the climatic circumstances and availability of suitable energy carriers (biomass, fuel wood) in the northern part of the country;
  - According to the available information (Strategy of Development of Energy Sector in Montenegro until 2030.), there are only two plants for district heating of lower importance in Pljevlja (Public Heating Company and Sports Center Ada);
  - The expansion of the district heating system is planned for Pljevlja and it will be done when the new unit of power plant Pljevlja is built according to the mentioned energy strategy (the estimated district heating capacity of the future system is about 70 MW_{th});
  - District heating systems are planned to be constructed in other northern cities, but in lower amount than it is planned for Pljevlja (about 12 MW_{th}).
- **Gas**
  - Liquid natural gas is not available in Montenegro due to the absence of necessary infrastructure. This energy carrier is not treated as an important strategic potential (within the Energy Strategy) until 2021. Since then it is expected to be known which option for connecting of Montenegrin consume on the Adriatic gas transmission system will be available (Ionic-Adriatic Pipeline or Trans Adriatic Pipeline);
  - Liquid petroleum gas is present in the energy balance of an average household, but with a very low share.

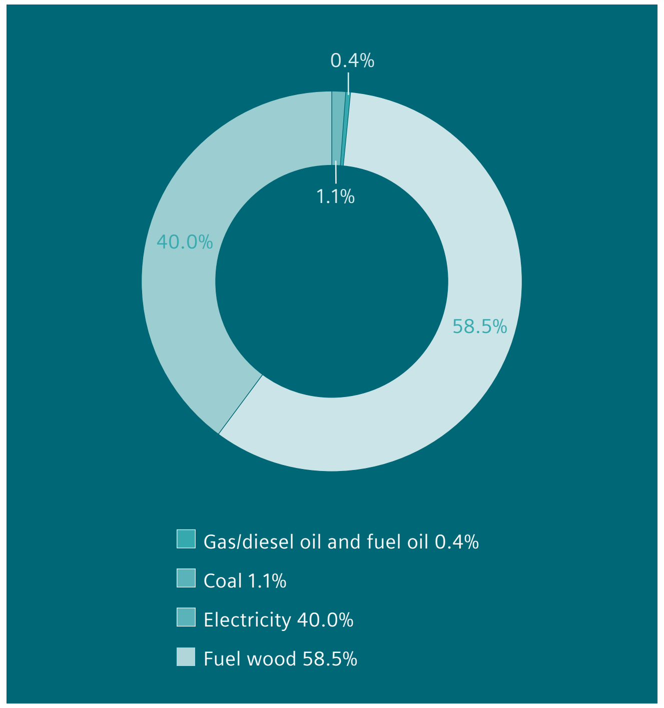


Figure 2.1.6 Final energy consumption structure per fuel for household sector in Montenegro [Monstat, 2012]

The structure of final energy use for household sector according to the data from Monstat 2012 is given in Figure 2.1.6. The main reason for the differences between the energy balances for 2008 and 2012 is due to the change in methodology for collection of data related to the use of fuel wood in Montenegrin households, which is changed in 2010 by the Statistical Office of Montenegro (the data for the both balances are essentially obtained from the same source – Statistical Office of Montenegro). Due to the mentioned methodology, the absolute value of fuel wood consumption increased for more than 3 fold (3.43) between 2008 and 2012. A small part of increase can be explained by certain increase in consumption due to the increase of electricity price, but the main reason is dominantly the change in the methodology. Therefore, the share of fuel wood consumption in the final energy consumption of household sector is greatly increased.

At the same time, the absolute value of electricity consumption has also changed, but not as drastically as the fuel wood. Consumption of electricity increased by about 10%. On the other side, consumption of coal and oil derivatives has decreased for 49% and 67% respectively, which makes their share in the final consumption of household sector almost negligible (1.5% share in the total final energy consumption of households). The district heat component is neglected by the recent energy balance prepared by Statistical Office of Montenegro. Therefore, from the energy point of view, there are only two energy carriers of significance in use in household sector, i.e. residential buildings: fuel wood and electricity.

The greatest share of the energy of a household is used for space heating (Figure 2.1.7), and this need is fulfilled by using all available energy carriers (Figure 2.1.7 a). The most dominant energy carrier used for space heating is fuel wood (50.7%) and it is followed by electricity (37.2%) and coal (8%). District heat, LPG and other petroleum products have a total share of 4.2%. Taking into account the recent statistical data, the share of coal, district heat, LPG and other petroleum products is even smaller (1.5% share in the total final consumption of household sector in 2012). It can be concluded that significant share of energy used for space heating is represented by electricity, which is a great potential for energy efficiency measures. Thus, for the present state, use of energy carriers other than fuel wood and electricity for space heating can be neglected.

The other energy intensive needs of a household are cooking (Figure 2.1.7 b) and hot water preparation (Figure 2.1.7 c). There are three energy carriers used for cooking in household sector: electricity (68.1%), fuel wood (26.3%) and LPG (5.6%). Therefore, the share of electricity is dominant, and its dominance is even greater for households from southern cities. Households from northern part of the country rely more on fuel wood as an energy carrier due to its availability and price. It is interesting to note that LPG has a share that should not be neglected, although there is no gas infrastructure in Montenegro. When LPG is in question, it also should be pointed out that the level of aware-

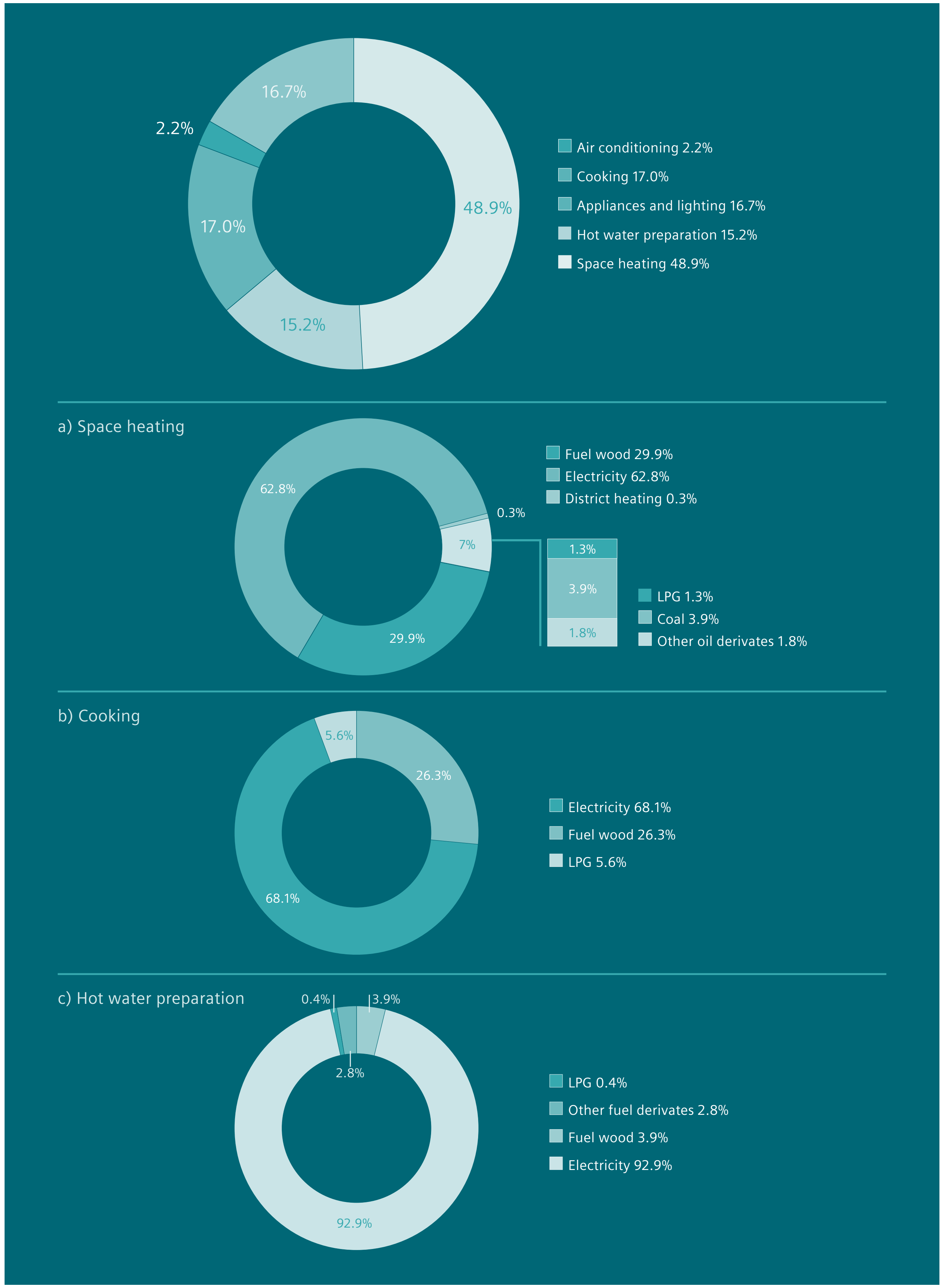


Figure 2.1.7 Final energy consumption structure for household sector in Montenegro [1]

Purpose of the objects	Number of objects	Area [m²]
City management	10	20.939
City utility companies	37	36.569
City regional bodies	48	11.446
Culture related buildings	14	9.779
Sport related buildings	5	59.504
Other buildings	1	3.408
Residential and commercial buildings (parts of)	213	23.324

Table 2.1.1 Number and area of building objects owned by the capital city [2]

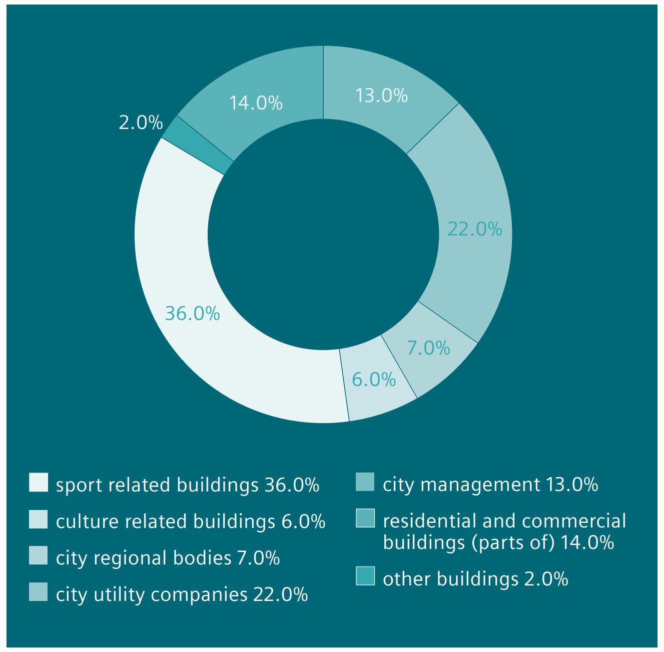


Figure 2.1.8 Structure of the buildings (owned by the capital city) area per their purpose [2]

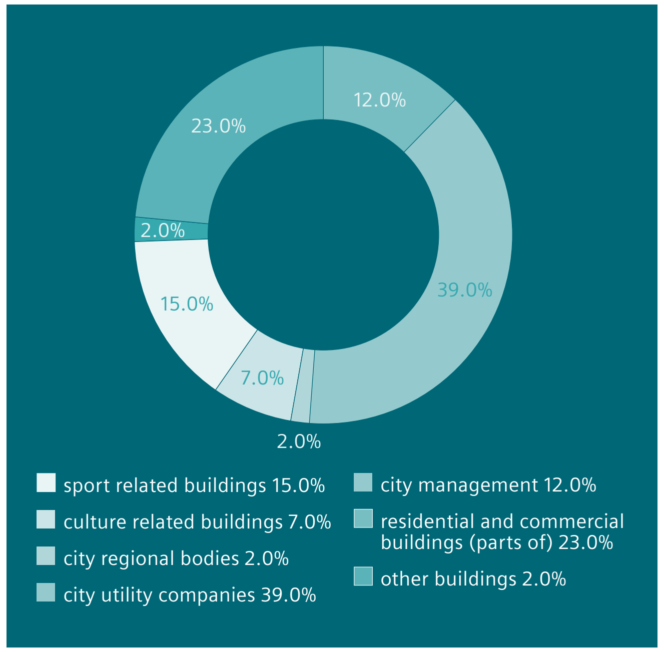


Figure 2.1.9 Structure of the buildings (owned by the capital city) energy consumption per their purpose [2]

ness about LPG good energy characteristics, as well as about safety issues, is rather low in household sector, which certainly limits its greater usage.

On the other hand, almost the only energy carrier used for hot water preparation in households is electricity (92.9%). Only small amount of households is equipped with boilers that use fuel wood (3.9%), LPG (0.4%) or other petroleum products (2.8%). In terms of energy intensity, with respect to other energy needs of a household, it can be said that present energy use for hot water preparation is the least efficient. If it is taken into account the availability of solar thermal potential in Montenegro and level of its usage, the situation is even worse.

According to the national strategic documents and plans, the most important target for measures, taking into the account the implementation potential, are buildings managed (owned) by the government or municipality, i.e. public buildings. Therefore, buildings managed by the capital city should be target of the special attention when energy balance is in question. There are 328 objects (including part of buildings) owned by the capital city (Table 2.1.1).

The share of buildings per purpose in the total building area is presented in Figure 2.1.8. Although it is expected that sport related objects have the greatest share due to their nature, a significant share in the total area corresponds to the city utility companies, city management and various residential and commercial buildings. The mentioned buildings should be the main target when analyzing potential energy performance improvement. However, beside the share in the total area, it is important to analyze the energy consumption of the respective buildings.

The structure of the final energy consumption per building groups owned by the capital city is presented in Figure 2.1.9. It is evident that the energy consumption structure differs from the area structure, but there are some similarities. City management buildings have almost the same share in the total consumption as in the total area, but city utility companies and various residential and commercial buildings have significantly greater share in the total final energy consumption than in the total building area. This situation points out the fact that the buildings used by city utility companies and various residential and commercial buildings are characterized by greater energy intensity with respect to the rest of buildings managed by the capital city.

Energy performance indicator is often used for buildings is the ratio of the annual final energy consumed and the total area of the building (Figure 2.1.10). Its value is indicative for evaluation of how intensive is energy used by some building. High energy intensity is often a good indicator of potential for energy performance improvement. By combining it with other performance indicators that calculate with the activity indicators of buildings (number of employees, production rate, etc.), a more reliable evaluation of energy performance can be made.

According to the data regarding energy consumption and area, the highest consumption per unit of area corresponds to city utility companies. Residential and commercial buildings are also characterized by high specific energy consumption. National rulebooks and analyses in the field of energy efficient buildings treat energy classes of buildings. It is expected that these classes will be available in the near time, but taking into account the working material in Figure 2.1.10. the line that corresponds to the buildings with energy class A (green energy buildings) is marked. It can be seen that most of the buildings managed by the capital city correspond to the lower energy classes, i.e. there is a lot of potential for improvement of energy performance.

Another important aspect of energy balance beside energy consumption structure and energy intensity is the diversification of energy carriers used by the buildings managed by the capital city (Figure 2.1.11). The overall dominance of electricity is evident, which participates with approximately 94% in all energy needs of buildings in question. Other used energy carriers are fuel wood (approximately 5% share) and residual fuel oil (approximately 1% share). Therefore, the level of energy carrier diversification is very low, which represents an indication of low energy performance. The most obvious conclusion is that electricity is dominantly used for heating purposes, which is not energy efficient taking into account how the electricity is produced (approximately 40% of electricity in Montenegro is produced by thermal plant Pljevlja), and in addition, there is no distributed renewable resources in the capital city. On the other hand, energy carrier diversification leads to higher energy supply security.

In order to design reliable measures that target improvement of the capital city energy performance (on municipality level or for only directly managed objects), it is necessary to create reliable energy balance, which is only possible in the presence of the reliable energy consumption monitoring system. This system should be on the object level in case of public objects (Figure 2.1.12), and in the case of residential sector, it should be a hybrid system of monitoring metered and estimated energy consumption data. In both cases, there are available hardware and software solutions with friendly interfaces that could be operated by the municipality staff designated for energy management.

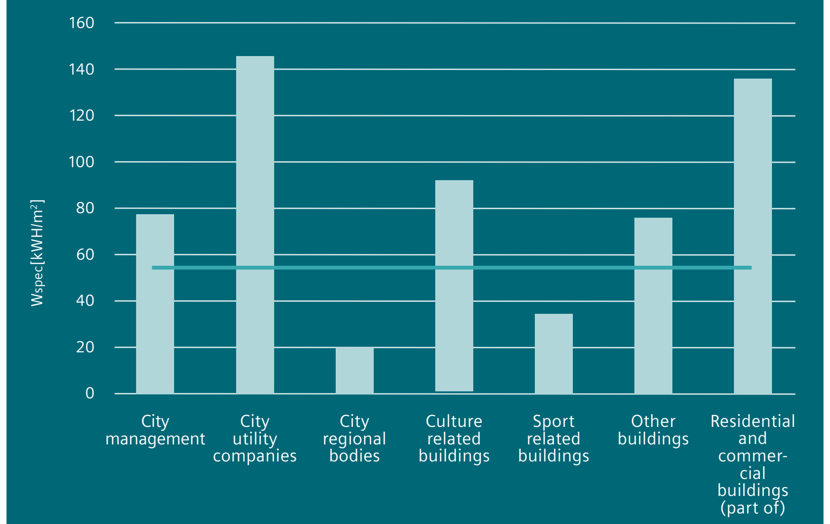


Figure 2.1.10 Annual energy consumption per unit of area of the buildings owned by the capital city

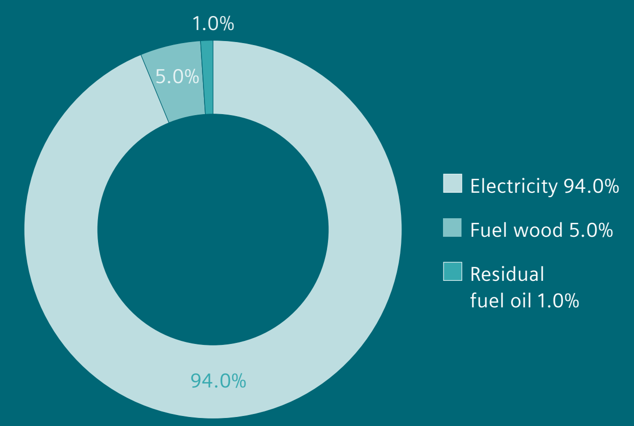


Figure 2.1.11 Energy consumption structure per fuel for the buildings owned by the capital city

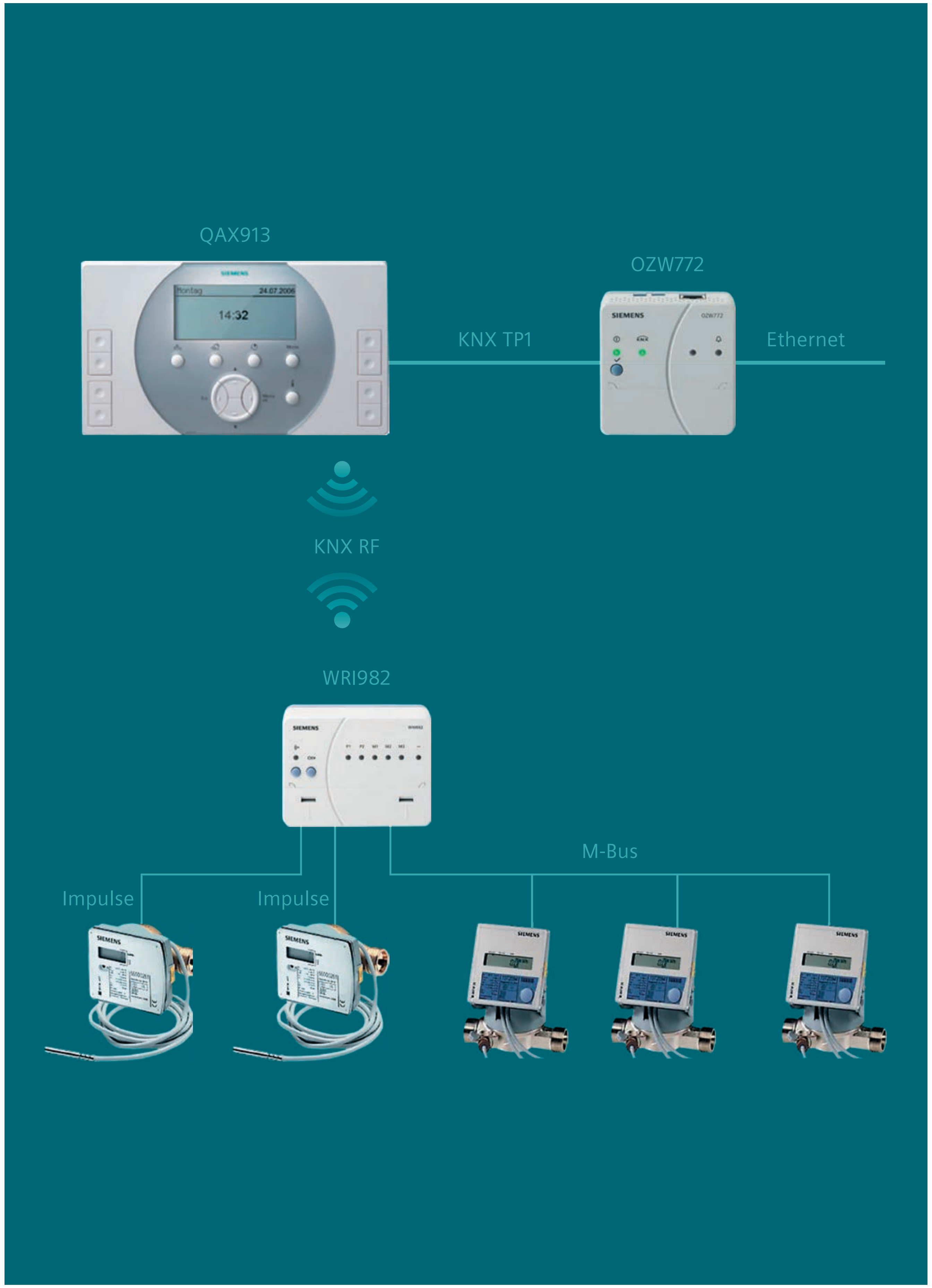


Figure 2.1.12 An example of the energy consumption data collection system [Siemens]

2.1.3 Improvement possibilities

Despite the fact that establishing of the energy management system is an obligation defined by the law, the evident positive impact on energy performance improvement is enough reason for municipalities to strongly support the development and operation of an energy management system. There are various guidelines for the best manner of energy management system establishing, but the most referent is International Standard ISO 50001. This standard represents the guideline for development of energy management system of arbitrary complexity (for a process, an object or an organization), and therefore it is the best start for a municipality that needs reliable and effective energy management system.

On the other hand, for building related energy management there are various solutions available on the market. These solutions are designed basing on the recommendations from ISO 50001, although their standard is EN 15232 that covers building automation and control. These solutions are BMS (building management systems) and they are common part of modern business buildings, but BMS can also be installed in old buildings. There are various simple BMS for residential buildings that are not cost demanding but provide significant energy performance improvement.

A possibility of improvement of energy consumption monitoring and archiving that is free is the establishing of direct communication with energy suppliers in order to collect the consumption data from their databases. Energy suppliers often dispose of advanced information systems that collect and archive consumption data from all of their customers. The data can be obtained from them after an agreement between all sides is made. This is a simple procedure which enables access to reliable consumption data for long time periods. The access to reliable energy consumption data is of crucial importance for energy management process.

In the following text, the mentioned improvement possibilities for the present energy management system in the capital city will be analyzed with more details.

2.1.3.1 Fulfilling of ISO 50001 requirements

The main goal of this International Standard is the implementation of an energy management system which will result in improved energy performance. The Standard implies that the organization will periodically review and evaluate its energy management system in order to identify opportunities for improvement and their implementation. The organization is given flexibility in how it implements the energy management system. The organization can take into account economic and other considerations when determining the rate, extent and timescale of the continual improvement process.

The standard defines the scope and boundaries of an energy management system, which allows flexibility to the organization to define what is included within it. The main scope is to achieve energy performance improvement, which includes energy use, energy efficiency and energy consumption. The organization can choose which of the mentioned aspects of energy performance it will select as the focal point of its interest. A model of energy management system according to ISO 50001 is presented in Figure 2.1.13.

In order to perform energy management tasks, the energy management team should be defined. For small organizations, it can be one person, but for larger organizations, a cross-functional team provides an effective mechanism to engage different parts of the organization in the planning and implementation of the energy management system.

As it can be seen from the model (Figure 2.1.13), energy policy is the starting point, or the driver of an energy management system. The policy may be a brief statement that members of the organization can readily understand and apply to their work activities. In case of municipality, energy policy has to be in line with the national energy policy which, through corresponding strategic documents treats energy goals in various sectors and levels, i.e. the municipality level. Also, regulatory obligations should be taken into account when designing energy policy, i.e. defining goals in the energy related sphere.

With the energy policy available, the next step is the planning phase. Energy planning is an obligation of a municipality mandated by Law on Energy Efficiency, and the important element of an energy management system. It is a complex process (Figure 2.1.14) of analyzing energy supply/demand chain in order to identify hot spots, barriers and opportunities for energy performance improvement. The main result of an energy planning process is the action plan with clearly specified measures that should result with

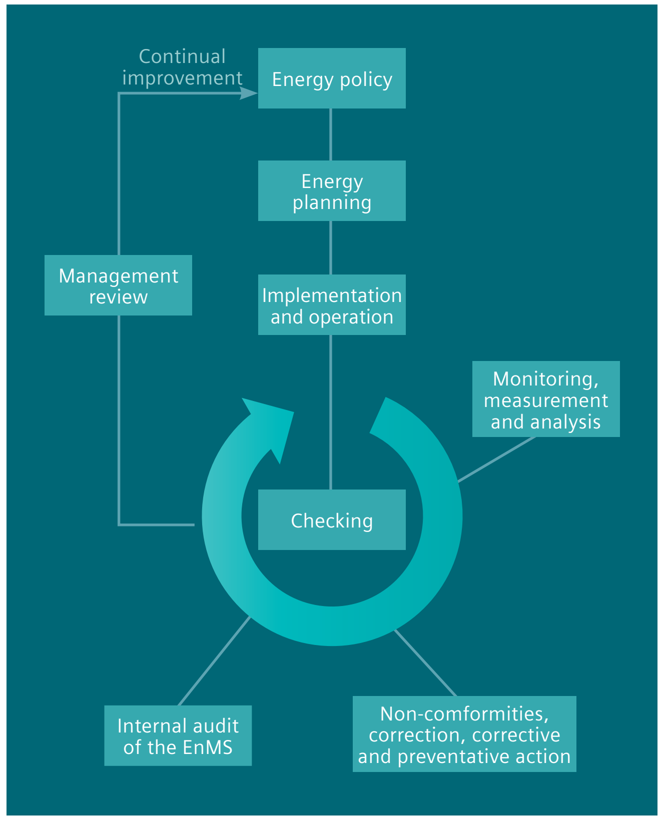


Figure 2.1.13 Energy management system model for ISO 50001

reaching of the desired goals. The significance of the reliable energy consumption monitoring is evident from Figure 2.1.14 since it represents the necessary input of the planning process. The quality of the planning outputs is directly impacted with the availability of reliable data regarding energy consumption and other variables affecting significant energy use (activity indicators).

The core of an energy planning process is the energy review. It represents a set of analyses performed on the available data affecting the energy use with the goal to detect and identify energy consumption hot spots (energy intensive consumers) and possibilities to improve overall energy performance. An energy audit is a detailed review of the energy performance of an organization (or single object or process). Energy audits of public buildings are an obligation for all municipalities in Montenegro.

The results of the planning process are:

- Energy baseline – a quantitative reference(s) providing a basis for comparison of energy performance for the specified time period. It is also used for calculation of energy savings, as a reference before and after implementation of energy performance improvement actions. It is essential for monitoring and evaluation of the effects of implemented measures;
- Energy performance indicators – adopted quantitative values that closely describe monitored characteristics, i.e. energy performance. There are simple (energy consumption, generation, activity, etc.) and complex indicators (specially customized indicators that include various quantities impacting energy performance of a specific object or process);
- Objectives – a general direction of action for which measures are selected (fuel substitution, solar power utilization, building envelope improvement, etc.);
- Targets – quantification of the selected objectives (desired level of renewable energy production, energy consumption), i.e. achieving of the specified values of selected energy performance indicators;
- Action plans – a set of selected measures designed for reaching the specified objectives and targets which ensure desired level of energy performance improvement. The action plan should include the methodology of monitoring and evaluating its implementation and effects.

After the finalization of the energy planning phase, the designed Action Plan enters the implementation phase and the measures provide the first effects on the energy performance. The implementation phase includes the need for contracting external services. The energy management team handles the process, as well as the monitoring of the ActionPlan realization, i.e. the effects of measures through monitoring of the adopted energy performance indicators. The organization defines competence, training and awareness requirements based on its organizational needs. Competency is based on a relevant combination of education, training, skills and experience. The energy management team prepares periodical reports regarding the Action Plan implementation with potential corrective measures proposals. The efficiency of Action Plan, i.e. the quality of achieved results is the main indicator of energy management process quality. The energy management is defined by the degree of achieved energy performance improvement. It is a process of continuous improvement of energy performance.

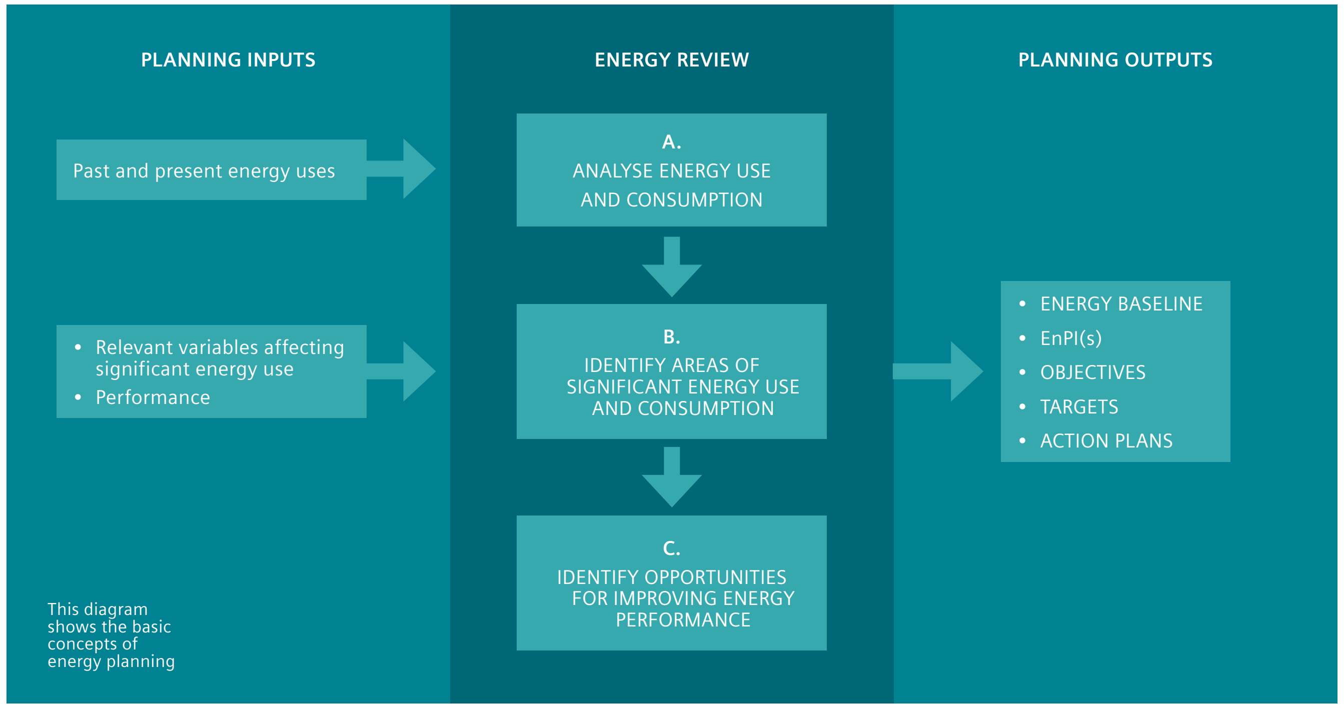


Figure 2.1.14 Energy planning process (ISO 50001)

However, internal audits of an energy management system should be periodically performed. The audits can be performed by personnel from within the organization, or by external persons selected by the organization, working on its behalf. In either case, the persons conducting the audit should be competent and in a position to do so impartially and objectively. In smaller organizations, auditor independence can be demonstrated by an auditor being free from responsibility for the activity being audited.

2.1.3.2 BMS systems in public buildings

In order to support the Directive of Energy Performance of Building (EPBD) to enhance energy performance of buildings in the member states of the EU, standard EN 15232 that treats BMS is developed. Standard EN 15232 specifies methods to assess the impact of Building Automation and Control System and Technical Building Management functions on the energy performance of buildings, and a method to define minimum requirements of these functions to be implemented in buildings of different complexities.

BMS has an impact on building energy performance from many aspects. It provides effective automation and control of heating, ventilation, cooling, hot water and lighting appliances, etc., that increase operational and energy efficiencies. Also, it calculates the "natural" energy gains – passive solar, ventilation cooling, daylight, etc. together with internal gains (occupants, lighting, electrical equipment, etc.). BMS includes monitoring and control of renewable energy sources production and cogeneration on the building premises. Complex and integrated energy saving functions and routines can be configured on the actual use of a building depending on real user needs to avoid unnecessary energy use and CO_2 emissions. BMS provides information for operation, maintenance and management of buildings especially for energy management – trending and alarming capabilities and detection of unnecessary energy use. An energy demand/supply scheme form BMS systems is presented in Figure 2.1.15.

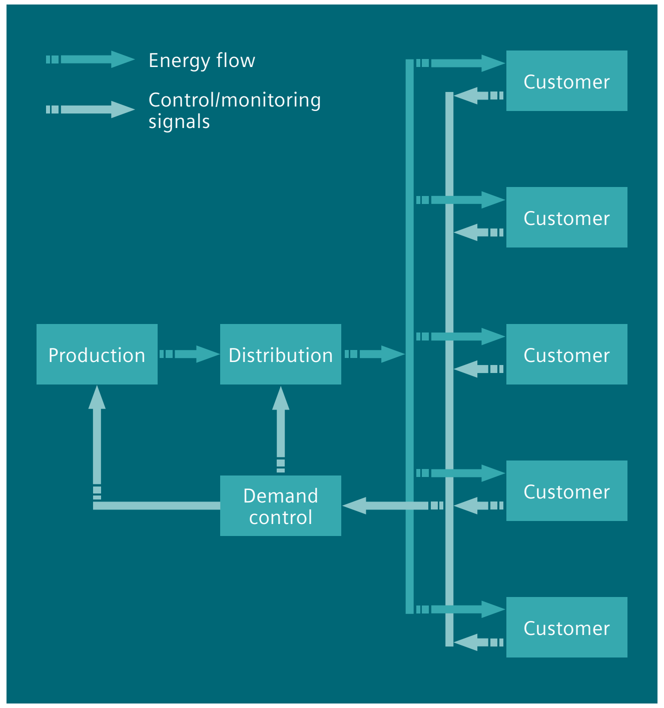


Figure 2.1.15 Energy demand/supply model in buildings for BMS

It is evident from the presented energy demand/supply model (Figure 2.1.15) that each significant consumer is monitored (energy consumption quantity as well as respective consumption patterns) as well as the available energy supply (including production available on site, like RES). The main goal is to supply energy to the consumer according to energy demand signals, keeping the losses in distribution and generation to an absolute minimum.

Energy efficiency-relevant functions of BMS are:

- **Heating control**
  - Emission control
    - Central automatic control - Supply output depending on the outside temperature for example (corresponding to the probable heat demand of the consumers). Energy losses under part load conditions are reduced, but no advantage can be taken of individual heat gains in the rooms;
    - Advanced central automatic control - Taking advantage of self-regulating effects during operating times fulfills comfort requirements in all the rooms and reduces heat demand as much as possible. Different setpoints for heating and cooling (e.g. through the use of a setpoint range for the flow temperature) can prevent unnecessary overheating or undercooling. Additional energy can be saved by compensating for known heat gains in the building (e.g. by adjusting the flow temperatures over the weekend in office buildings – if there are no internal heat gains). Within a specified outside temperature range (transition period), the changeover between heating and cooling occurs (indirectly) based on heat gains in the building. This may enhance comfort and automate operation (no need for the operator to manually change over);
    - Individual room control - Supply output based on room temperature (= controlled variable). It considers heat sources in the room as well (heat from solar radiation, people, animals, technical equipment). The room can be kept comfortable with less energy;
    - Individual room control with communication - schedulers make it possible to reduce output during non-occupancy, and operating and monitoring functions further optimize building energy supply operation;
    - Individual room control with communication and presence control - Effective occupancy control results in additional energy savings in the room under part load conditions. Demand-controlled energy provision (production of energy) results in minimum losses in provision and distribution.
  - Control of distribution network hot water temperature (supply or return)

- Outside temperature-compensated control - Distribution temperature is controlled depending on the outside (corresponding to the probable temperature demand of the consumers). This reduces energy losses under part load conditions;
- Demand-based control - Distribution temperature depending on the room temperature (controlled variable). It considers heat sources in the room as well (solar irradiance, people, animals, technical equipment). Keeps energy losses under part load conditions at an optimum (low).

○ Control of distribution pumps in networks

- On off control - Electrical power for the pump is drawn only as required – e.g. during occupancy periods or in protection mode (frost hazard);
- Multi-stage control - Operating at a lower speed reduces power consumption of multi-speed pumps;
- Variable speed pump control - With constant or variable Δp and with demand evaluation to reduce the auxiliary energy demand of the pumps.

○ Intermittent control of emission and/or distribution

- Automatic control with fixed time program - Savings in emission and/or distribution outside the nominal operating hours;
- Automatic control with optimum start/stop - Additional savings in emission and/or distribution by continuously optimizing the plant operating hours to the occupancy times;
- Automatic control with demand evaluation - The operating time and/or the temperature setpoint for emission and/or distribution is determined based on consumer demand.

○ Generator control for combustion and district heating

- Variable temperature control depending on outdoor temperature - Generation temperature is controlled depending on the outside temperature (corresponding to the probable temperature demand of the consumers), considerably reducing energy losses;
- Variable temperature control depending on the load - Generation temperature is controlled depending on the effective heat demand of the consumers, keeping energy losses at the generator to an optimum (low).

○ Generator control for heat pumps

- Variable temperature control depending on outdoor temperature - Generation temperature is controlled depending on the effective temperature demand of the consumers, keeping the COP at an optimum (high);
- Variable temperature control depending on the load - Priority control adapts current generation output (with priority to renewable forms of energy) to current load in an energy-efficient manner.

○ Sequencing of different generators

- Priorities only based on loads - Only the generators for covering the current load are in operation;
- Priorities based on loads and demand of the generator capacities - adaptation of the current generator output to load can be more precise, the large generators operate in a more efficient partial load range;
- Priorities based on generator efficiency - The generator operational control is set individually to available generators, so that they operate with an overall high degree of efficiency or using the cheapest energy form (e.g. solar, geothermic heat, cogeneration plant, fossil fuels).

• **Domestic hot water supply control**

○ Control of DHW storage temperature with integrated electric heating or electric heat pump

- Automatic control on/off and charging time release - Release of the charging time results in energy savings (losses in the DHW storage tank) by defining the charging duration and preventing frequent charging. If the DHW temperature drops below a certain reduced level, recharging takes place even without a time-based release;
- Automatic control on/off and charging time release and multi-sensor storage management - Multi sensors allow for dividing the DHW storage tank into various zones ensuring better adaptation to usage. This reduces heat losses in the storage tank.

○ Control of DHW storage temperature using heat generation

- Automatic control on/off and charging time release - Release of the charging time enable results in energy savings (losses in storage tank) by defining the charging duration and preventing frequent charging. If the DHW temperature drops below a certain reduced level, recharging takes place even without a time-based release;
- Automatic control on/off, charging time release and demand oriented supply or multi-sensor storage management - Demand-controlled supply temperature reduces heat losses in generation and distribution. The supply temperature can be matched to the DHW storage tank temperature and increased as needed. Spreading the load over time (e.g. heating circuits) lowers the maximum output for generation: Generation can be operated in an optimum part load range;
- Automatic control on/off, charging time release, demand oriented supply or return temperature control and multisensory storage management - Multisensors allow for dividing the DHW storage tank into various zones, ensuring better adaptation to usage. This reduces heat losses in the storage tank. Lower return temperature can be achieved through a reduction in the supply volume. These are required for condensing boilers, heat pumps, and district heating substations and save energy.

○ Control of DHW storage temperature, varying seasonally: with heat generation or integrated electric heating

- Automatic selected control with charging pump on/off or electric heating and charging time release - Generator is shut down automatically during non-heating periods and electric heating is released. Just the opposite during heating periods. This increases the level of use for the heat generator. If the DHW temperature drops below a certain reduced level, recharging takes place even without a time-based release;
- Automatic selected control with charging pump on/off or electric heating, charging time release and demand-oriented supply or multi-sensor storage management - Demand-controlled supply temperature reduces heat losses in generation and distribution. The supply temperature can be matched to the DHW storage tank temperature and increased as needed. Spreading the load over time (e.g. heating circuits) lowers the maximum output for generation: Generation can be operated in an optimum part load range and efficiency;
- Automatic selected control with heat generation, demand oriented supply and return temperature control or electric heating, charging time release and multi-sensor storage management - Multi sensors allow for dividing the DHW storage tank into various zones, ensuring better adaptation to usage. This reduces heat losses in the storage tank. Lower return temperatures can be achieved through a reduction in the supply volume. This is required for condensing boilers, heat pumps, and district heating substations and saves energy.

○ Control of DHW storage temperature with solar collector and heat generation

- Automatic control of solar storage charge (Prio. 1) and supplementary storage charge - The solar collector can recharge any amount of freely available energy up to the maximum DHW storage tank temperature so that the maximum possible share of solar energy is used. Heat generation only supplements the required energy amount to ensure a sufficient DHW temperature at any time.
- Automatic control of solar storage charge (Prio. 1) and supplementary storage charge and demand-oriented supply or multi-sensor storage management - Solar storage tank charging has the highest priority. The remaining, required coverage is provided by the heat generator via demand-controlled supply temperatures, thus reducing heat losses in generation and distribution. Multi sensors allow for dividing the DHW storage tank into various zones, ensuring better adaptation to usage. This reduces heat losses in the storage tank;
- Automatic control of solar storage charge (Prio. 1) and supplementary storage charge, demand-oriented supply, return temperature control and multi-sensor storage management - Solar storage tank charging has the highest priority. The remaining, required coverage is provided by the heat generator via demand-controlled supply temperatures, thus reducing heat losses in generation and distribution. Lower return temperature can be achieved through a reduction in the supply volume flow. This is required for condensing boilers, heat pumps, and district heating substations and saves energy. Storage tank management is optimized to use only heats storage tank zones required for the respective demand. This reduces heat losses in the storage tank.

○ Control of DHW circulation pump

- With time switch program - Heat losses in hot water circulation are limited to primary occupancy periods;
- Demand-oriented control - Heat losses in hot water circulation are limited to current occupancy periods. Use can be determined using consumption measurement or acquiring the circulation temperature. The windshield washer function (periodic pump run, measuring circulation temperature, deciding on whether a pump run is needed) can also be used to determine use.

• **Cooling control**[8]

○ Emission control

- Central automatic control;
- Advanced central automatic control - Using different setpoints for heating

[8] In general, similar advantages as from heating control. Some differences are pointed out depending on the control mode.

and cooling (e.g. through the use of a setpoint range for the flow temperature) can prevent unnecessary overheating or undercooling. Additional energy can be saved by compensating for known heat gains in the building (e.g. by adjusting the flow temperatures over the weekend in office buildings – if there are no internal heat gains). Within a specified outside temperature range (transition period), the changeover between heating and cooling occurs (indirectly) based on heat gains in the building. This may enhance comfort and automate operation (no need for the operator to manually change over);

- Advanced central automatic control with intermittent operation and/or room temperature feedback control - Even more electricity can be saved through the pump cycling. In addition, the switch-on phases can be executed in some cases if energy efficiency can be gained or at times when energy is available at lower rates (e.g. cooling at night at lower outside temperatures or at lower electricity rates). Heat gains can be used to save energy through the use of room temperature control in a reference room by readjusting the flow temperature setpoint. Room temperature control automates the compensation of additional or missing heat gains and if required corrects incorrectly set weather-compensated control in a restricted range;
- Individual room control;
- Individual room control with communication;
- Individual room control with communication and presence control.

- Control of distribution network cold water temperature (supply or return)
  - Outside temperature compensated control;
  - Demand based control.
- Control of distribution pumps in networks
  - On off control;
  - Multi-stage control;
  - Variable speed pump control.
- Intermittent control of emission and/or distribution
  - Automatic control with fixed time program;
  - Automatic control with optimum start/stop;
  - Automatic control with demand evaluation.
- Interlock between heating and cooling control of emission and/or distribution
  - Partial interlock (dependant of the HVAC system) - The outside temperature-dependent generation setpoints for heating and cooling can prevent – to some extent – that room temperature controllers used in connection with terminal units reheat in the summer or recool in the winter. The more apart the setpoints of all individual room controllers for heating and cooling (large neutral zones), the more efficiently provisioning can be locked;
  - Total interlock - A complete lock (e.g. a room temperature sequence controller) prevents any energy absorption in the individual room. The demand-dependent setpoints for heating and cooling from the rooms can prevent that the room temperature controllers used in connection with terminal units reheat in the summer or recool in the winter. The more apart the setpoints of all individual room controllers for heating and cooling (large neutral zones), the more efficiently provisioning can be locked.
- Different generator control
  - Variable temperature control depending on outdoor temperature;
  - Variable temperature control depending on the load.
- Sequencing of different generators
  - Priorities only based on loads;
  - Priorities based on loads and demand;
  - Priorities based on generator efficiency.

- **Ventilation and air conditioning control**
  - Air flow control at the room level
    - Time control - Air flow for the maximum load in the room is used up during nominal occupancy times, resulting in significant energy losses under part load conditions in the room;
    - Presence control - Air flow for the maximum load in the room is only used up during current occupancy times. Energy losses under part load conditions in the room are reduced to actual occupancy;
    - Demand control - Air flow in the room controlled by an air quality sensor, for example, ensuring air quality at lower energy for air handling and distribution.
  - Air flow or pressure control at the air handler level
    - On off time control - Air handling unit supplies air flow for a maximum load of all;
    - Connected rooms during nominal occupancy times, still resulting in significant energy losses under part load conditions;
    - Multi-stage control - Operation at a lower speed reduces the electrical consumption of multi-speed fan motor;
    - Automatic flow or pressure control - Air flow adapts to demand of all connected consumers. Under part load conditions, electrical power is reduced at the fan in the air handling unit.
  - Heat recovery exhaust air side icing protection control
    - With defrost control - The power of the exhaust air fan needs not be increased with icing protection limitation control.

  - Heat recovery control (prevention of overheating)
    - With overheating control - Temperature sequence control at heat recovery prevents unnecessary recooling of the supply air.
  - Free mechanical cooling
    - Night cooling - During the night, heat stored in the building mass is removed by cool outdoor air until the lower limit of the comfort range is reached, reducing the use of active cooling energy during the daytime;
    - Free cooling - Reduces energy demand on active cooling of supply air. Heat recovery is opened whenever the exhaust air temperature is lower than the outside temperature. Production of chilled water with outside air has priority (favorably priced energy) as long as the outside temperature suffices for cooling;
    - H,x- directed control - Heat recovery is opened whenever exhaust air enthalpy is lower than outdoor air enthalpy, reducing energy demand on active cooling of supply air.
  - Supply air temperature control
    - Constant set point - The supply air temperature is set manually. The air is supplied to the rooms or provided for re-treatment. Temperature is increased manually as needed, but then often not reduced to correct levels. Behavior is suboptimum;
    - Variable set point with outdoor temperature compensation - Supply air temperature is controlled depending on the outside temperature (corresponding to the probable demand of the individual rooms). Individual load of all individual rooms is not, however, considered. As a result, there is no way to influence how many individual room temperature controllers reheat in the summer or recool in the winter;
    - Variable set point with load dependant compensation - Supply air temperature is controlled depending on the load in the single room plant or reference room plant (single room case). The supply air temperature is controlled depending on the largest individual load of all individual rooms. This reduces the number of individual room temperature controllers that reheat in the summer or recool in the winter (multi room case). Energy demand placed on the HVAC plant drops as the load decreases. The more apart the setpoints of all room controllers for heating and cooling (large neutral zones), the smaller the energy demand placed on the HVAC plant.
  - Humidity control
    - Dewpoint control - Control to the dewpoint requires additional energy to ensure the required inlet temperature direct humidity control;
    - Direct humidity control - Only cooled, humidified, and reheated to the extent required, resulting in lower energy consumption.

- **Lighting control**
  - Occupancy control
    - Manual on/off switch + additional sweeping extinction signal - The luminary is switched on and off with a manual switch in the room. In addition, an automatic signal automatically switches off the luminary at least once a day, typically in the evening to avoid needless operation during the night;
    - Automatic detection - Current occupancy is recorded in each area, in large rooms, hallways, etc. Then, automatic lighting control: turns on lighting in an area at the start of occupancy, reduces lighting to a maximum of 20% in the area at the end of occupancy, turns off lighting in the room 5 minutes after the end of occupancy.
  - Daylight control
    - Automatic - Automatically supplemented lighting to the incoming daylight always ensures that there is sufficient lighting at minimum energy.

BMS includes various additional functionalities that are not directly related to energy management and depend on the building purpose, i.e. its operation needs. An example of simple BMS for a residential building is presented in Figure 2.1.16 with BMS components legend given in Table 2.1.2.

Figure 2.1.16 BMS for a single building [Siemens]

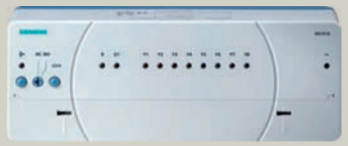
1		The heart and brain of the system. From here you can control all different functions for up to 12 rooms quickly and easily and monitor them via the display.
2		The room unit measures the room temperature and allows the settings entered into the central apartment unit, such as temperature and operating parameters, to be adjusted for individual rooms. The comfort settings can be extended at the push of a button. The room temperature sensor measures the room temperature and communicates this by radio to the central apartment unit.
3		Receives the pre-set desired temperature for this room by radio signal from the central apartment unit and regulates room temperature by adjusting the radiator valve. It can also regulate up to 5 additional radiators per room, thereby ensuring an even temperature between radiators.
4		The heating circuit controller compares the actual values and setpoints for each room communicated from the central apartment unit via RF and regulates the temperature by adjusting the valve settings of the heat distributer. The multicontroller is for precontrol of up to 2 independent hydraulic room groups (e.g. radiators, floor heating) or for control of ventilation plant with up to 3 stages.
5		The web server connects the home automation system to the internet. It allows you to access and operate the system from a remote location via smartphone, tablet or PC. With the HomeControl app from Siemens, you have an intuitive and simple control for your heating, air conditioning and ventilation system, as well as light and shading control. Alarm messages, reports and consumption data can be sent to email recipients as required.
6		The consumption data interface collects consumption data of heat/cool energy, electricity, water and gas.
7		Acquires the outside temperature and atmospheric pressure and communicates this via RF to the central apartment unit.
8		Convenient control of lighting and blinds – centrally, locally in the room, or as a scene. Naturally, the components can also be operated automatically, e.g. via time programs or simulation of presence.
9		Monitors the status of windows, doors and gates and transmits the relevant data to the central apartment unit. In the case of deviations from the norm, the system can alert you in a variety of ways. In addition, it saves energy and makes stay comfortable.
10		Supervision of laundry machine, dish washer, aquarium or any other potential source of water damage. The water monitor with detached sensor for detecting water leaks sends its status by radio to the central apartment unit in the event of a water leakage.

Table 2.1.2 BMS components [Siemens]

An important component of energy management system is the user interface, i.e. software that collects, archives, analyzes and presents the energy related parameters in order to enable performing analysis and actions towards improvement of energy performance of a monitored building(s). An interface of one of the available software is presented in Figure 2.1.18. All of the mentioned functions are available and great care is given to the graphical data processing in order to ease the analysis process. The energy management software is an important tool in the process of selecting energy performance improvement measures, i.e. preparing plans and other documents which are indispensable part of any energy management system.

The advantages of building automation solutions in terms of energy performance improvement are evident. However, since there are various solutions available on the market, it is necessary to select the solution that corresponds to the needs, taking into account the possible energy performance improvements as well as the financial aspect of BMS system installation. Therefore, in case of the buildings managed by the capital city, there is a need for feasibility study of BMS solution that would be the optimal choice. As mentioned earlier, with respect to the analyzed energy performance indicators of the buildings, there is an evident potential for energy performance improvement. However, in order to select the precise technical parameters of the needed BMS, a detailed inspection of the buildings has to be performed, and the financial feasibility analysis needs to be prepared. This inspection can be done at the same time with energy audits of the buildings, which is an obligation for all public buildings. The data from energy audits of buildings would enable reliable design of the needed BMS, as well as the financial analysis, which would result with the establishing of an energy management system.

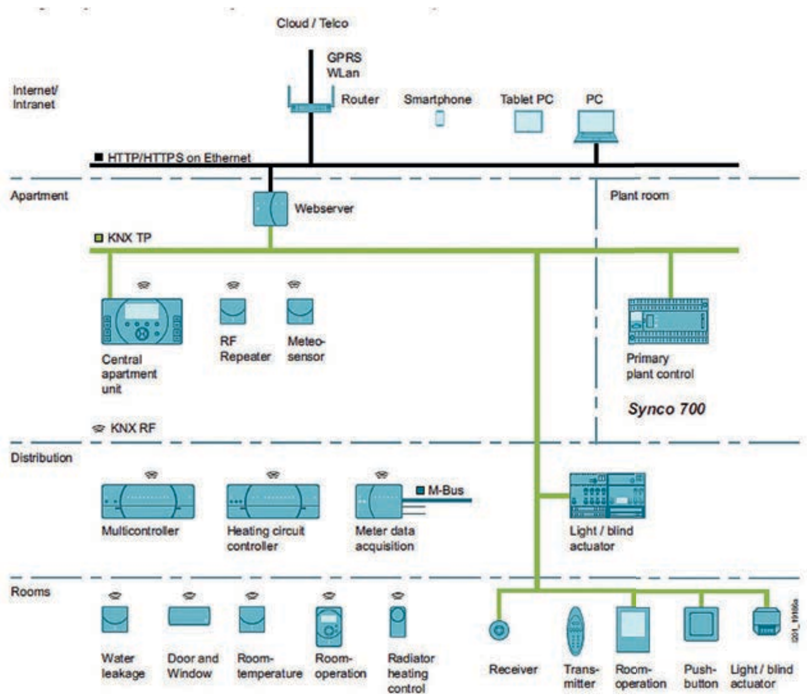


Figure 2.1.17 Communication between BMS components

Figure 2.1.18 An example of energy management software

2.1.3.3 Establishing communication with energy resources suppliers

The analysis of energy performance of an object or group of objects includes time series of data regarding energy consumption. In the absence of energy monitoring system (or energy management system), the only source of the mentioned data are energy bills. As the archiving of the bills is often not performed, the only source of data are energy suppliers. Therefore, the existence of communication link with suppliers is of the most importance for establishing energy monitoring (and management) system. Modern supplier companies rely on the modern information systems which enable simple access to energy consumption information of any client for arbitrary time period. Therefore, taking into account the flexibility of modern ICT solutions, it is possible to connect energy information system with the supplier's information system to enable simple data collection, which includes only software adjustments.

In the case of Montenegro, not all suppliers possess modern information systems. National electric company is the only supplier with the advanced information system that can provide the opportunity of interaction with energy information systems of consumers (objects, municipalities). Taking into account that electricity is the most dominant energy carrier, this opportunity should be used. As the suppliers of other energy resources in Montenegro cannot provide the mentioned service, the energy information system should rely on the own data collection possibilities. This is done through design of appropriate procedures for data collection as well as through designation of the necessary staff for the task. These procedures depend of the object in question, energy suppliers and available staff.

An example of electricity consumption data that can be obtained from electricity supplier for a large consumer is presented in Figure 2.1.19. The mentioned data can be extracted for a desired time interval, taking into account that billing is performed on monthly base. The data include all metered values that are billed (active energy, reactive energy and peak power), which is necessary for reliable consumption analysis, and as a result, for designing appropriate measures for energy performance improvement. The procedure for collecting the data from energy supplier is straight forward even in the absence of energy information system. Although, in the absence of the energy information system (and software), data preparation and processing have to be done by the staff experienced in the field.

In the case data collection is performed manually, there are some hardware and software solutions that can improve the efficiency of the process and decrease the need for the staff: installation of metering devices, data loggers, or some simple BMS systems, etc. In case that the hard copy bills are the only available energy consumption data source, there is a possibility to design a PC application that would convert the bills data into an electronic format whose use is more versatile. When the energy consumption data is available in electronic format, there are various applications for data processing (graphical presentations, trends extrapolation etc.) that are available or that can be designed in order to process the data. There are specialized softwares for energy data analyzing (Figure 2.1.18) that are available with or without the connection with energy consumption monitoring system.

Regardless whether the energy consumption data are collected manually or from the supplier, the data have to be archived in order to enable reliable energy performance analysis. The data represent the energy signature of an object that is the target of energy management. In the absence of the data (which is often the case for some energy carriers and longer past periods in Montenegro), estimations have to be made, which significantly decreases reliability of the results of planned measures for energy performance improvement. Therefore, the first step in the establishing of energy management system has to be the energy information system forming, preferably ICT based in order to enable a flexible transition towards modern energy management systems.

Datum od: 23.09.2013 Datum do: Aktivno brojilo: 97729917 Tip brojila: ZMG410CR4. Proizvođač LANDIS GYR

Reaktivno brojilo: 97729917 Obrač. konstanta: 30000 Konst. maxigrafa: 1 Prikaz aktivnih čitanja

Datum čitanja	Prethodno stanje VT	Stanje VT	Potrošnja VT	Prethodno stanje MT	Stanje MT	Potrošnja MT	Potrošnja AKT	Za obračun AKT	Prethodno stanje VTR	Stanje VTR	Prethodno stanje MTR	Stanje MTR	Potrošnja REA	Za obračun REA	Stanje max.	Ang. snaga	% gubitaka	Neoči-tan	Vrsta čit.
30.04.2015	116.173	123.44	7.267	66.177	69.756	3.579	10.846	325380	21.369	21.891	9.871	9.905	0.556	16680	0.049	1470			A
31.03.2015	115.354	116.173	0.819	65.645	66.177	0.532	1.351	40530	21.368	21.369	9.87	9.871	0.002	60	0.023	690			A
28.02.2015	115.354	115.354	0	65.645	65.645	0	0	0	21.368	21.368	9.87	9.87	0	0	0	0			A
31.01.2015	115.354	115.354	0	65.645	65.645	0	0	0	21.368	21.368	9.87	9.87	0	0	0	0			A
31.12.2014	107.672	115.354	7.682	61.134	65.645	4.511	12.193	365790	21.104	21.368	9.728	9.87	0.406	12180	0.03	900			A
30.11.2014	106.727	107.672	0.945	60.328	61.134	0.806	1.751	52530	21.095	21.104	9.727	9.728	0.01	300	0.024	720			A
31.10.2014	106.507	106.727	0.22	60.275	60.328	0.053	0.273	8190	21.095	21.095	9.726	9.727	0.001	30	0.02	600			A
30.09.2014	95.721	106.507	10.786	54.267	60.275	6.008	16.794	503820	19.11	21.095	8.789	9.726	2.922	87660	0.042	1260			A
31.08.2014	76.591	95.721	19.13	42.423	54.267	11.844	30.974	929220	13.538	19.11	5.487	8.789	8.874	266220	0.08	2400			A
31.07.2014	54.351	76.591	22.24	28.275	42.423	14.148	36.388	1091640	6.602	13.538	0.931	5.487	11.492	344760	0.129	3870			A
30.06.2014	52.284	54.351	2.067	26.919	28.275	1.356	3.423	102690	6.199	6.602	0.771	0.931	0.563	16890	0.046	1380			A
31.05.2014	46.772	52.284	5.512	24.555	26.919	2.364	7.876	236280	5.234	6.199	0.658	0.771	1.078	32340	0.052	1560			A
30.04.2014	39.094	46.772	7.678	20.199	24.555	4.356	12.034	361020	4.585	5.234	0.454	0.658	0.853	25590	0.058	1740			A
31.03.2014	32.251	39.094	6.843	16.444	20.199	3.755	10.598	317940	4.569	4.585	0.454	0.454	0.016	480	0.027	810			A
28.02.2014	25.323	32.251	6.928	12.86	16.444	3.584	10.512	315360	4.566	4.569	0.454	0.454	0.003	90	0.029	870			A
31.01.2014	22.338	25.323	2.985	11.592	12.86	1.268	4.253	127590	4.558	4.566	0.454	0.454	0.008	240	0.03	900			A
31.12.2013	13.48	22.338	8.858	6.184	11.592	5.408	14.266	427980	4.434	4.558	0.425	0.454	0.153	4590	0.055	1650			A
30.11.2013	4.925	13.48	8.555	4.255	6.184	1.929	10.484	314520	3.912	4.434	0.387	0.425	0.56	16800	0.027	810			A
31.10.2013	4.925	4.925	0	1.663	4.255	2.592	2.592	77760	3.912	3.912	0.336	0.387	0.051	1530	0.043	1290			A
30.09.2013	1.71	4.925	3.215	0	1.663	1.663	4.878	146340	3.09	3.912	0	0.336	1.158	34740	0.042	1260			A

Figure 2.1.19 An example of energy card from the database of electricity supplier

2.2 Energy efficiency potential

2.2.1 Previous note

The only form of energy that exists in unlimited quantities is energy efficiency. Any more serious national energy strategy or a local energy plan unavoidably addresses the potential of energy efficiency (EE) and renewable energy sources (RES). It is considered that increasing energy efficiency can be the cheapest and the most productive energy alternative, with practically unlimited possibilities. Rationalizing energy use can significantly contribute to stimulating innovation, employment and economic growth and reducing greenhouse gas emissions (GHG). With relatively small investments, better choice of energy-efficient technologies, better organization and quality improvement, significant energy and financial savings can be achieved.

World experience shows that energy inefficiency needs to be attacked across the whole front, from production to end consumer. In view of the complexity, in order to prepare and implement a comprehensive EE strategy and action plans, it is necessary to engage in the long-term available domestic potentials from the science and industry sectors in order to accurately identify the potentials of EE and to promote modern, highly efficient and environmentally friendly energy technologies, measures and procedures for the production and use of energy in Montenegro. The encountered challenges should be tackled with international expert and financial support. The potential of EE is huge, as energy savings are realized on the producer's side (coal, oil, gas and electricity production, transmission and distribution) as well as on the users' side (energy use in households, transport and industry).

The term EE is the most often encountered in two possible meanings, one of which refers to devices and the other to measures and behaviors. An energy efficient device is one that has a high degree of useful effect, i.e. small losses when transforming one type of energy into another. For example, "ordinary" incandescent bulbs convert a large portion of electricity into heat energy, and only small in useful light energy, and in that sense it represents an energy-inefficient device.

Consequently, constant concern about increasing EE is one of the fundamental components of sustainable development of Montenegro and a strategic goal at the national level. It is clear that in order to balance or mitigate the expected increase in energy consumption in all sectors, a decisive energy policy is needed, with emphasis on measures in the building sector (housing and commercial) and in the transport sector. From the EE point of view, a particularly high share of electricity used for space heating (over 50%) is a particularly high problem, which is the first consequence of low electricity prices over a long period of time.

A significant improvement in EE and increased use of RES is closely linked to general economy and social policies. There is a real potential for contributing to sustainable development and economic growth that can affect all areas of economic activity. In order to achieve energy goals, Montenegro must take on international obligations regarding institutional, legal and other changes. The implementation of EU norms and standards in the field of EE will have an impact on the integration of Montenegro into the EU.

2.2.2 Harmonization of Montenegrin legislation with EU in the field of energy efficiency

2.2.2.1 Basic legislation on the state level

Montenegro opened negotiating Chapter 15 - Energy in December 2015. The European Commission and the Energy Community in their reports note that the adoption of the new Law on Energy and the Law on Efficient Use of Energy in Montenegro has made some progress in the field of harmonization of Montenegrin legislation with the Third EU Energy Package. However, these institutions estimate that in order to further harmonize and implement EU energy policies, especially in the areas of EE and RES, it is necessary to complete the by-laws and establish effective mechanisms for meeting the set objectives in these areas.

The main documents and policy in the field of energy are: Energy Efficiency Strategy of the Republic of Montenegro (SEE, 2005), Energy Policy of Montenegro until 2030 (EP 2030, 2011), Energy Development Strategy of Montenegro by 2030 (SRE 2030, 2014), with the accompanying Action Plan for the period 2016-2020 (2016) and the Energy Efficiency Action Plan for 2016-2018 (APEE, 2016). The basic legislations is: Law on Efficient Use of Energy ("Official Gazette of Montenegro" No. 3/2015) and Law on Energy ("Official Gazette of Montenegro", No. 5/2016).

The indicative target of increasing EE in Montenegro from 2010 is defined at the level of 9% of the saving of the average final energy consumption by 2018. This target amount is also confirmed in the APEE in 2016. However, the new Energy Efficiency Directive 2012/27/EU3 (EED) requires from member states a compulsory savings of 20% of the average final energy consumption by 2020. The EED defines savings of 20% of the average final energy consumption by 2020, and Article 7 of this Directive defines the establishment of an EE obligatory scheme requiring all Member States, from 1 January 2017, to start to realize annual energy savings of 0.7% of total final energy consumption.

Ministerial Council of the Energy Community (EC) in October 2015 made the decision (D/2015/08/MC-EnC), which transpose of the new EED becomes obligatory for the EC Member States and therefore also for Montenegro. Since Montenegro's indicative target of 9% expires in 2018, according to the undertaken obligations under the EC membership, Montenegro has the obligation to define an indicative target after 2018 in accordance with the EED. According to the available data, Montenegro is still in the process of making a decision on the application of the EE scheme, with some modifications that would imply an objective of 0.5% savings for 2017 and 2018. and 0.7% in 2020.

Following the Law on Efficient Use of Energy as a basic legal document in this field, 17 by-laws (regulations, orders and instructions) have been adopted, which regulate more closely the respective sub-areas.

2.2.2.2 Basic legislation on the municipality level

Article 12 of the Law on Energy defines the obligation of local self-government units to plan the needs and the way of energy supply, as well as the measures for efficient use of energy, energy from RES and cogeneration, with the local energy plan. The local energy plan (LEP) that should be adopted for a period of 10 years and for the area of local self-government includes the following:

1) presentation of the situation in the energy sources supply, as well as the presentation of all types of energy production (electricity production, district heating and / or cooling systems and other types of energy production);
2) data on energy consumption, by type of energy source and sectors of activity and households;
3) data on local emissions and greenhouse gases;
4) estimation of planned energy consumption, by type of energy source and sectors of activity and households;
5) assessment of energy production possibilities;
6) assessment of the possibility of using EE measures in all sectors of activity and households, especially in the public sector;
7) assessment of the potential and possibilities of increasing the use of energy from RES;
8) assessment of the possibility of introducing a district heating and / or cooling system;
9) energy targets and indicators for their monitoring;
10) measures to achieve the set goals;
11) assessment of the financial resources needed for the implementation of the local energy plan and possible sources of financing.

The LEP must be in line with the key documents at the national level: the Energy Development Strategy, the Renewable Energy Action Plan, the Action Plan for the Development and Use of District Heating and / or Cooling and High Efficiency Cogeneration and the Energy Efficiency Action Plan. The local self-government unit is obliged, in accordance with the possibilities, to give priority to the heating and / or cooling energy from the RES in the process of urban infrastructure planning.

Also, the Law on Efficient Use of Energy, Article 11, obliges the local self-government communities to adopt energy efficiency improvement programs for their territory for a period of three years. Such a program should include:

1) Proposal of EE measures to include:
    - The plan for the adaptation and maintenance of buildings used by local self-government and public service bodies established by the local self-government, with the aim of improving EE;
    - Plans for improving the system of public utility services (public lighting, water supply, waste management, etc.) and traffic to improve EE;
    - specific EE measures in buildings that are protected as cultural property, etc;
    - other EE measures to be implemented in the area of local self-government;
2) the dynamics and the way of implementing EE measures
3) the resources necessary for the implementation of the program, the sources and way of their provision.

In January 2008, the European Commission launched a major initiative to connect mayors of European cities, that are aware of needs of sustainable energy management, in a durable network, with the aim of exchanging experiences in applying effective measures to improve energy efficiency in urban areas. The Covenant of Mayors is the first and most ambitious initiative of the European Commission aimed directly at the active involvement and continuous participation of city administrations and citizens in the fight against global warming.

By signing the Agreement, the Mayors committed themselves to the creation of the Sustainable Energy Action Plan (SEAP) that should be submitted to the European Commission for a period of one year. In accordance with this obligation, on the basis of collected information on the situation, Podgorica prepared and adopted the "Action Plan for Sustainable Use of Energy as a Resource", with the period of implementation of the Action Plan until 2020.

Also, on the basis of the obligations from the Law on Energy, the capital city has prepared and adopted "Local Energy Plan of capital city 2015 - 2025" (LEP). One of the important prerequisites for a successful implementation of the LEP is its full compliance with relevant strategic documents, national legislation and all applicable local documents.

Finally, based on the Law on Efficient Use of Energy, the Secretariat for Spatial Planning and Environmental Protection of the Capital City in 2016 prepared the "Energy Efficiency Improvement Program for the Period 2017-2019" (PPEE). One of the main goals of the Program is to establish in the coming period the energy management system in the capital city, as well as to implement measures that will influence the reduction of both energy needs and energy consumption in the future. Establishment of an integral system involves the identification of all places of energy consumption in the capital city, the creation of a database and an adequate structure that will manage energy in all facilities. These facilities not only include public buildings, but also public lighting, water supply and wastewater systems, as well as all other consumers, individual facilities, sports centers, public fountains, street billboards, traffic lights and festive lighting. Only such an approach can provide a complete insight into energy costs and give a clear overview of the effects of the measures to be applied.

The most important goal of this PPEE is to reduce annual energy and water costs by 10% - 15% by the end of 2019. It is emphasized that EU experience as well as examples from other municipalities in Montenegro show that this goal is realistic and that with the establishment of an integrated energy management system, this can be achieved without major investments. In the document, the goal is given optionally: 10% is the minimum savings that need to be made by the end of the implementation period. On the other hand, a more ambitious 15% variant, which is considered to be still realistic in PPEE, is conditioned with the moment of launching of program implementation activities.

2.2.3 Building sector

2.2.3.1 Importance and EE improvement techniques in buildings

According to the European Parliament's analysis, EU buildings account for 40% of total energy consumption and 36% of CO_2 emissions. Globally, the building sector accounts for more electricity use than any other sector, 42%. No wonder considering that we spend more than 90% of our time in buildings. Also, energy used in buildings (residential and commercial) accounts for a significant percentage of a country's total energy consumption. This percentage depends greatly on the degree of electrification, the level of urbanization, the amount of building area per capita, the prevailing climate, as well as national and local policies to promote efficiency.

With increasing urbanization, higher in developing countries, the number and size of buildings in urban areas will increase, resulting in an increased demand for electricity and other forms of energy commonly used in buildings. Investments in energy efficiency in a building can be compared with the cost of capital investments necessary on the supply side of the energy system to produce a similar amount of peak capacity or annual energy production. Usually, the capital costs of efficiency are lower than comparable investments in increased supply and there are no additional operating costs of efficiency compared to substantial operating costs for supply-side options. In addition, energy efficiency investments generally have much shorter lead times than energy supply investments, a particularly important consideration in countries where the demand for energy services is growing rapidly.

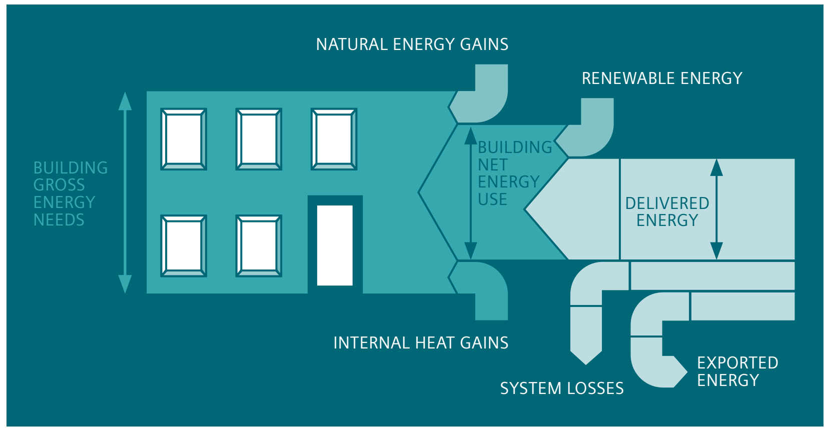


Figure 2.2.1 Typical energy flows in a building

Figure 2.2.1 illustrates the typical energy flows in a building. The building gross energy needs represent the anticipated buildings requirements for heating, lighting, cooling, ventilation, air conditioning and humidification. The indoor climate requirements, outdoor climatic conditions and the building properties (surface/transmission heat transfer and heat transfer due to air leakage) are the parameters used for determining what the gross energy needs of the building will be.

As illustrated in the diagram, delivered energy, natural energy gains and internal heat gains all contribute to providing the energy needs of a building.

Natural energy gains include passive solar heating, passive cooling, natural ventilation flow and daylight. Intelligent maximization of natural energy gains can result in significant reduction of delivered energy required to meet a building's energy needs. Environmentally smart buildings make intelligent use of energy resources, while minimizing waste.

Natural energy gains can be maximized by exploiting the potential contribution to a building's performance offered by the site and its surroundings through:

- A building plan which places functions in locations that minimize the need for applied energy;
- A shape which encourages the use of daylight and natural ventilation, and reduces heat losses;
- An orientation that takes account of the potential benefits from solar gains while reducing the risk of glare and overheating;
- Effective use of natural daylight combined with the avoidance of glare and unwanted solar gains;
- Natural ventilation wherever practical and appropriate, with mechanical ventilation and/or air conditioning used only to the extent they are actually required;
- Good levels of thermal insulation and prevention of unwanted air infiltration through the building envelope;
- Intrinsically efficient and well-controlled building services, well-matched to the building fabric and to the expected use.

This is best achieved at the building's design stage but can also be done during refurbishment.

Internal heat gain is the thermal energy from people, lighting and appliances that give off heat to the indoor environment. This is desirable in cold weather as it reduces the energy requirements for heating, in hot weather it increases the energy required for cooling. In office buildings, commercial stores, shopping centres, entertainment halls, etc. much of the overheating problem during the summer can be caused by heat produced by equipment or by a high level of artificial lighting. When there is a large number of occupants or clients, their metabolic heat can also add to the problem.

Delivered energy is the amount of energy supplied to meet a building's net energy demand i.e. to provide energy for heating, cooling, ventilation, hot water and lighting. It is usually expressed in kilowatt hours (kWh) and the main energy carriers are electricity and fuel, i.e. gas, oil or biomass for boilers. As seen in Figure 2.2.1, the delivered energy could be supplemented by on-site renewable energy, this could be in the form of solar PV, solar water heaters or wind.

Exported energy is the fraction of delivered energy that, where applicable, is sold to external users.

System losses result from the inefficiencies in transporting and converting the delivered energy, i.e. of the 100 per cent delivered energy, only 90 per cent may be used to provide the actual services, e.g. lighting, cooling or ventilation, due to the inefficiency of the equipment used.

When addressing the energy efficiency issue in buildings, the main focus is on the energy used to attain the required indoor climate standards. The amount of energy a building will be required to purchase to attain this is dependant on:

- The properties of the building:
  - The level of heat transfer: the lower the heat transfer the lower the heat loss during cold weather and heat gain during warm weather. This will reduce the energy requirements for heating or cooling;
  - Whether the building is designed to minimize the need for applied energy depending on the outdoor climatic conditions.
- How efficiently the delivered energy is used to meet the building's net energy demand i.e. the efficiency of the equipment and appliances used;
- How efficiently energy is used by people in the building;
- The percentage of the building's energy requirement that is supplied by renewable energy.

2.2.3.2 Determining a building's energy performance

The calculation of energy use in buildings is based on the characteristics of the building and its installed equipment. It is structured in three levels as illustrated below (Figure 2.2.2), and the calculation is performed from the bottom-up.

Step One is the calculation of the building's net energy requirements, i.e. the amount of energy required to provide the indoor climate requirements as specified by the building code. The calculation is used to determine the net energy required based on the outdoor climate and indoor climate requirements while considering the contributions from internal gains, solar gains and natural lighting and losses due to building properties, i.e. heat transmission and airflows (air infiltration and exfiltration). This calculation is used to determine the intrinsic energy performance of the building.

Step Two is the determination of the building's delivered energy, i.e. the energy performance of the building in actual use. This is the amount of energy used for heating, cooling, hot water, lighting, ventilation systems, inclusive of controls and building automation, and includes the auxiliary

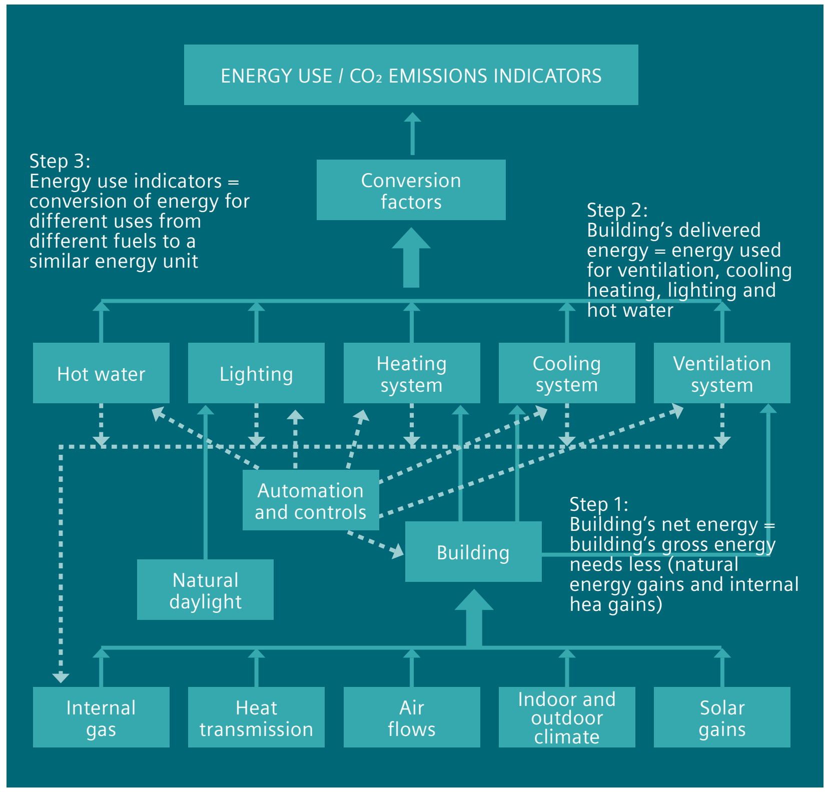


Figure 2.2.2 Overview of the process of calculating energy consumption indicators for buildings

energy needed for fans, pumps, etc. Energy used for different purposes and by different fuels is recorded.

Step Three is the determination of the overall energy performance indicators: It combines the results from Step 2 above for different purposes and from different fuels to obtain the overall energy use and associated performance indicators. Since a building can use more than one fuel (e.g. gas and electricity), the different energy sources have to be converted and combined in terms of primary energy to provide the optional end result of the calculation of energy performance. Commonly used energy indicators for buildings are kWh/m² (energy consumption in kilowatt hours per square meter of floor area) or CO_2 emissions.

It is the government's responsibility to provide, at national or local level, calculation guidelines and methodologies for determining energy performance. In most instances, software is developed for these calculations.

The general framework for the calculation of EE buildings is defined by the Directive 2010/31 / EU of the European Parliament and the Council on Energy Efficiency of Buildings (recast) as well as a methodology that takes into account the following aspects:

(a) the following actual thermal characteristics of the building including its internal partitions:
  (i) thermal capacity;
  (ii) insulation;
  (iii) passive heating;
  (iv) cooling elements; and
  (v) thermal bridges;

(b) heating installation and hot water supply, including their insulation characteristics;

(c) air-conditioning installations;

(d) natural and mechanical ventilation which may include air-tightness;

(e) built-in lighting installation (mainly in the non-residential sector);

(f) the design, positioning and orientation of the building, including outdoor climate;

(g) passive solar systems and solar protection;

(h) indoor climatic conditions, including the designed indoor climate;

(i) internal loads.

The positive influence of the following aspects shall, where relevant in the calculation, be taken into account:

(a) local solar exposure conditions, active solar systems and other heating and electricity systems based on energy from renewable sources;

(b) electricity produced by cogeneration;

(c) district or block heating and cooling systems;

(d) natural lighting.

Therefore, the improvement of EE in buildings means a continuous and wide range of activities, which is the ultimate goal of reducing the consumption of all types of energy with the same or better conditions in the facility. As a result of the reduction of the consumption of fossil fuels due to EE measures and the use of OIEs, there is a reduction in the emission of harmful gases (CO_2, etc.) which contributes to the protection of the natural environment, the reduction of global warming and the sustainable development of the country. Because of the long lifespan of buildings, their impact on the environment in which we live is long and uninterrupted and cannot be neglected. Satisfying 5E forms: Energy-Economy-Ecology-Efficiency-Education is a new challenging goal set before planners, designers and builders.

Low-energy buildings and "almost zero energy buildings"[9] (NZEB) can make a significant contribution to saving energy and reducing GHG emissions. Therefore, the EU adopted the 2010 Directive on Energy Performance of Buildings and the 2012 Energy Efficiency Directive, which state that all public buildings by 2018 and all new buildings by 2020 must be near zero energy. The regulations clearly point out that smart initiatives have to incorporate more 'smart grid' technologies and technical automation processes into existing infrastructure. From a sociological standpoint it is necessary to spread holistic and sustainable systems thinking through the different layers of society. This requires a critical discussion of sustainable development and innovation itself, and how theoretically viable concepts can be realized in practice.

[9] "Nearly zero energy building" or "energy-neutral building" is a building with a very high EE. A large share of energy required should be covered from renewable sources, including energy produced at the site of the building or nearby.

To achieve NZEB and deep renovation uptake on a large scale, two particular requirements have been identified as vital: firstly, insight and understanding of the attitudes and motives of building owners and investors, and secondly, the availability of suitable finance. Regarding the motives and decision making processes of these parties, energy efficiency is not often the main argument and there are different perspectives from different stakeholders. Thus, there is a need for information to be configured in a versatile way for different decision makers. For building owners, it may be an overall upgrading of building quality and asset value, improved productivity or comfort, while for governments it may be employment content or health benefits, as well as climate policy advancement. A useful illustration of the multiple benefits of energy efficiency is given in (Figure 2.2.3).

2.2.3.3 Building management systems (BMS) and Siemens Desigo CC platform for building management

As can be seen from Figure 2.2.2, one consistent quality in the building sector is that it is subject to a high degree of regulation. Building codes often influence material use and appliance standards that have a significant effect on energy efficiency. Regulatory regimes, to the extent that they exist, may therefore provide a pathway to improve efficiency for both building construction and a variety of building appliances.

A large number of buildings can be monitored continuously, with reports generated automatically when certain conditions are detected. More recently there has been interest in building management systems (BMS) as another means of continuously collecting data about system performance. European Standard EN15232:2012 was created to establish conventions and methods for estimating the impact of building automation and control systems on energy performance and energy use in buildings. A building control assessment scheme implementing EN15232:2012 and a rating label has been developed by the trade association (eu.bac) to facilitate this. The assessment scheme and label are concerned with control capability rather than measured energy performance of systems and buildings, but they may have a role to play in determining how relevant data can be captured and transmitted to automatic monitoring schemes for continuing long-term analysis.

The increasingly wide use of BMS may be the key to further progress, though standard data formats and transmission protocols will have to be agreed to ensure interoperability between devices and equipment from different manufacturers and the networks infrastructure.

Today's buildings are becoming increasingly complex, and the need to integrate dissimilar systems into a comprehensive platform is growing. Desigo CC is the latest building management platform from Siemens (Figure 2.2.4).

Desigo CC is based on a SCADA platform, making it fully compliant with BACnet Advanced Operator Workstation (B-AWS) and enabling integration from single to multiple building disciplines, such as building management – heating, ventilation and air conditioning, lighting and shading – up to fire safety and security. Its extensible driver concept allows integration through BACnet or other protocols. As a building management platform, it is certified to fulfill the highest possible BACnet profile B-AWS. Thanks to its extensive scalability, the platform is an ideal choice for medium and large commercial buildings as well as large, distributed building complexes and campus infrastructures. Desigo CC can grow along with building management requirements as well as integrate successive additional disciplines.

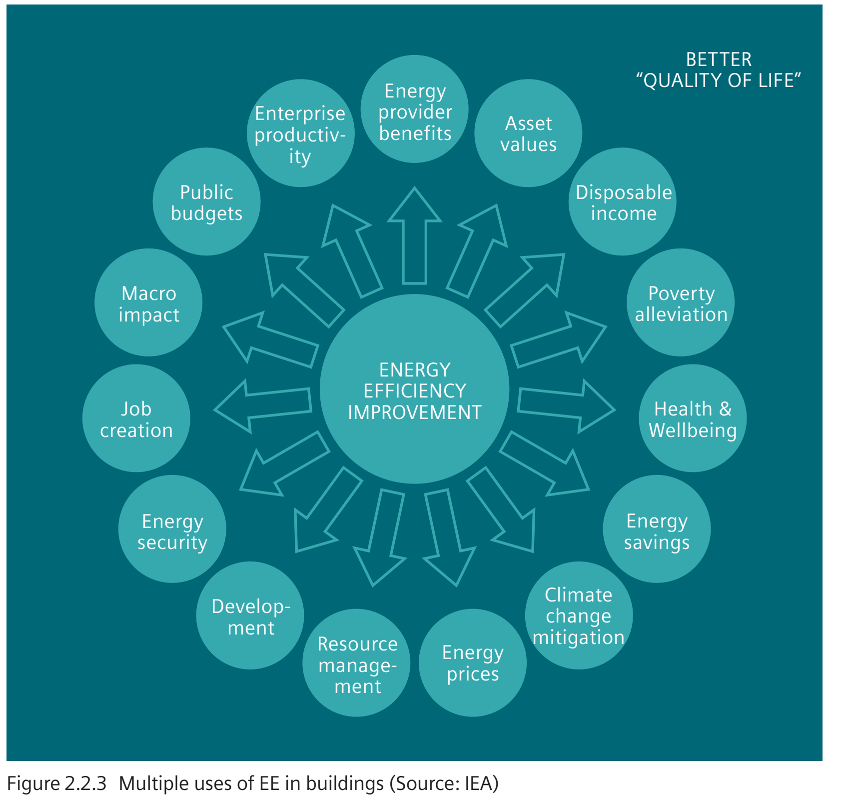


Figure 2.2.3 Multiple uses of EE in buildings (Source: IEA)

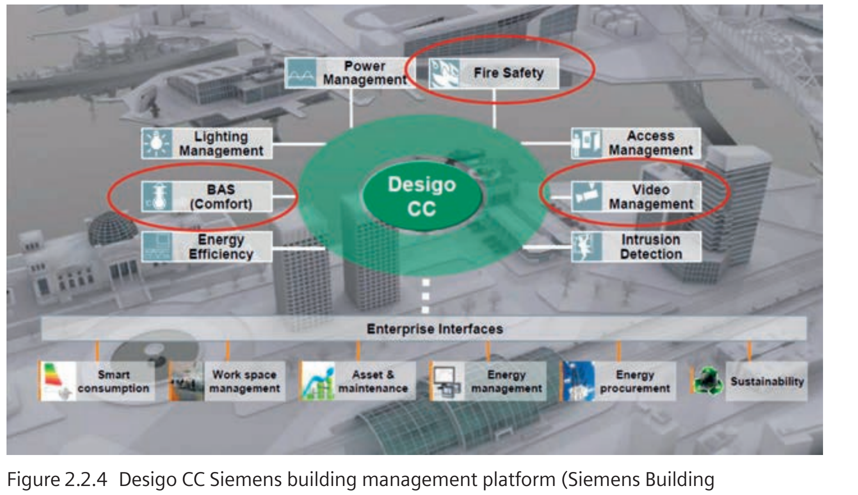


Figure 2.2.4 Desigo CC Siemens building management platform (Siemens Building Technologies - Outlook 2015)

2.2.3.4 Energy consumption of the capital city of Podgorica

According to the LEP, the energy balance and corresponding CO_2 emissions include building, traffic, public lighting, water and sewage and industry sectors (without KAP). Results of data processing for energy consumption of the sector by energy products for 2012 are shown in the following table (Table 2.2.1) and figure (Figure 2.2.5).

In the energy balance two sectors are dominant: building (53.11%) and traffic (44.63%), and among energy products: diesel (gas and diesel) with 42.05%, followed by electricity with 38.28% and heating wood with 18.22%. This indicates that, if KAP is excluded, the greatest potential of EE is in building and transport sectors. The share of other fuels (LPG and fuel oil) in consumption is considerably less and their amount is under 1.5%.

2.2.3.5 Estimation of EE potential in building sector of the capital city

For the purpose of the calculation EE in building sector, according to Directive 2010/31 / EU of the European Parliament and the Council on Energy Performance Buildings (EPBD-Recast), buildings are classified into the following categories:

a) single-family houses of different types;

b) apartment blocks;

c) offices;

d) educational buildings;

e) hospitals;

f) hotels and restaurants;

g) sports facilities;

h) wholesale and retail trade services buildings;

i) other types of energy-consuming buildings.

For the consideration of various aspects in determination of the energy performance of buildings, the following categories are recognized in the LEP of the capital city (2015):

1. Buildings used by the city administration;
2. Buildings used by city enterprises;
3. Buildings used by local authorities;
4. Buildings used for the needs of institutions in the sphere of culture;
5. Buildings for sporting activities;
6. Other buildings and premises owned by the city;
7. Residential buildings and business premises;
8. Residential buildings - households.

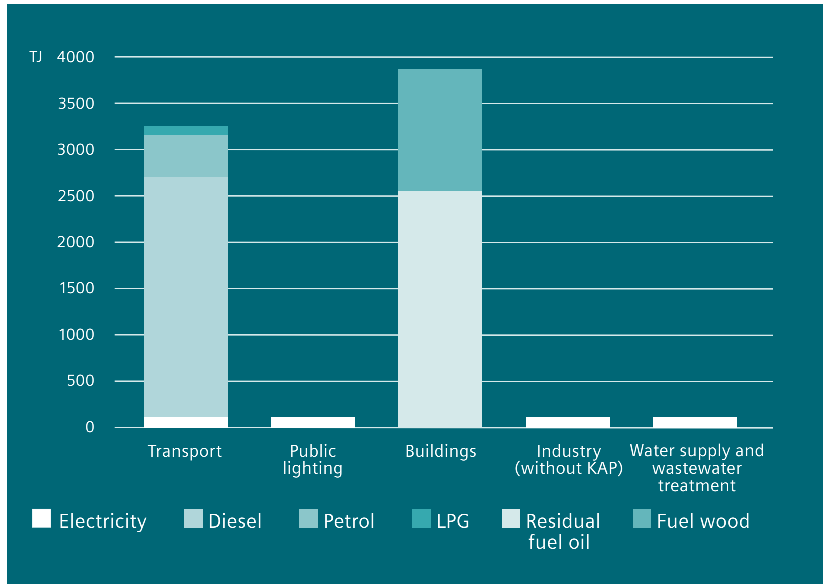


Figure 2.2.5 Energy consumption in the capital city by sector and energy (without KAP) 2012

Energy carrier	Transport	Public lighting	Buildings	Industry (without KAP)	Water supply and waste water treatment	Total per energy carriers (TJ)	%
Diesel	2.571,98					2.571,98	35.72 %
Petrol	455,68					455,68	6,33 %
LPG	104,52					104,52	1,45 %
Electricity	81,03	45,24	2.511,77	64,04	53,89	2.755,97	38,28 %
Residual fuel oil			0,52			0,52	0,01 %
Fuel wood			1.311,71			1.311,71	18,22 %
Total	**3.213,21**	**45,24**	**3.824,01**	**64,04**	**53,89**	**7.200,39**	**100 %**
Sectorial share	**44,63 %**	**0,63 %**	**53,11 %**	**0,89 %**	**0,75 %**	**100 %**	

Table 2.2.1 Energy consumption by sectors of the capital city 2012 (TJ)

This division is incomplete because it has not included a significant number of facilities of international institutions and representative offices, state-owned buildings (Parliament, Government and line ministries, judicial authorities, departments, directorates, agencies, funds, army, etc.) that are also located in the territory of the capital city. Only after providing data on the areas, age and energy consumption of the facilities of these categories it will be possible to evaluate the potential of EE in the building sector of the capital city.

In the period 1991-2011, the number of dwellings in the municipality almost doubled. By far the strongest increase was recorded by the area of GUP, where a large number of newly built housing blocks developed. The number of apartments in the city suburban area has also increased, among other things, due to the formation of informal settlements.

According to the 2011 Census, the use of housing facilities has the following distribution (Figure 2.2.6):

- There are 56 249, or 77,02%, accommodation facilities for dwelling, as follows:
  - Housing in apartments 55 721, or 76.30% of the total number of facilities;
  - Housing with activities 272, or 0.37%;
  - Facilities for performing activities 256, or 0.35%.
- There are 12 698, or 17.39% uninhabited housing facilities, as follows:
  - Temporarily uninhabited 11,937, or 16.34% of the total number of objects
  - Abandoned 761, or 1.04%
- There are 3 754, or 5.14% temporary facilities, as follows:
  - Cottage house 2 289, or 3.13% of the total number of facilities;
  - Family homes 1 452, or 1.99%;
  - Another type of building 13, or 0.02%;
  - There are no data for the remaining 332 or 0.45% of objects.

a. Potential of EE in households

We will begin this analysis for the category of household that is tightly linked to the building, and it has the greatest potential for improving the EE. If KAP is excluded, the building sector participates with around 35% in the energy balance of the capital city. In the LEP of the Capital City for Energy Consumption in the household category, data for 2012 are used. The total number of objects for permanent dwellings in 2012 was 68 346 with an area of 5 084 597 m². The average area of the apartment is 74.4 m². According to Montenegrin Electric Enterprise data, 57 346 households consumed 452 501 843 kWh of electricity in 2012. The highest consumption was recorded in winter months (maximum in February 51 185 562 kWh), and the smallest in May and September, in the months when there was no heating and cooling of space (Figure 2.2.7).

As an additional energy source, 29 463 households (51.4%) have used wood for heating in 2012., in the total amount of 142,685.56 m³. Of this, in urban settlements, 21 593 households (0.73% of the number of households use wood for heating) have consumed 102 136,14 m³. In addition to the wood for heating, a small percentage of households (about 1%) use as supplementary energy LPG and fuel oil.

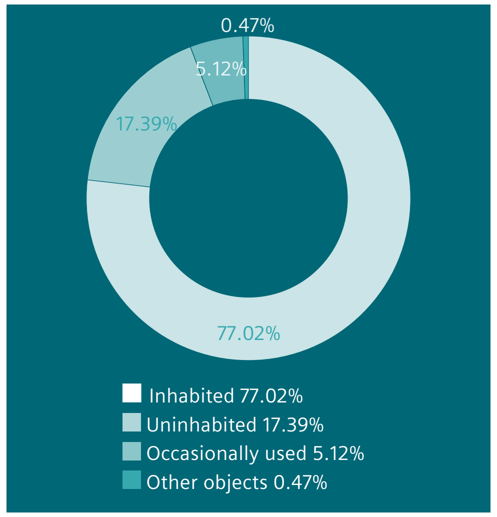


Figure 2.2.6 Overview of the use of residential facilities 2011

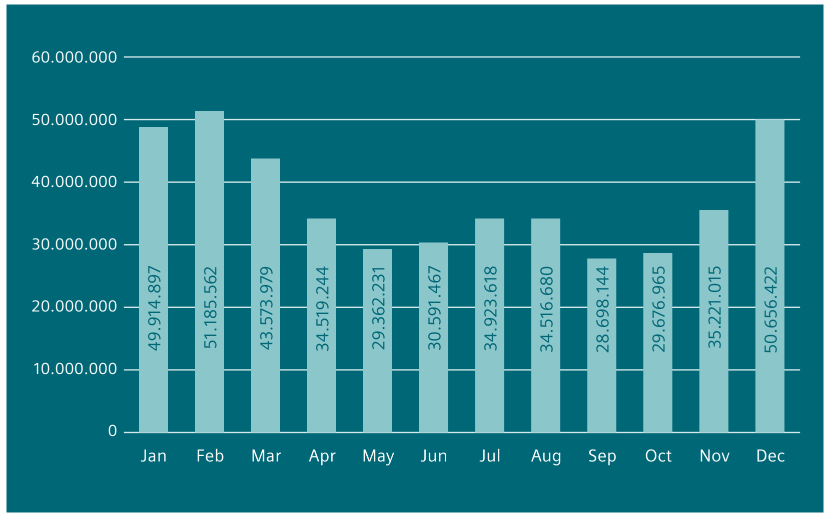


Figure 2.2.7 Total energy consumption in households in 2012 (kWh)

The following table (Table 2.2.2) gives an overview of the total energy consumption in households.

Taking into account the tables (Table 2.2.1 and Table 2.2.2), households in energy consumption participate with 76.8%. If a total residential area of 5 084 597 m² is taken, it follows that the average specific energy consumption in the household category is 160.5 kWh / m² / year. Both data from this analysis on specific energy consumption in kWh / household and kWh / m² / year testify to the significant potential of EE in existing housing facilities. For estimation of EE potential, data on the age of permanently inhabited housing are also relevant. Using data from the MONSTAT statistics office, the data from the 2011 census on the number and total areas of permanently occupied housing units by construction periods from 1919 to 2011 are presented in table (Table 2.2.3).

From the table (Table 2.2.3) it is obvious that up to the year of 1980, 30 300, or about 45% of housing units were built. However, according to the available data of the Real Estate Directorate, 16 382 objects in cadastral municipalities in the territory of the capital city - Podgorica, which were built contrary to the law, were entered in the evidence of Real Estate Directorate. The total area of these facilities is 1 285 665 m², or an average of 78.48 m² per object. Out of the above number, 15 187 objects were completed, with the total area of these facilities of 1 984 061 m², or an average of 130.64 m² per object. Bearing in mind the fact that the competent Real Estate Directorate in the previous period made the registration of the objects most often at the request of the party, it is expected that the number of illegal buildings in the territory of the capital city will be higher than the above. The following figure shows the areas of illegal construction (Figure 2.2.8).

Parameter	Value
Number of households	57.346
Total electricity consumption energy (kWh)	452.501.843
Specific electricity (kWh / household)	7.891
Heating energy from wood	363.705.492
Specific energy of fires. wood (kWh / household)	6.342,6
Total (kWh / year)	816.207.335
Specific total (kWh / household / year)	14.233,6

Table 2.2.2 Overview of energy consumption in households (kWh)

Podgorica	Dwellings built				
	Until 1919	1920-1945	1946-1960	1961-1970	1971-1980
Number	1.430	924	6.016	8.469	13.461
Area (m²)	88.901	62.677	363.851	544.878	1.028.062
	1981-1990	1991-2000	2001-2011	Unknown year of construction	Unfinished but habitated dwellings
Number	11.614	9.561	15.332	1.538	1
Area (m²)	942.392	822.252	1.130.332	101.208	44
		Total			
		Number	**68.346**		
		Area (m²)	**5.084.597**		

Table 2.2.3 Dwellings for permanent living by year of construction and area, census 2011

However, the number of informal facilities is considerably higher than the data provided by the Real Estate Directorate, especially taking into account the fact that a significant number of informal facilities are not registered in the Real Estate Evidence. Also, it is not known how many illegal buildings were built before and after 1980, but it can be assumed that at least 50% were raised during the transition after 1990. It can also be assumed that a significant number of illegal buildings are energetically inefficient, and they can also be treated as if they were built before 1980.

As already mentioned, the main potential of energy savings in buildings is the thermal insulation of buildings. Insufficient thermal insulation leads to increased heat losses in winter, cold peripheral structures, damage caused by condensation (humidity) and overheating of the area during the summer. Consequences are damage to the structure, uncomfortable and unhealthy housing and work, increasing the cost of using and maintaining space and increasing environmental pollution. Thus, due to the construction method and the lack of and failure to comply with the regulations on thermal protection, during the period of the largest housing construction from 1950 to 1980, a series of residential and non-residential buildings with an average energy consumption of heating exceeding 200 kWh / m² / year were built. The average old buildings consume 200-300 kWh / m² / year of energy for heating, standardly insulated buildings under 100, modern low-energy buildings below 40, and passive buildings and "almost zero consumption" buildings 15 kWh / m² / year. It means that energy consumed in a standardly isolated house today can heat up to 3 to 4 low-energy, or 8 to 10 passive houses. The average energy for residential buildings in the EU is 138 kWh / m² / year.

Buildings built before 1970 were built in the period when new materials, static lighter and thinner structures appeared, and at the same time in the period of cheap energy and lack of regulations on the need for their thermal protection. Today such buildings are large energy consumers and do not meet the modern tendencies of reducing energy consumption in them, in order to achieve greater comfort, more pleasant and healthier stay, and environmental protection and reduction of climate change.

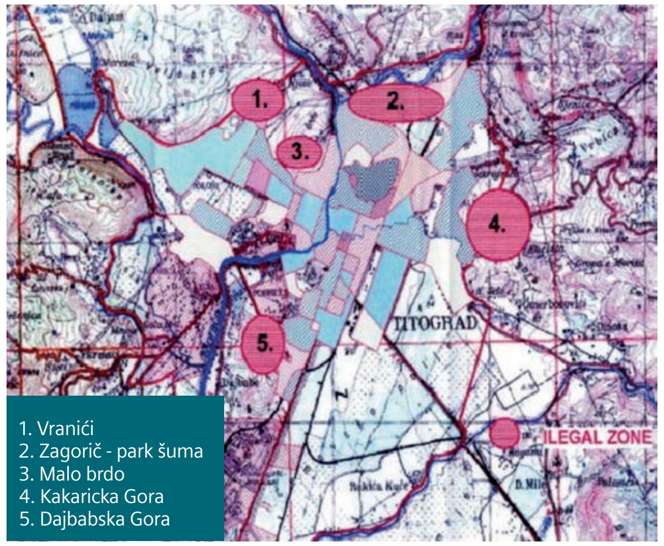


Figure 2.2.8 Critical areas of illegal construction

Even 70% - 80% of housing and non-residential buildings, built after the adoption of technical conditions in terms of thermal protection within the standard JUS U. J5. 600 from 1987, can be considered to have unsatisfactory thermal protection, with an average energy consumption for heating the space from 200 to 250 kWh / m². With the growing presence of refrigeration units in recent decades, the problem of thermal insulation of buildings is equally related to space cooling. In essence, the rapid development of the market, the economy, penetration and the influence of capital leave a trace on architectural realizations that are often of doubtful quality and without an energy concept. However, in recent years, there has been a practice of installing external thermal insulation on buildings as well as windows with better thermal characteristics. This is a consequence of the increased awareness of investors, buyers and tenants, as well as the implementation of the Rulebook on Minimum Energy Efficiency Requirements which is in force since 2013.

The low cost of electricity in the past in the residential sector, as well as the benefits of using electrical devices for space heating, have led to dominant use of electricity for heating the space in residential buildings, especially in urban areas. Heat pumps / air conditioners ("split systems") commonly used for heating have generally "low" performance, primarily because of their poor quality, inadequate installations and poor maintenance. Direct electric heating (heat accumulators, electric heat boilers, electric heaters) are often used to heat rooms, sometimes as the only source of heat. Electricity is also used to prepare hot water in households, especially in urban areas. Thermal solar systems are rarely used. There is usual use of conventional electric bulbs in Montenegrin households. In the summer period, there is an evident increase in electricity consumption due to the massive use of air conditioners for the needs of room cooling. In rural as well as in suburban areas, the use of wood for room heating is significant. Otherwise, as in all of Montenegro, natural gas is not available, and district heating is not developed.

As it is emphasized in the APEE 2016-2018, Montenegro has not yet finalized activities to create the conditions for certification of energy characteristics of buildings. National software for assessment and certification of energy characteristics is still not available, and there are no relevant databases of buildings in Montenegro (number, structure, ownership, construction period, construction and technical characteristics, etc.).

Under these circumstances, it is difficult to make a more precise estimate of energy savings in the household category in the shorter and longer terms. The situation further complicates the lack of up-to-date statistics on the average share of household energy consumption by purpose (heating, cooling, cooking, lighting, etc.). Otherwise, the potential of EE is different for individual purposes, so it is the largest in heating and cooling and in thermal consumers such as stoves, washing and drying machines, dishwashers, etc.

For the purposes of Illustrations, as well as some resemblance to the trends in the households of the Capital City of Podgorica, Figure 2.2.9 presents the share of individual energy needs according to US sources[10].

As shown in Figure (Figure 2.2.10), since 1980, the area of housing units in the United States grew, while the number of tenants per dwellings declined. Fewer people have more space due to factors such as higher income, smaller families and postpone of marriages.

[10] Energy efficiency trends in residential and commercial buildings, U.S. Department of Energy, October 2008

[11] The pie chart includes 4.7% of energy that is a statistical adjustment by the Energy Information Administration to reconcile two divergent data sources.

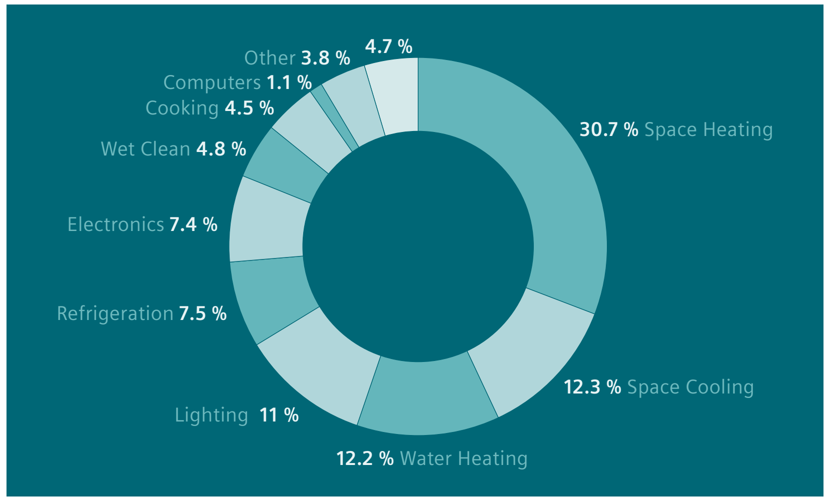


Figure 2.2.9 Residential primary energy end-use splits, 2005 [11]

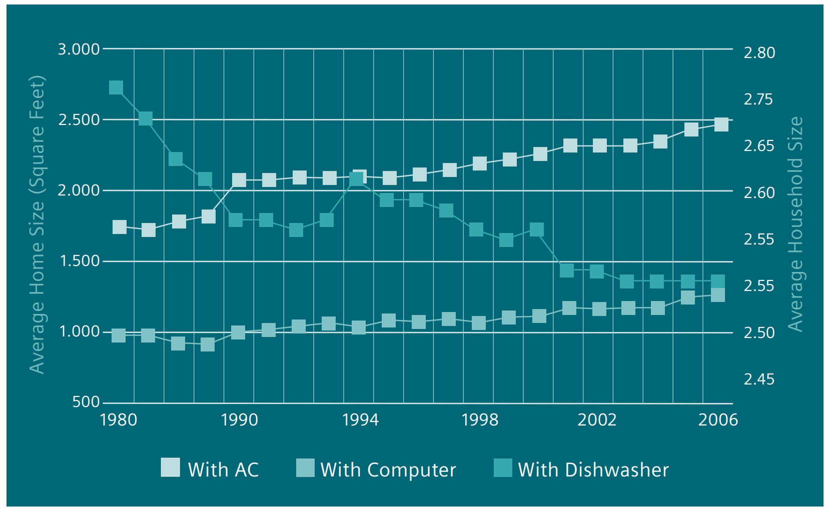


Figure 2.2.10 Average size of new dwellings and average number of persons per household

As home size grows, so does residential energy consumption, with new end uses driving much of the growth (Figure 2.2.11). Air conditioners, dishwashers, computers, televisions and small appliances are increasingly prevalent in American homes. Microwave ovens were found in 8 percent of homes in 1978; by 1997, 83 percent of households had them. Over that same period, households with air conditioning increased from 56 percent to 78 percent. Personal computers, nonexistent 25 years ago, are now almost standard in U.S. homes.

Most of the energy used in a home goes towards conditioning the space, which is often more affected by the size of the house than the number of occupants. Heating, cooling, and lighting are still the largest single energy end-uses in a home, despite increased energy efficiency of this equipment (Figure 2.2.9).

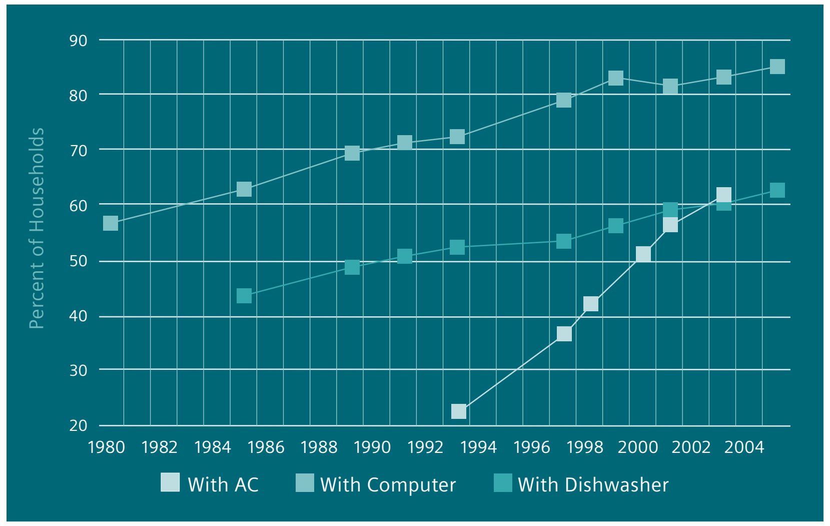


Figure 2.2.11 Market saturation for residential equipment and appliances

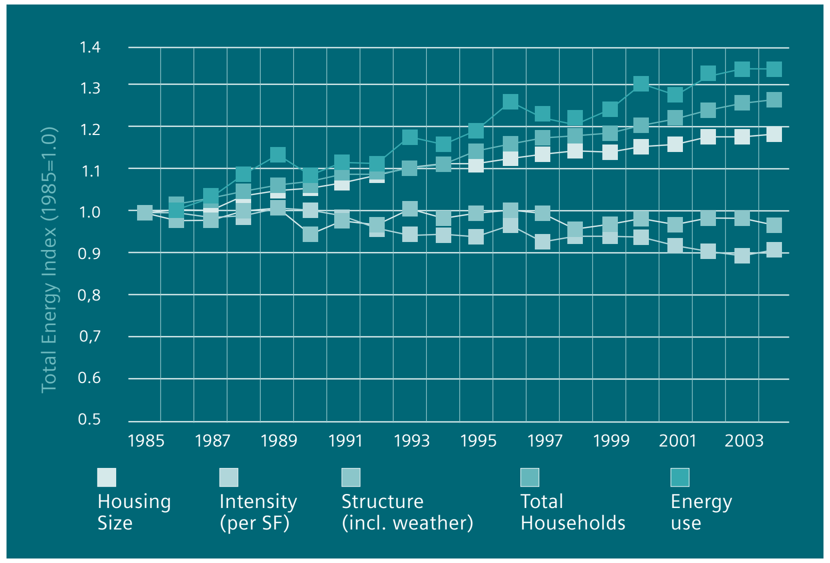


Figure 2.2.12 Energy use intensity and factors in the residential sector

Figure 2.2.12 is an index for total energy consumption, number of households, house size, a combined structural component that captures many of the "other explanatory factors," and energy intensity over the period from 1985 to 2004. The number of households increased over this period is 27.5 percent, while energy consumption increased 34 percent. Residential energy consumption, measured as total energy (i.e. including electricity losses), increased overall by about 34 percent. Consumption declined in 1990, 1997, 1998 and 2001, years of mild winter weather. The overall effect of non-efficiency-related changes has been to increase energy use by about 15.5 percent. The residential energy intensity index, based on energy use per square foot, has generally trended downward since 1985, with the greatest declines observed in the early part of the 1990s.

For a more precise assessment of EE potentials in Montenegrin households, it would be very important to conduct similar research, either for the Montenegro or at the level of the regions (southern, central and northern), and even better at the level of local self-governments.

As already pointed out, energy consumption in the building is influenced by: characteristics of the building, energy systems, i.e. heating and cooling units in the building, climatic conditions and user habits. The lack of natural gas and low, subsidized electricity prices in the past have resulted in excessive direct use of electricity for space heating and domestic water heating. Regardless of the social and economic sensitivity of this sector, rising energy prices already have affect to its more rational consumption and substitution with cheaper and more affordable energy sources. In this regard, not only energy wasted in housing and other work facilities is in scope of interest, but also the energy quality of devices used in buildings (cookers, refrigerators, water heaters, dishwashers and washing machines, etc.) and their rational use.

Of the total number of apartments for housing, based on data from the 2011 Census published by MONSTAT, 71.5% of apartments in the capital city have air conditioning systems, while 6.1% of the apartments have central heating installations, with no available data on the use of the system itself. The remaining 22.4% of the dwellings use heating wood in combination with an electrical heating device (heaters and heat accumulators). According to SEAP, the share of heating wood in the residential sub-sector was 15%, and individual heating appliances were then represented with 7.4%.

According to numerous sources, around 80% of households spend about 80% for heating and cooling space, about 14% for domestic hot water, and about 6% for total heat consumption. Also, in the balance of total consumption of households, the stated needs in the heat energy are about 80%, so it can be estimated that the energy for heating and cooling of the space is about 60-65% of the total household energy consumption. Due to the moderate Mediterranean climate, the capital city can be counted with a lower value of 60%. Also, when heating households, especially with wood, they do not heat and cool all rooms. It is realistic to assume that the living area that is heated is about 60% of the average area of the apartment in the capital city, or 44.4 m². Starting from the total household energy given in Table 2.2.2 and assumed percentage participation, it is estimated that the engaged energy for heating and cooling of residential space in the capital city is 489 724 401 kWh / year. It follows that specific energy consumption for heating and cooling in the households of the capital city is 160.5 kWh / m² / year, or about 16% above the EU average.

The first key objective of the SRE by 2030 in the field of EE households is to reduce the consumption of heating energy to the level of 80 kWh / m² of heated area from 2014, to only 15 kWh / m² after 2020 (a building with almost zero consumption), through the application of the regulations on thermal protection in new buildings. Taking into account that this is in the scope of future objects, it remains to use the stated potential of EE by consistent application of construction regulations.

The second key goal of the SRE is to rehabilitate 30% of existing housing units by 2030, with a reduction in heat losses by a rehabilitated housing unit by 60%. This would mean that 20,000 housing units will be rehabilitated in the capital city by 2030, or around 1,370 units per year from 2015. The specific energy consumption for heating and cooling the area of rehabilitated dwellings should be reduced to 64.2 kWh / m² / year. The average annual savings would be 58 577 364 kWh per year in the category of households in the capital city.

The third key objective of the SRE is to reduce the net consumption of household electricity by 150 kWh per year by 2030. This goal is based on measures of energy labeling of household appliances and other measures on the consumption side. Accordingly, the savings in electricity from non-thermal consumption in the households of the capital city, taking into account 57 346 consumers in 2012, would be 8 601 900 kWh. It is obvious that with the expected increase in the number of consumers, this amount would grow proportionally.

On the basis of the estimates presented above, the potential of EE in households in the capital city at the level of 2012 is 67 179 264 kWh / year, i.e. 8.2% of the total household energy consumption.

It is important to note that through the implementation of EE measures there is also improvement of comfort in housing objects by the fact that using the same or less energy can heat the entire living space instead of the current around 50% of the surface. However, despite the aforementioned technical rationalization capabilities, the achieved results, even in technically-technologically developed countries, are significantly below the savings potential of 50-60% in older buildings. Due to the known inertia of this sector, the success of the program for the rational use of energy in households implies long-term persistent engagement of various subjects, and primarily the citizens themselves. In fact, these are actions that should become an integral part of the lives of all people who live and work in a particular urban environment.

b. Public and commercial buildings

From the previous analysis, it can be concluded that public and commercial buildings have a share of 23.2% in the energy consumption of the building sector, which is equivalent to 243 311 750 kWh / year energy. However, apart from residential and public buildings owned by the capital city, there are no data on the share of energy sources, total areas and areas for heating and cooling for state owned buildings, foreign offices and commercial sector (shops, services, business buildings, tourist facilities, etc.). Therefore, it is impossible to estimate more accurately the potential of EE in this part of the building sector, which makes up a large number of buildings of different ages, thermal technical performance, daily and seasonal activities etc.

According to LEP data, total energy consumption (electricity, heating wood and fuel oil) of buildings owned by the capital city was 13 549 328 kWh in 2012, or 5.5% of the energy of all public and commercial buildings. The total area of 328 buildings owned by the capital city (administration, public companies, local authorities, culture, sports, housing and other facilities) is 164 969 m². The heating and cooling energy of these facilities is 7 490 196.6 kWh, or 55.3% of the total energy of the buildings owned by the capital city. Assuming that 70% of the total space is heated, the specific energy of heating and cooling the room would be 64.8 kWh / m² / year. The value obtained indicates that they are comfortable buildings of recent construction with good insulating properties. Namely, as stated above, the value of specific heating and cooling consumption should be reduced to the level of previously built dwelling buildings after their rehabilitation. However, a significant part of the commercial activities is located in previously built buildings, so the specific consumption for heating and cooling of other non-owned buildings would be above 64.8 kWh / m² / year, so it is undisputed that in this segment of construction there is a significant potential for EE.

As for households, the SRE for the commercial and public buildings sector also insists on the application of the regulations on thermal protection in new buildings, which will reduce the consumption of heat energy to a level of 80 kWh/m2 of heated area from 2014 to the level of 15 kWh/m² after 2020. Then, as a goal, the rehabilitation of two-thirds of the area of the services sector is established, to a consumption level of 70 kWh / m² to 2030, according to the situation in 2010. Finally, there is the reduction of electricity consumption for non-thermal needs up to 10% through the operation of energy agencies and ESCO companies. As noted above, certain data are missing for a more precise quantification of energy savings, which should be argued by a separate study. Considering the experience of some countries in the region, it is possible to estimate that it is possible to save at least 20%, or 48,662,350 kWh / year.

Taking into account the previously obtained assessment for households, the total savings in the building sector of the capital city (taking into account the level in 2012) would be 115,841,614 kWh / year, or 10.9% of the total energy consumption of this sector, which was 3824.01 TJ / year, or 1 062 225 000 kWh / year in 2012.

2.2.4 City lighting and traffic signalization

2.2.4.1 Modern approaches for improvement of city lighting and traffic signalization EE

Nowadays, the human need for mobility has generated the necessity of high-quality public lighting, both during the day through natural, and during the night through artificial sources of light. Quality public lighting enables us to securely carry out traffic and smoothly perform various activities, gatherings, sports, socializing and entertainment, etc. Exterior lighting can be divided into road lighting (street lighting), urban lighting (lighting of squares and pedestrian zones) and reflector lighting (lighting of facades and prestigious objects).

The basic recommendations for efficient public lighting and dynamic savings are:

- use of energy efficient light sources (advanced technologies);
- use of efficient lamps (light pollution);
- design of public lighting in accordance with the norms;
- efficient management of public lighting;
- monitoring the costs and consumption of public lighting (cadaster of lamps, tariff model selection);
- regular maintenance.

Regarding the energy efficiency of light sources, lifetime and basic photo-technical characteristics, there is a historical process of continuous improvement, as illustrated in Figure 2.2.13 and Table 2.2.4. The lamps of the classical type and modern, energy-efficient type are shown in Figure 2.2.14.

White light sources, similar to natural sunlight, such as LED (Light Emitting Diode) are increasingly used for high-quality and energy-efficient lighting. There are numerous advantages of this technology, which has been used so far in various industrial applications, mobile phones, computers, internal lighting, and in recent times, its great benefit is brought to public lighting. LED is a light semiconductor diode that emits directional light due to the effect of electroluminescence. It represents a special type of semiconductor diodes, and consists of a LED chip from semiconductor materials, cathodes and anodes, reflectors, lenses and enclosures. LED public lighting lamps consist of a small diode matrix that gradually weakens in intensity, not all at once.

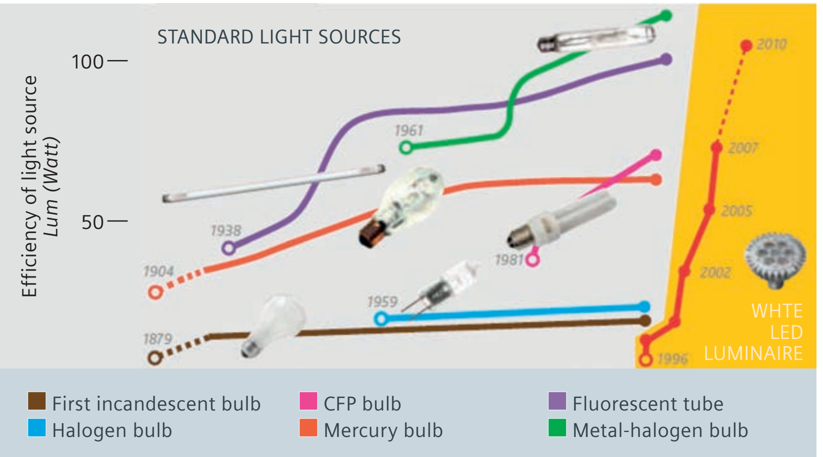


Figure 2.2.13 The efficiency of light sources[12]

[12] www.osram.hr

Bulb type	Application	Efficiency (lm/W)	Operation life (h)	Color reproduction
Fluorescent tubes	Energy saving up to 80% compared to a standard bulb; one of the most popular light sources; application in public and commercial buildings.	60-100	20.000	Good
Low pressure sodium lamp	Extremely high efficiency and relatively poor color reproduction; produced with power from 10 to 180 W; not used in new systems.	200	18.000	Bad
Mercury lamp	Used in road and industrial lighting, produced with power of 50-1000 W; will be banned in the EU due to the high content of mercury	40-60	16.000	Acceptable
Metal-halogen bulb	It is applied in a very wide area, from automotive to interior and exterior lighting; it is produced with power of 20-2000 W; it is possible to get different color temperatures	to 120	20.000	Very good
Sodium bulb	Maximum efficiency, but with poorer color reproduction (accentuated warm yellow), the best solution for road lighting	to 150	32.000	Bad

Table 2.2.4 Characteristics of light sources used for public lighting

Street lighting is a public service whose expenditures are not at all negligible. Namely, in electricity consumption, in order to illuminate the streets in some cities, up to 40% of the city budget for energy is spent. By replacing existing street lighting, LED bulbs reduce energy and maintenance costs by up to 50%. In order to take full advantage of LED lighting, these bulbs should be networked. This allows remote control and improved operation with the possibility of dimming street lighting and controlling their time of operation depending on conditions (for example, shorter/longer days). This principle of controlled networking action brings an additional 10-20% of the energy savings in addition to the savings made by the use of LED lighting alone. Networking makes it easier to detect outages, and thus reduce maintenance and repair costs with more precise dispatch. Networked LED lamps bring slightly higher investment costs, but they have more advantages and a significant benefit than just installing LED lamps.

LED lamps should be accompanied by a manufacturer's declaration on the energy efficiency class, where the classification of lamps is carried out according to the EU Regulation 874/2012, as an addition to the European Directive 2010/30/EU. It is recommended that the lamps belong to the energy class A+, which includes the highest quality LED modules and bulbs.

2.2.4.2 EE potential of capital city public lighting

Public lighting in the energy balance of the capital city took part with 45.24 TJ (i.e. with 12 568 463 kWh of electricity) in 2012, i.e. with 0.63%. The size of the EE potential of this sector in relation to the overall EE potential of the capital city is low, but it is very high in relation to its own sector consumption and, in the case of switching to networked LED technology, it can be 70-80% of present consumption. The effects of this replacement would greatly relieve the city budget and, at the same time, raise the quality and functionality of public lighting.

According to LEP data in 2012, in the public lighting system there were 22,165 lamps, 17,973 different poles and 45 semaforized intersections. As far as the bulbs in use are concerned, most of them are high-pressure sodium (Na) lamps, while mercury (Hg) bulbs are represented by 2%. The bulb structure per installed power is:

- Na high pressure bulbs - 400 W 5%;
- Na high pressure bulbs - 250 W 40%;
- Na high pressure bulb - 100 W 40%;
- Na high pressure bulb - 70 W+110W + energy saving 13%;
- Hg bulb 2%.

About 96% of the luminaires do not have the ability to control the brightness level. Only about 4% of luminaires have this possibility using two-stage ballasts (ballast with two levels) for night mode. There are no luminaires with dimming functionality.

In the public lighting system there are traffic lights that regulate traffic to a total of 45 intersections in the capital city (Figure 2.2.15). Since 2009, the complete traffic light system is based on LED technology, so their consumption is almost negligible. Also, the complete traffic light system is time-programmed. The power of traffic light bulbs ranges to about 7-8 W, so the total power along the intersection should not be greater than 150-200 W, which in terms of energy requirements is at a satisfactory level.

It should be noted that the holiday lighting that is used from December 19th to January 15th belongs to the public lighting system. Generally, modern decorations with low energy requirements (LED technology) are used, and there are over 400 units that are supplied from the distribution network of public lighting.

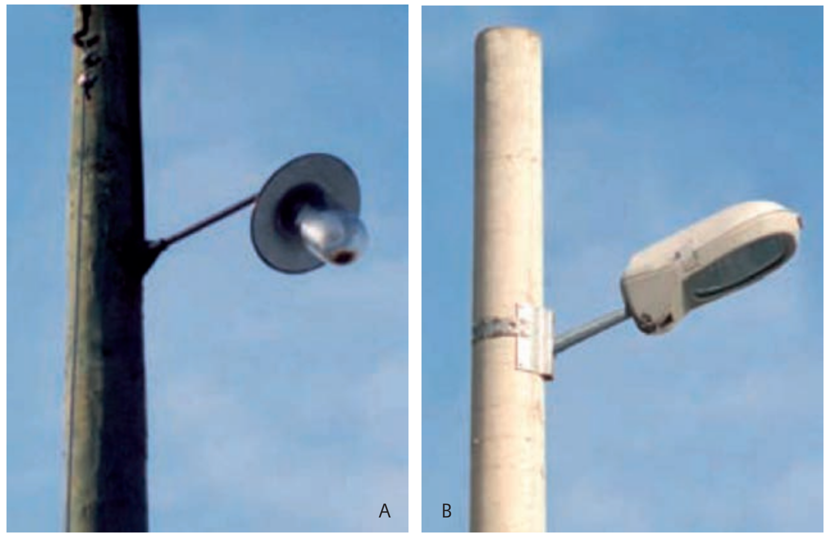


Figure 2.2.14 Classical (a) and modern, energy efficient lamp (b)

According to the planning documents, as well as this year's information from the media[13], we see a proactive local government policy in the direction of switching of the complete system of public lighting on LED technologies in the next period. By implementing this ESP-ESCO model, the capital city will save over 80% of the current consumption. From this savings, the installed luminaries will be repaid and maintained in the next twelve years. The saving in the public lighting sector would amount to about 36 TJ if calculated at the 2012 consumption level.

[13] Vijesti online, June 12, 2017, "Podgorica model" of public lighting modernization presented in Vienna, First forum on sustainability of EEC

2.2.5 Transport

2.2.5.1 Previous note

The task of determining the energy efficiency potential in the transport sector in cities is a very complex problem, with many influencing factors. It is not enough, as it often happens to us, to state the legislative framework, table out the energy consumption by type of energy sources, types and number of registered vehicles and the road infrastructure sketches. First of all, it is necessary to take into account global current trends of improving the operational and energy efficiency of transport in cities, new more efficient generation of vehicles and propulsion fuels, with smaller GHG emissions and, finally, socio-economic opportunities of the observed city. The following is a brief overview of the listed factors that impact the energy efficiency of transport in cities.

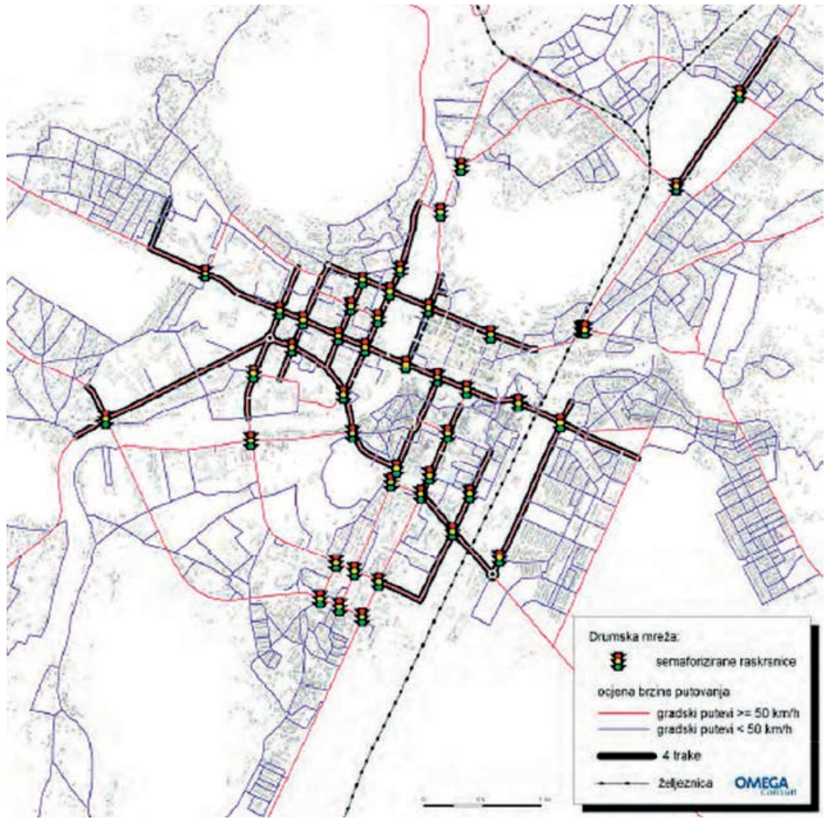


Figure 2.2.15 The network of semaforized intersections in the capital city in 2010[14]

[14] Basic study of spatial traffic development of the narrower and wider area of the capital city - Podgorica, RIKO doo, OMEGA consult d.o.o., Ljubljana, 2010

Decision makers in developing cities face the challenge of establishing sustainable urban transport systems. The pursuit of energy efficiency is a huge opportunity for achieving this goal. Not only do energy efficiency measures reduce fuel consumption, they also help us tackle other transport-related problems. Organising and operating urban transport efficiently reduces costs (for energy), and also lowers congestion, noise emissions, local air pollution, accident risks and global greenhouse gas emissions, while securing economic growth.

2.2.5.2 Transport and economy

Transport is often called the "engine" of economy. Affordable modes of freight transport allow other economic sectors to optimize the various steps in the value chain from raw materials to final products. Personal mobility offers freedom to people and allows them to optimally organise work, living and recreation, as such transport is inextricably connected to the structure of our modern society. Transport policies therefore aim to improve the mobility of people and goods as a prerequisite for further economic growth.

The transport sector in itself represents a large amount of economic activities, comprising the activities of e.g. transport companies, vehicle manufacturers, oil companies, building companies for construction and maintenance of infrastructure, and a range of supply industries and services. In some large European countries 10% of the population directly or indirectly works for the automotive industry.

Developing countries and emerging economies are experiencing a rapid increase in demand for transport energy. High rates of population growth and urbanisation are causing transport needs to expand, and the emerging middle class aspires to the use of private motor vehicles, which means fuel consumption is also escalating. It is therefore no longer a luxury but a necessity to establish an efficient transport system that meets demand, but consumes as little energy as possible. This is important as the fast and safe transportation of people and goods is a prerequisite for economic growth. Considering the challenges of climate change, limited resources, increasing energy prices, environmental pollution and health risks, it is essential that we take the right path in order to cope with the rapidly growing demand for transport.

2.2.5.3 Transport share in the global energy consumption

Currently, the global mobility of people and goods accounts for 20% of total primary energy use and 25% of energy-related CO2 emissions (IEA, 2012a). Worldwide 98% of the energy consumption by transport is based on oil. For that reason the transport sector is very dependent on the price and availability of oil. Recent years have shown that the oil price can increase to unexpected heights due to e.g. geopolitical instabilities, natural disasters and technical setbacks. Furthermore the worldwide demand for oil is increasing due to increased demand from Western countries and the rapid economic development of some Asian countries. Although worldwide oil resources are still considerable, they are much more limited than the resources of coal and gas. In any case exploitation costs of oil are expected to increase. At the same time, various analysts expect that in the next one to three decades the world-wide oil production will reach a peak ("peak oil"), with supply no longer able to meet growing demand. This is expected to lead to large fluctuations in oil price with possible negative economic consequences.

The World Energy Outlook (WEO), published each year by the IEA, provides an insight into possible future trends in energy supply and demand. For example, in their Reference Scenario (WEO 2009) the IEA describes how global energy markets will evolve if governments make no changes to their existing policies and if the trends in energy demand and supply continue. The Reference Scenario should not be seen as a forecast, as it does not include possible or likely future policy initiatives.

Average annual worldwide primary energy demand is projected to increase by 1.5% by 2030 (Figure 2.2.16). This would lead to an overall increase in energy demand of 40% between 2007 and 2030. Fossil fuels will remain the primary source of energy worldwide, while the share of renewables will only increase slowly.

The growth in energy demand will vary regionally. Over 90% of the projected increase will come from non-OECD countries. They will experience an annual increase in primary energy demand of 2.4%, whereas the OECD countries are expected to have an annual growth of 0.2%. The highest growth rates are projected for China, India, and the Middle East. Despite the higher annual increase in the demand for energy of non-OECD countries, their per-capita consumption will remain much lower than in the rest of the world.

The different sectors of end use (transport, industry, households, services, agriculture and non-energy uses) will drive the growth in demand in different ways, but transport will remain the single largest final energy consuming sector (Figure 3.2.19).

Road transport consumes approximately 70% of the energy used in the global transport system. Road passenger transport alone accounts for 50% of this energy consumption. There is close correlation between income levels and passenger light-duty vehicle (LDV) ownership, although a specific per capita income does not always result in the same ownership rate. For example, today the LDV ownership rate in the USA is higher than 700 per 1 000 people, while the highly industrialised countries of Europe have around 500 vehicles per 1 000. By contrast, in emerging countries like China and India the ownership is well below 100 per 1 000 people. In the Capital City of Podgorica LDV ownership was 291 vehicles per 1000 people in 2012.

2.2.5.4 Improvement of energy efficiency in transport sector

Energy-efficient transport offers huge potential for reducing the demand both for oil and for energy in general. The IEA estimates that advanced technologies and alternative fuels (e.g. hybrid vehicles, electric vehicles and fuell cell vehicles) can

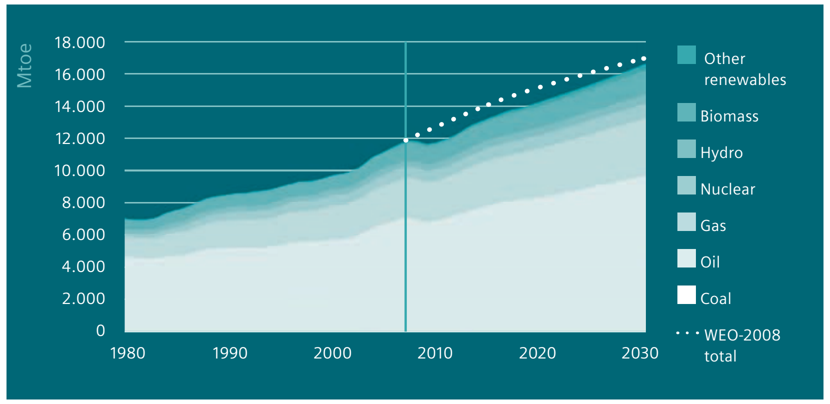


Figure 2.2.16 World primary energy demand by fuel in the Reference IEA Scenario (2009)

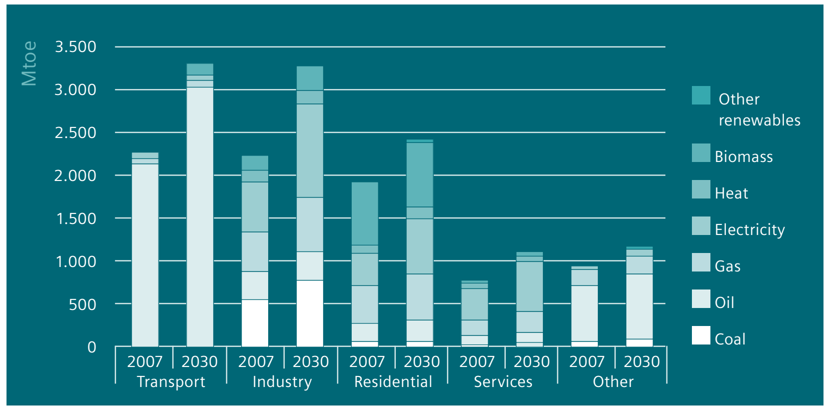


Figure 2.2.17 World final energy consumption by fuel and sector in the Reference IEA Scenario (2009)

reduce the energy intensity of transport by 20 to 40% by 2050, compared to its own Reference Scenario. Such achievements could also halve the need for fossil fuels. However, even if the energy intensity is reduced, the total energy demand is still likely to rise above current levels due to overall increase in demand for transport and motorisation. To cut future demand from the current levels, it is necessary not only that we shift to more efficient modes of transport, but also that we reduce the overall per capita demand for travel.

At the moment it is difficult to quantify the value of energy efficiency improvement and alternative fuels in relation to the issue of energy security. The economic value certainly seems larger than the avoided fuel consumption alone. In order to better balance various objectives in the formulation of new policy measures it would be advisable to develop a methodology to quantify energy security aspects in such a way that they can be made comparable to environmental indicators such as greenhouse gas abatement costs.

Improving energy efficiency means using less energy to provide the same service or level of activity, or it means getting more of a service for the same energy input. A relative reduction in energy consumption may be associated with technological changes, but it can also be achieved through better organisation and management, and through behavioural changes.

Energy-efficient transportation needs to be encouraged on three different levels. There is potential to achieve greater energy efficiency for individual vehicles (*vehicle efficiency*) and trips (*travel efficiency*), as well as the whole transport system (*system efficiency*).

Corresponding to these three levels of energy efficiency in transport, three basic strategies exist to improve energy efficiency:

- Avoiding increased transport activity and reducing the current demand for transport;
- Shifting demand to more efficient modes of transport;
- Improving the vehicles and fuels used.

These principles are summarised in the known Avoid-Shift-Improve (ASI) Approach, which provides a holistic framework for strategic action to encourage a sustainable transport system (Figure 2.2.18). Each strategy addresses a different level of energy efficiency: avoiding/reducing the demand for transport improves system efficiency; shifting demand increases travel efficiency; and improving vehicles and fuels will increase vehicle efficiency.

As Figure 2.2.18 shows, overall energy efficiency of the urban transport system results from the performance on all three levels:

Urban transport =
vehicle efficiency × travel efficiency
× system efficiency.

In the following sections, each of the tree levels is described in more detail. These sections are followed by an outline of indicators that can be used for measuring energy efficiency performance.

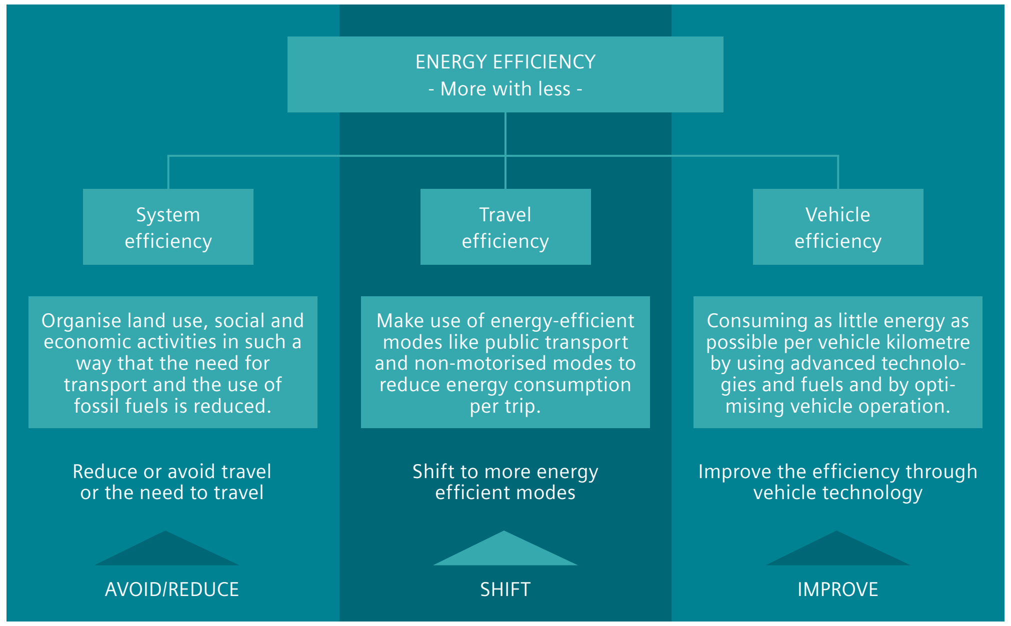


Figure 2.2.18 The ACI concept of EE in traffic

a. System efficiency - the avoid/reduce strategy

System efficiency relates to how the demand for transport and the different mode of transport are generated. Research has shown that infrastructure and city structures influence transport demand. Energy consumption per capita rises proportionally as city density falls. The reduction of traffic volume is a crucial aspect of energy efficient transport. Land-use planning should therefore optimise the positioning of settlement and production structure to avoid traffic or to reduce travel distances. A dense urban structure with mixed uses is essential for high system efficiency. It involves shorter travel distances and a model shift from road transport (which consumes an enormous amount of space) to more efficient transport modes such as walking, cycling and public transport. The prerequisites for system efficiency do not only include a dense city system, but also proper management of the demand for transport and an adequate public transport network.

Freight transport also benefits from dense city structures with short distances. Combining residential and commercial areas reduces transportation of private goods. The challenge, however, is to ensure there is sufficient space and high-quality infrastructure for modern industry. One possible solution is to locate a dense, suburban industrial area close to a freight consolidation centre. This would make it possible to consolidate cargo from/to similar sources/destinations. Outgoing and incoming freight is therefore organised and freight transport can be improved. Moreover, the bundling of deliveries to the city centre minimises pollution and noise.

Generally, to measure the success of energy efficiency strategies and to quantify the energy saving achieved, it is necessary to use several indicators, which together describe the performance of the transport system at all tree levels of efficiency. Most indicators are based on local statistics, or they require passenger and household surveys. Limited data availability often impedes proper planning or adequate evaluation energy efficiency potential and corresponding measures.

As already pointed out, the traffic volume generated and the system efficiency of a city are closely connected. Travel activity is influenced not only by the urban structure, but also by economic, cultural or behavioural factors. Nevertheless, planning decisions have a significant effect on traffic volume and the efficiency of the system.

- Because energy consumption is directly related to traffic volume, a key indicator for evaluating system efficiency is the per capita annual passenger-km. This is calculated by dividing the amount of total distances travelled in a given period by the number of people who travelled. For instance, in 2006, in Germany approximately 15 000 km per capita were travelled in urban, interurban and rural areas, while in China the figure was just 2 400 km per capita.
- Another indicator for system efficiency is urban density (person/km²), which can reveal structural reasons for different traffic volumes.
- A possible third indicator is passenger transport energy use per capita (MJ/person). This summarises the different measurements of urban energy efficiency.

b. Travel efficiency – the shift strategy

Travel efficiency relates to the energy consumption of different modes of transport. The main parameters of travel efficiency are the relative preponderance of different transport modes (modal split) and the load factor of the vehicles. Specific energy consumption per passenger-kilometre or per tonne-kilometre varies between different modes of transport. An alternative way of enhancing energy efficiency is to encourage travelers or shippers to use more efficient forms of transport, such as public transport and non-motorised vehicles.

In general, private motorised modes of transport are much less energy-efficient than public transport. Other important alternatives include non-motorised forms of transport that do not need any fuel at all. Per capita energy consumption depends to a great extent on the occupancy rate of the vehicles used.

Travel using motorised transport needs to be reduced, while the share of non-motorised and public transport must be increased. Especially in urban areas, most journeys involve distances of below five kilometers. A variety of measures can be implemented to encourage citizens to travel such distances by bike or on foot, thus avoiding unnecessary fuel consumption. For longer journeys, public transport provides an alternative to the automobile. Increasing the share of public transport will lead to higher rate of occupancy in buses and trains, which will further increase their energy efficiency.

Beside passenger transport, energy efficiency also needs to be increased in freight transport. Rail freight is particularly energy efficient because of the high load factor; its flexibility is of course, limited. A sophisticated logistics network, including multimodal logistics centres (rail/road or port/road) can help to shift freight to more efficient modes of transport.

Therefore, travel efficiency depends mainly on the share of energy-efficient modes of transport used. Besides that, the energy intensity of each mode of transport used is also important, which depends on both the vehicle efficiency and the occupancy rate.

- The share of each mode of transport in the total number of trips made, as well as the respective passenger-km (pkm) or tonne-km (tkm) moved can be used as an indicator for travel efficiency;
- It is also necessary to consider the energy use per passenger-km (MJ/pkm) or tonne-km (MJ/tkm) of each mode;
- Finally, the occupancy rate of vehicles is a crucial aspect of travel efficiency. This is already considered under energy use per pkm/tkm, but a separate analysis is often useful.

c. Vehicles efficiency – the improve strategy

Reducing the per-kilometre fuel consumption of vehicles increases their efficiency. This can be done with technology and design improvements, but also through efficient driving techniques. Measures can be clustered into three categories:

- Improvement of existing vehicles;
- New fuel concepts;
- Development of new car concepts.

The strategy of improvement is not only relevant for private cars, but also for freight and public transport. Specific measures for passenger cars include the use of lightweight materials, downsizing (reducing the volume of the engine and the size of the car) and/or using hybrid engines. A combination of such measures significantly reduces energy consumption in comparison to an average passenger car. Comparing different cars of the same size, where consumption can vary by as much as 20%, underlines the potential benefits of vehicle technology.

Such technological improvements are mainly a job for vehicle manufactures and research institutes. However, legislation and fiscal measures can be important drivers of technological advances. Local and national authorities can support the diffusion of efficiency technologies in the market by setting standards, raising awareness and creating incentives for consumers to buy more energy efficient vehicles.

Fuel efficiency can be measured in terms of fuel consumption (litres per 100 km) or fuel economy (km travelled per litre). In different countries different measures have to be taken, such as meeting standards for fuel economy and CO_2 emissions. Figure 2.2.19 shows fuel economy standards in units of energy intensity from current volume and GHG standard (1 litre gasoline = 32 MJ).

Unlike travel efficiency, which is measured using passenger-km or tonne-km, vehicle efficiency is important both for private motorised vehicles and for public transport vehicles.

- Measuring the fuel or energy consumption per vehicle-kilometre (MJ/km) is an easy way to monitor vehicle efficiency. As fuel consumption and CO_2 emissions are related, another way to assess vehicle efficiency is by measuring CO_2 emissions per vehicle-kilometre (gCO_2/km), However it is important to consider that not all fuels provide the same energy output;
- The overall vehicle efficiency or a city's fleet is also influenced by the average age of the fleet.

Cities differ in terms of their topographical, historical, economic and political circumstances. It is best to compare one's own transport system with those of other cities with similar conditions, as this will ensure that the results are transferable. Table 2.2.5 gives examples of values for several performance indicator in different world regions. It should be noted that the values refer to the situation in 1995. Thus, they cannot reflect the status quo, but such a comprehensive analysis gives a unique overview about cities in different world regions.

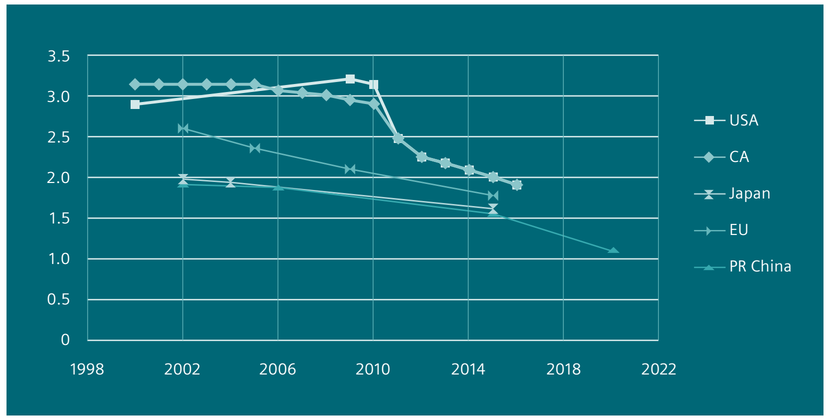


Figure 2.2.19 Fuel economy standards in units of energy intensity extrapolated from current volume and GHG standards

Indicator	US cities	Western European cities	High income Asian cities	Latin American cities	African cities
SYSTEM EFFICIENCY					
Passenger transport energy use per capita (MJ/person)	60.034	15.675	9.556	7.283	6.184
Private individual mobility (pkm/capita)	18.200	6.321	3.971	2.966	2.711
Urban density (person/km^2)	1.490	5.490	15.030	7.470	5.990
TRAVEL EFFICIENCY - "Modal split" of all trips					
Non-motorised modes	8,1%	31,3%	28,5%	30,7%	41,4%
Public transport	3,4%	19,0%	29,9%	33,9%	26,3%
Motorised private modes	88,5%	49,7%	41,6%	35,4%	32,3%
Energy use per public transport passenger – km (MJ/pkm)	2,31	0,83	0,48	0,76	0,51
VEHICLE EFFICIENCY					
Energy use in private passenger vehicle-km (MJ/km)	4,6	3,3	3,3	3,2	3,7
Energy use per public transport vehicle-km (MJ/km)	26,3	14,7	14,4	16,9	9,5

Table 2.2.5 Examples of values for different efficiency indicators – mean values of several cities in each region, 1995

2.2.6 Additional benefits approach

In the transport sector, municipalities often have to bear additional costs to provide energy-efficient transport systems, although it is companies and the population that benefit from them. However, some investment do pay back in the long run. Energy efficiency improvements may have multiple benefits and thus provide an additional incentive for local and national governments to carry out the expensive measures, depending on the local circumstances, and the co-benefits of energy efficiency policies might even be the original reason for enacting them, and may justify the investment. Common co-benefits can be grouped into the following four categories (Figure 2.2.20).

a. Stronger economic development

As a rule, dependency on oil and cars does not foster local jobs or the sustainable, economic development of cities. Like in Montenegro, in many countries vehicles and fuels are the largest category of imported goods and such costs can be reduced significantly. By contrast, an increase in the share of public transport and non-motorised modes of transport can bring economic advantages for cities. For instance, a reduction in congestion leads to time savings. The more efficient use of energy resources is also accompanied by greater efficiency in the use of other scarce and valuable resources, such as land. An urban transport system that is based on public transport needs far less space than on automobile based transport system.

Cities with a smart urban transport system and low congestion levels often attract higher levels of foreign direct investment than other cities, because large companies acknowledge that their employees are healthier, that they can commute more easily and arrive punctually, and that they like the place in which they work. The functionality of such cities as business locations is also secure, since deliveries and business trips can be planned and carried out efficiently using a smart urban transport system. Singapore and Hong Kong are impressive examples of this in Asia.

b. Increased quality of life

Lower energy consumption reduces emissions of pollutants and enhances urban air quality. Urban space is limited and a transport system based on the car usually consumes a lot of space for roads and parking. This is at the expense of urban parks, sidewalks or recreation areas. In contrast, public transport needs far less space to fulfil similar demands, which means that city planners can provide green roads as well as parks and other areas for recreation. Noise from road transport impairs the quality of life of many residents, and it decreases the value of land and buildings. Sustainable transport also reduces health risks in terms of road safety as well as air pollution. Furthermore, as many people in developing cities cannot afford to own a vehicle, investments in public transport and non-motorised modes of transport count as pro-poor policies.

c. Better energy security

Fuels subsidies and other forms of support for the automotive sector put pressure on a government's budget, while also worsening energy security and increasing the dependency on oil imports and prices. As 'peak oil' becomes a reality, worldwide oil production is likely to fall over the next decade. Oil prices will rise further as a result, reaching 170€/barrel or more. However, lower fuel consumption due to energy efficiency measures reduces the oil dependency of a state or individual regions.

d. Other benefits

By promoting the role of public transport, traffic congestion and accident risks can be reduced significantly. A large proportion of a city's budget is spent on mitigating the negative consequences of road transport. Such costs are not borne directly by user but are imposed upon society. Cities may have to invest in noise prevention measures, for instance, or in health care to cover diseases caused by air pollution and accidents.

2.2.6.1 Geotransport position and transport infrastructure of the capital city

It was previously emphasized that the potential of EE in the transport sector depends largely on the level of construction and functionality of the transport system. Trans-

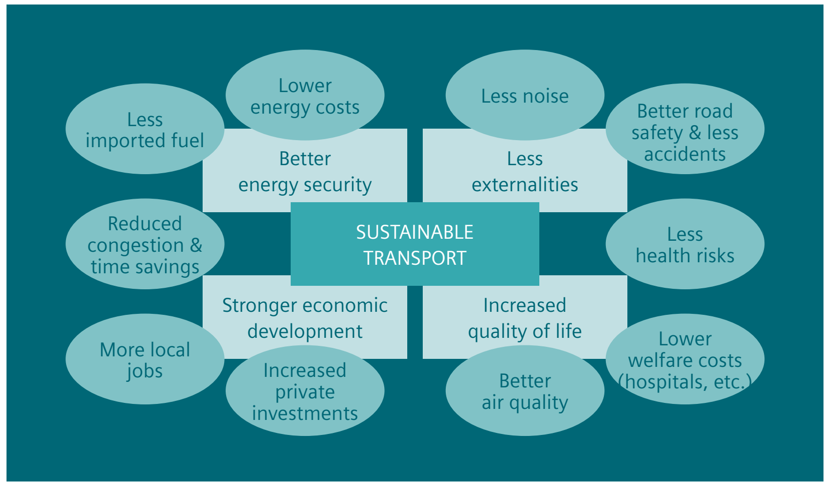


Figure 2.2.20 Possible (co-)benefits of improved EE in the transport sector

port infrastructure in European cities today is developing primarily in the direction of relocating transit traffic to city bypass, adapting to public passenger and non-motorized traffic.

The main incentive generators of transport development are the traffic position in relation to regional communications, demography, economic activity and employment, educational and cultural profile of the population in a certain territory. For this reason, a shorter view of the traffic system in the territory of the capital city follows, with the situation around 2012.

The wider area of the capital city, especially the hilly and mountainous part, is not supported by adequate and quality roads that would improve the existing conditions and enable integrated development on the basis of evident potentials (agriculture, energy, tourism, forestry...).

The characteristic that essentially affects the quality of the road network of the capital city is its age. Namely, over 66% of the regional and main roads are older than 25 years, and investments in their construction and maintenance have been very low for the last 20 years. In addition, 25% of the network is above 1 000 m. Vehicles are often inadequately loaded (transit cargo), which contributes to the rapid decline of roads.

In addition, during the tourist season (June-September), the road network is overloaded with transit traffic when traffic is increased up to 20 times. Transit traffic takes place through the urban area of the capital city, or interweaves with the city traffic system, which diminishes the quality and contingency of traffic on the main roads.

Mini bypass built in 2011 in the length of 7 km on the north-south road (from the direction of Zlatica, through Konik and the Old Airport), significantly relieved local and transit traffic and pointed to optimal future solutions. In addition to the bypass, very efficient solutions for urban centers are also roundabouts, especially when it comes to highways designing.

The traffic load of Podgorica's road infrastructure with the number of daily passengers and the amount of cargo on the transport network can be seen from the figures shown below. Figure 2.2.21 shows the main source - target (S-T) passenger flows that come from Montenegro and international space to Podgorica on a working day in 2010. Traffic flows of passengers in the capital city - Podgorica are out of the main tourist season of the order of 2000 passengers / day from the direction of Bijelo Polje, while from the direction of Niksić more than 15 000 passengers / working day.

It is a similar situation with transit traffic S-T cargo flows across the capital city. Outside the main tourist season, cargo road traffic is about 190 t / day in the direction of Bijelo Polje - Nikšić, 260 t / working day in the direction of Nikšić - Bar, while in the direction of Serbia - Bar there are 400 t / working day. Accordingly, the total daily S-T cargo transport of the capital city is about 850 t / business day.

Another synthetic map of traffic flows in the city area is presented in the following figure (Figure 2.2.22). The number of passengers in the direction of the capital city exceeds 50 000 a day. The most intense urban traffic flows are towards the city center from suburban settlements and towards the southern part of the city, where the density of jobs is higher. Obviously, a large part of traffic flows flow through the very center of the city, which makes the overall traffic system ineffective in functional, energy and ecological terms.

The entire spectrum of relief characteristics of the area (plains, hills, mountains, river valleys, canyons, surfaces) with different climatic conditions of individual zones of 4.5 m to 2 487 m above sea level were conditioned by the volume and quality of the built road and railroads. This is also the main reason that most of the settlements in the hilly and mountainous area of the capital city are very poorly supported by road infrastructure. Namely, almost all the roads in this area are significantly below the basic existential requirements for activating the development possibilities of local resources. Large climbs and falls, low road width, serpentine, contrabands, often in bad condition, cause a long and uncertain journey to the city center of Podgorica. Time distances to individual settlements range up to 115 minutes (for example, Tuzi Ljevorečke). Also, it should be kept in mind that some mountain and mountain settlements in snow conditions are often inaccessible, or with extremely difficult communication.

The following figure shows the population density in the capital city area, with a special focus on the urban area (Figure 2.2.23). This indicator, as well as the spatial distribution of workplaces, significantly determines the configuration, bandwidth and functionality of the road network. The potential of EE depends on these indicators, which assessment is, ultimately, the main goal of this chapter.

Driveway constructions of the city network in 2012 were maintained in the length of 258 km, 852 000 square meters of block roads with parking lots. Also, traffic on the territory of the capital city is characterized by a large number of 106 bridges. A number of major city streets have insufficient bandwidth to the position of joining with the main, regional and local road directions.

Problems related to road traffic and non-moving traffic are still present, although the bridges on Morača and Ribnica have been built as well as the internal city ring (which has improved the connection within certain central zones of the city), and the part of the eastern by-pass (the relocation of transit traffic from old and new towns). The undeveloped traffic network and the parking management remain a serious problem in the city.

The total length of local roads in 2012 was 825.5 km (covered with asphalt 563.70 km, and the other part is 262.3 km of macadam and slip roadway). Most of the local roads were made without previously designed project documentation. As a consequence, there are a number of local roads that have damage and represent a danger to the safety of road users.

The scheme of existing urban and suburban lines is shown in the following picture (Figure 2.2.24).

Public transport on the territory of Podgorica in 2012 was performed by 103 buses on 12 city and 16 suburban lines and about 400 taxi vehicles. More detailed information on the lengths of bus lines, the number of stops and stations, the number of rides on working and non-working days, etc. can be found in available literature. For illustration purposes, a graphical and tabular display of the city line 1 Masline - Zabjelo

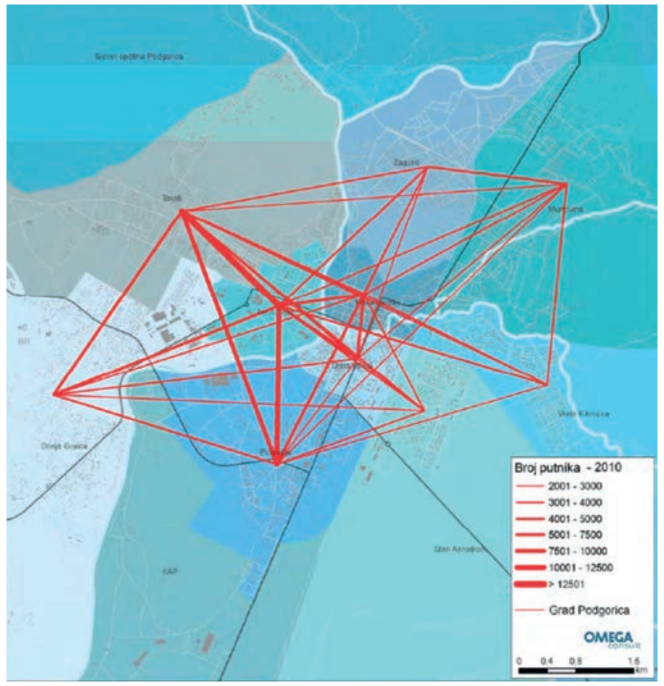


Figure 2.2.22 Traffic network load - motorized passengers on a working day in 2010 (source: OMEGA consult, d.o.o., 2010)

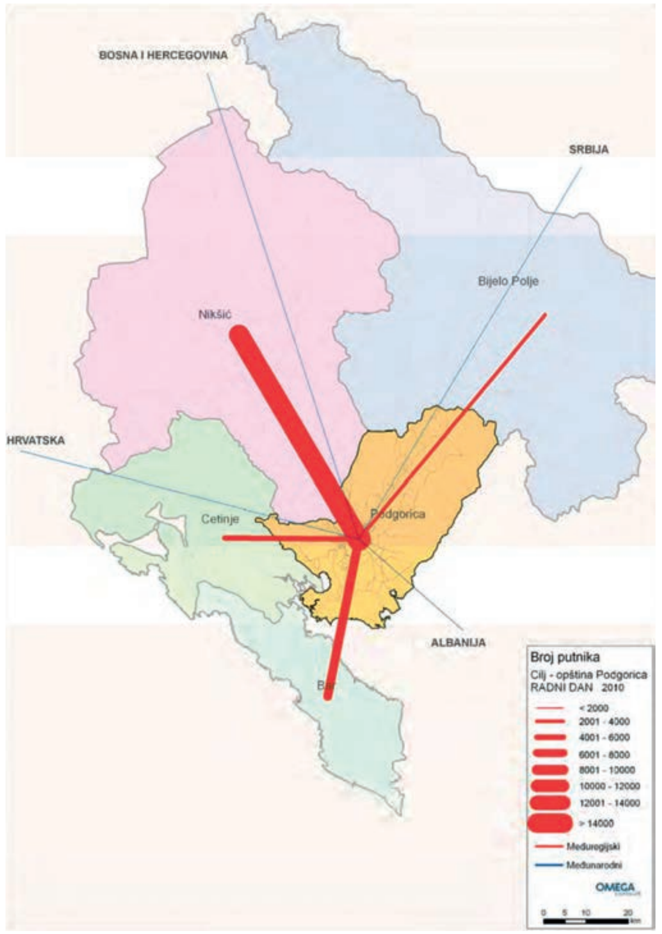


Figure 2.2.21 Traffic S-T passenger flows to Podgorica (source: OMEGA consult, d.o.o, 2010)

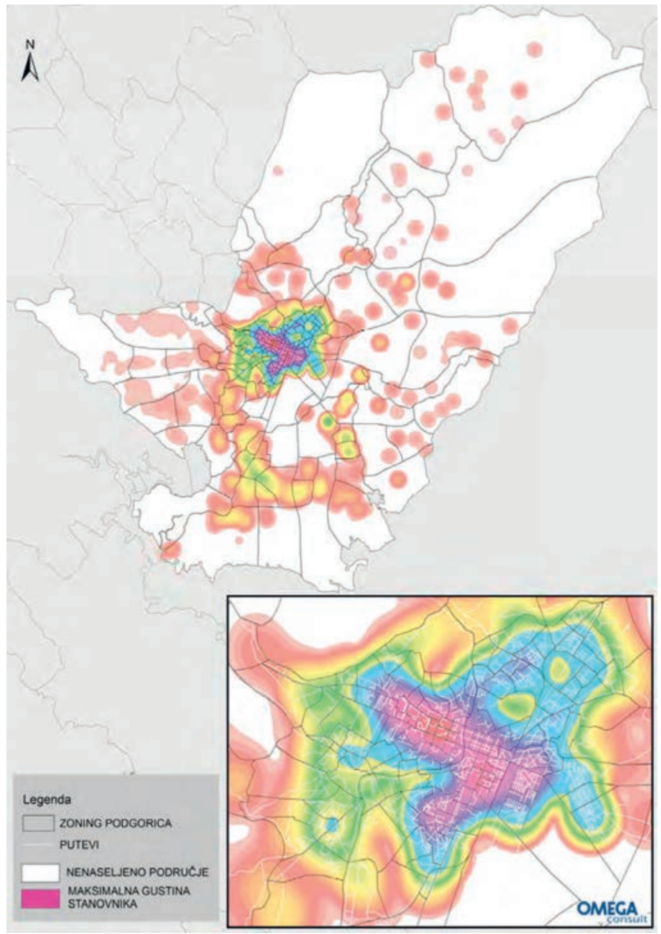


Figure 2.2.23 Population density in the area of the capital city, with a focus on the city zone

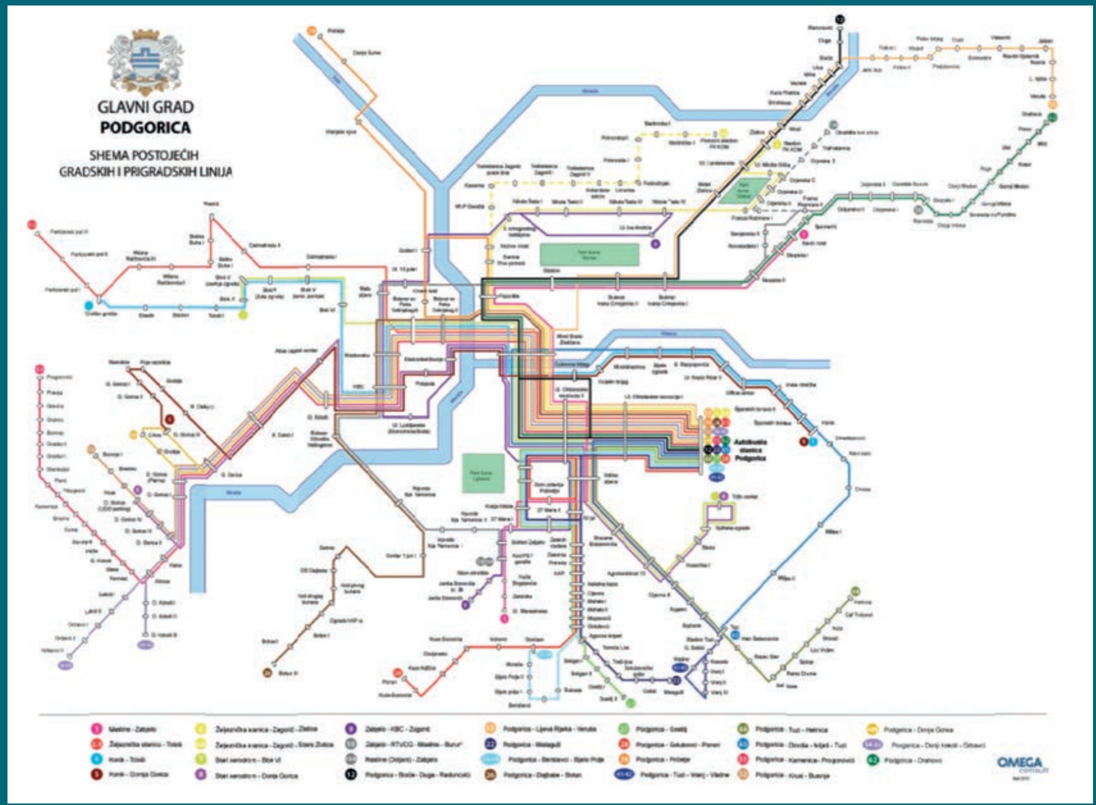
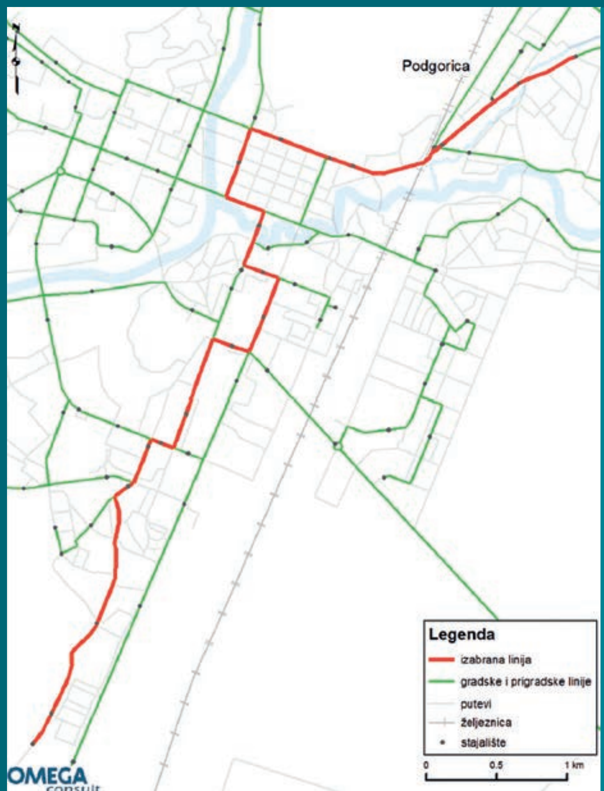


Figure 2.2.24 The scheme of existing urban and suburban lines in Podgorica



Line designation	1 Masline - Zabjelo
Operator	BLT
Bus type	Standard
No. of vehicle	2
Fare zone	1
Line A	Masline - Zabjelo
Line length (km)	8,4
No. of bus stops	18
No. of stops per km	2
Smjer B	Zabjelo - Masline
Line length (km)	8,4
No. of bus stops	17
No. of stops per km	2
Working day	05:30 - 23:00
Frequency (A and B)	138
Total length, Line A	1154
Total length, Line B	1153
Saturday	05:30 - 23:00
Frequency (A and B)	138
Total length, Line A	1154
Total length, Line B	1153
Sunday	06:00 - 22:30
Frequency (A and B)	66
Total length, Line A	552
Total length, Line B	551

Figure 2.2.25 Graphic presentation and basic data on the city bus line 1 Masline - Zabjelo

(Figure 2.2.25) is given. It is a diametric line that connects the northern axis to the southern part of the city. Driving on the line is equally distributed between 5:30 - 23:00.

Priority tasks in transport mean improvement of the traffic connections through better maintenance of the existing and construction of new infrastructure, full integration of environmental protection in the construction of infrastructure projects, reduction of traffic pollution and traffic safety.

2.2.6.2 Energy balance of the capital city transport sector

As in most countries and regions, the road sector is a major consumer of imported petroleum products. From an energy and environmental point of view, this circumstance requires special measures of savings and rationalization. Consumption analysis for 2012 is based on the data of the authorities of the capital city and the Ministry of Internal Affairs, published in the LEP of the capital city.

However, it should be noted that the presented data must be accepted with a certain doubt. Exact data on the amount of fuel consumed at the capital city level as a whole cannot be secured, because, in fact, it is impossible to keep accurate records of certain energy products. The fact is that Podgorica is a transit center with a high traffic dynamics, so data on the quantity of sold fuel on gas stations cannot represent enough relevant indicators. The total quantity of fuel sold would certainly deviate significantly from the quantities sold exclusively for the needs of vehicles moving within the city limits. Likewise, due to the absence of the relevant records, it is not possible to determine even the kilometers traveled in the territory of the city, and especially the indicators of the passenger-kilometer (pkm) and tonne-kilometer (tkm) which, according to the methodology, are the precondition for the quantification of EE potentials in this sector.

According to LEP data, the transport sector participated in 2012 (Table 2.2.1 and Figure 2.2.5) with 44.63%, or 3 213.21 TJ. Table 2.2.6 shows data on energy consumption in traffic at the capital city by type of vehicle and type of fuel, and Figure 2.2.226 share of individual fuels in total consumption in 2012. From the table and the figure it follows that in the transport sector the share of diesel (80%), then gasoline (14.2%) dominates, while gas (LPG) and electricity participate with 3.3% and 2.5% respectively. With regard to transport means, about 92% are involved in cargo vehicles (51.2%) and passenger cars (40.9%), so the highest EE potential is in the specific consumption and use of these two types of vehicles.

For the purposes of the analyses carried out in the LEP, the classification of energy consumption in three subsectors was performed:

- The fleet owned and used by the capital city;
- Public transport (city bus, taxi and rail);
- Private and commercial vehicles.

The analysis of the situation in this sector is based on the following characteristics:

- Number of vehicles by individual subsectors;
- Energy types in use;
- Consumed energy of individual energy sources in TJ.

a. The vehicles fleet owned and used by the Capital City of Podgorica

Table 2.2.7 shows the data of the vehicles fleet owned and used by the capital city in 2012 with the consumption of individual energy sources in TJ. The main city's fleet consists of vehicles used for the purpose of carrying out tasks within the jurisdiction of the services and the capital city. In 2012, the total number of vehicles was 342, out of which 145 were commercial and 197 official vehicles. Considering the activity they perform, city companies use cargo, combined, special and working vehicles (Čistoća doo, Zelenilo d.o.o, Deponija d.o.o, Protection Service and Municipal Police). The largest numbers of commercial vehicles are special and working vehicles, which number is 106 or 73% of the total number of vehicles owned by the capital city. The mentioned category includes fire trucks, excavators, bulldozers, auto couples, sweepers, grapples, snow blowers, etc.

Participation of this subsector's fleet in the total consumption of the capital city (Figure 2.2.227) is almost negligible

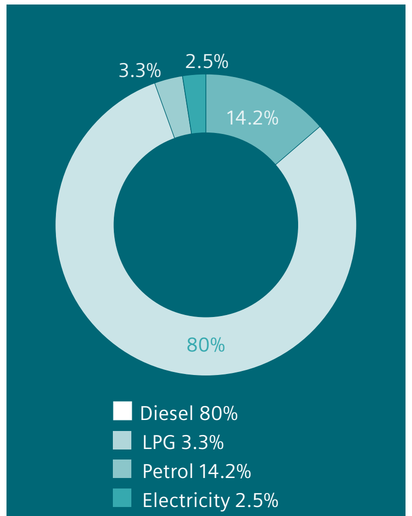


Figure 2.2.26 Share of individual fuels (%) in total consumption in 2012

Type of vehicle	Number	Fuel type and fuel consumption (TJ) Diesel	Gasoline BMB	Gas	Electric energy	Total (TJ)	% participation of vehicles in energy consumption
Motorcycle	961		10,52			10,52	0,3
Passenger car	60.239	764,62	445,16	104,52		1.314,3	40,9
Van	31	2,35				2,35	0,07
Buses	385	138,26				138,26	4,3
Trucks	4.722	1.646,53				1.646,53	51,2
Special Vehicles	1.066	8,2				8,2	0,25
Tractors	39	2,22				2,22	0,07
Railway	10.660	9,8			81,03	90,83	2,8
In total	**78.103**	**2.572**	**456**	**105**	**81**	**3.213,21**	
% participation of energy source		**80**	**14,2**	**3,3**	**2,5**	100	

Table 2.2.6 Energy consumption in the capital city traffic in 2012

(0.8%), and thus does not represent a significant domain for improvement of EE in traffic. Otherwise, a large number of old vehicles are replaced by new energy efficient models that have better performance, and consequently mitigates the negative impact on the environment compared to the previous period.

b. Public traffic

Public transport in the capital city is carried out using taxis, buses and railways. The type, number of vehicles and energy consumption are shown in the following table (Table 2.2.8), and percentage participation in the previous figure (Figure 2.2.227).

b.1 Public bus transport

It was stated that urban traffic transport in the territory of Podgorica in 2012 was carried out 3 carriers, which performed transport on 28 lines (12 city and 16 suburban), with a total of 103 vehicles (buses, vans and minibuses). The average age of the bus was from 3 to 35 years old, with an average of 19 years. The analysis also showed that the time availability of the lines was not adequate to the spatial. In the city center, the frequency of driving is approximately 15 minutes on average, but in a wider area about 120 minutes. Total number of passengers transported in 2012 was 1 647 005, which was less by 849 207 passengers compared to the previous period (2008-2012). The information obtained from the carrier does not contain information that defines the precise division of the number of passengers on city or suburban routes.

Based on the available data on the number of passengers carried, it can be determined that the daily average number of passengers per vehicle is 43.8. Bearing in mind that buses in the city and some in the suburban transport have dozens of departures and returns, the number of passengers in one turn of city lines is below 10. This low occupancy has the effect of significant energy inefficiency and low profitability of this traffic, which is significantly reduced by increased use of taxi.

Also, under certain assumptions it is possible to roughly estimate the mileage traveled in this subsector of public transport. The total consumption of diesel as the only propulsion fuel of these vehicles of 31.63 TJ corresponds to a quantity of 903.714 liters of that fuel. In the city run, buses with average consumption of about 26 l / 100 km are engaged, while on the suburban lines the average consumption of vans and minibuses is about 15 l / 100 km. Considering 10 times higher frequency of vehicles on urban lines compared to suburban ones, it is possible to assume that suburban transport, due to longer lines, participates with about 20% in total mileage. The average vehicle consumption is about 24 l / 100 km, and the total annual journey is 3 765 475 km, or 10 316.4 km per day, or 100 km per bus per day. Energy consumption per passenger is 0.55 liters or 19.2 MJ of diesel.

Unfortunately, no additional data are available, which are necessary to more precisely determine energy consumption indicators per km and traveler.

b.2 Taxi transport

Bearing in mind the lack of parking space, both in the narrow, and in the wider center of Podgorica, as well as the affordability of the taxi, this type of public transport is largely used in the city. In 2012, there were 13 registered companies with a taxi operator license, and the total number of taxi vehicles was 406, with the problem of a certain number of unregistered ("wild") taxi drivers present. Also, as mentioned above, this type of public transport is increasingly being used rather than a bus. Taxi passengers accept and take off from any departure to the desired address, and there is a practice of "car sharing" according to which more passengers use one taxi vehicle for transport to one or more destinations, where they share the cost of transportation.

The total amount of fuel consumed was approximately 1,543,185 liters of diesel. Also, the specific consumption for taxi vehicles is 3924.7 l / vehicle or 0.137 TJ / vehicle per year, while for buses in public transport specific consumption is 0.307 TJ / vehicle per year. With an estimated consumption of 9 l / 100 km taxis, the all-wheel drive is 17 702 055 km, or 121 km / vehicle per day. The reason for all of the states is that taxi transport has a significant place in the transport sector, in terms of traffic intensities, consumption of automotive fuel and environmental impacts.

Vehicle fleet	Number	Gasoline	Diesel	LPG	Total (TJ)
Vehicles	342	5,45	21,7	0,12	27,27
Total	**342**	**5,45**	**21,7**	**0,12**	**27,27**

Table 2.2.7 Consumption of fuels for vehicles fleet owned by the capital city in 2012

Fleet	Number	Gasoline	Diesel	Electric energy	Total (TJ)
Buses	103	0	31,63	0	31,63
Taxi vehicles	406	0	55,77	0	55,77
Railways	10.660	0	9,8	81,3	90,83
Total	**11.169**	**0**	**97,2**	**81,03**	**178,23**

Table 2.2.8 Consumption of energy sources in public transport in the capital city in 2012

b.3 Railway traffic

According to technical standards of rail transport, train traffic at the distance of stations up to 60 km is treated as suburban, which means that the territory of Podgorica is mainly covered by suburban rail traffic. These include routes from Podgorica to Bar, Kolašin and to Nikšić. The length of the line between Podgorica and Bar is 49.7 km, and Podgorica - Kolašin is 64.5 km. Traffic of passenger trains on the Podgorica-Nikšić route, in the length of 66.3 km, was established in October 2012. The intensity of passenger train traffic is determined by the number and type of car, the relation and the period of traffic, as well as the order of delivery of cars in the set on the relation of the train traffic.

Rail traffic in the public transport subsector in 2012 participated with 51%, with the consumed electricity of 22 508 277 kWh and consumption of 279.559 liters of diesel. There were 525 664 passengers and an unknown quantity of cargo transported. The journey was 29 630 058 km. For the performance of the comparative indicators on the efficiency of rail transport, detailed data on the transferred cargo, number and condition of the vehicle and technical infrastructure are missing.

As a transport system that dominantly uses electricity, rail transport vehicles can be classified into energy efficient consumers, and this is the biggest contribution of this type of traffic to the preservation of the quality of the environment. In general terms, trains need less power in relation to private and commercial vehicles and other public transport vehicles. This is explained by the lower resistance in contact between the wheel and rail wheels, as opposed to the contact of the road vehicle wheels on the asphalt. In addition, stopping and changing speeds are considerably less expensive, which also rationalizes the consumption of the power source.

However, the status of the Bar-Belgrade railroad as the most important railway segment of Montenegro does not correspond with the existing, and especially, developmental needs on the corridor that covers (insufficient frequency, slow travel, road congestion due to failures on the power supply network, etc.). Also, the upcoming economic development will require significantly more efficient cargo transport with this line. On the non-electric line Podgorica-Skadar only cargo transport is preformed, which is not rational either for Montenegro or Albania.

c. Private and commercial vehicles

Data on the energy consumption of certain categories of vehicles in this subsector are presented in Table 2.2.9. This transport subsector has a dominant share in total energy consumption of 93.7% (Figure 2.2.227) and thus represents the largest resource for increasing the EE of traffic in the capital city. Consequently there is also a great potential for reducing GHG emissions.

For the purposes of this document, the LEP data on the number of vehicles by type (passenger and cargo) and ownership (individual and legal entities) registered on the territory of the city are used as the most reliable. Number of registered motor vehicles and trailers in 2012 is 66 592. Because of the dominant number of passenger cars, the number of vehicles owned by private individuals is more than four times higher than the number of vehicles owned by legal entities.

Due to the lack of precise records, the transit character of Podgorica, etc., the estimation of consumption expressed in the LEP was done in the same way and with possible mistakes, both for public transport and for the fleet of the capital city. Namely, the quantities of sold fuel at gas stations cannot represent enough relevant indicators for vehicles registered in Podgorica. Approximate total consumption is based on data on the participation of certain types of vehicles, their age and average fuel consumption (l / 100 km), etc.

For the purposes of this analysis, vehicles are classified into seven categories (Table 2.2.9): motorcycles, passenger cars, vans, buses, trucks, special and traction vehicles and agricultural tractors. Total consumption is dominated by commercial vehicles (54%) and passenger cars (41%), which means that the other five categories participate with 5%. Therefore, the

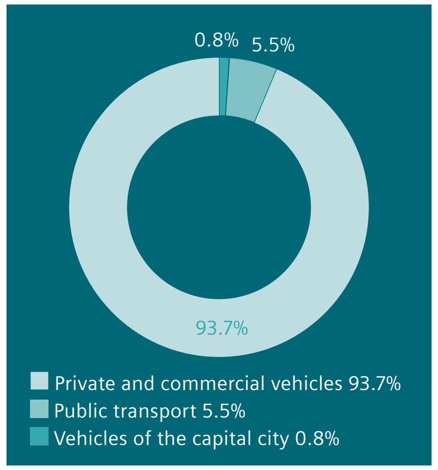


Figure 2.2.27 Participation of traffic sub-sector of capital city in energy consumption in 2012

Fleet	Number	Benzin	Disel	LPG	Total (TJ)
Motorcycles	961	10,52	0	0	10,52
Cars	59.491	439,71	687,15	104,40	1.231,26
Vans	31	0	2,35	0	2,35
Buses	282	0	106,63	0	106,63
Trucks	4.722	0	1.643,53	0	1.643,53
Special and tractive vehicles	1.066	0	8,2	0	8,2
Tractors	39	0	2,22	0	2,22
In total	**66.952**	**450,23**	**2.453,08**	**104,40**	**3.007,71**
% participation		**15**	**81,5**	**3,5**	**100**

Table 2.2.9 Consumption of private and commercial vehicles in the capital city in 2012

main area of EE potential is for these two categories. This does not mean that there is no need to repair EE within other categories, but this potential in absolute amount is almost negligible in relation to cargo vehicles and passenger cars.

The analysis of the structure of the fuels in this subsector (Figure 2.2.28) shows that participation of diesel is 81.5%, followed by gasoline with 15% and LPG with 3.5%. In the consumption of diesel, the utility vehicles have the highest share (67%), followed by passenger cars (28%), while five other categories participate with 5%, with no diesel consumption registered for the motorcycles.

The large share of sub-sectors of private and commercial vehicles in energy consumption of 93.7% indicates the already mentioned, rather worrying situation of over-individually motorized vehicles of 0.36 vehicles per inhabitant, or almost 1 vehicle per 3 inhabitants. This should be added to the large age of the vehicle as there are no available data for the capital city. However, having in mind that about 1/5 of registered vehicles in Montenegro are in the capital city, then MONSTAT data for Montenegro can be used for approximate estimation of the age of the vehicle (Figure 2.2.29). It follows that about 80% (or about 54 000 vehicles) were produced before 2006. Most of these cars were cheaply purchased from Western European countries which, due to their energy inefficiency, ecological standards and reduced security, get rid of their old cars.

Another unfavorable factor which made EE worse in the traffic of the capital city should be added. This is the problem of parking spaces, which are intended for only about 15,000 vehicles. This is significantly less than the number of registered motor vehicles from 2012, and it causes extended driving to find free parking. At the same time, improper parking causes conflict with the city space and other purposes of its use.

2.2.6.3 Estimation of EE potential in transport sector

a. Use of energy-efficient vehicles

As shown (Figure 2.2.19), new generation of all types of vehicles has improved energy and environmental performance. For example, the EU reduces the specific fuel consumption per vehicle by 25% (from 2 MJ / vehicle from 2002 to 1.5 MJ / vehicle in 2014), while this indicator in the EU in 2002 was significantly lower than that in the Montenegro for same period. For conventional car consumption in Montenegro of 9 l / 100 km, according to the same methodology, specific consumption is estimated at 3.4 MJ / vehicle. By taking measures to improve transport infrastructure and excluding older vehicles from 2006, specific consumption would reduce to 1.7 MJ / vehicle and the potential of EE in automotive traffic of the capital city would be 50%, or 615.6 TJ in relation to the 2012 consumption. The high potential of EE is replacing older vehicles, even at a level of 10%, which would result in savings of around 165 TJ on this basis. With a possible 20% savings in private bus traffic (around 20 TJ), the total EE potential of this dominant subsector is estimated at 800 TJ.

If 25% of public transport savings (44.6 TJ) based on improved infrastructure and fleet driving, especially taxi vehicles, and 20% savings in the capital city fleet (5.4 TJ) is added, it will generate the total EE potential of the traffic sector of 850 TJ. With this, the potential energy savings of the transport sector of the capital city would be about 26.4% compared to the level of consumption of the sector in 2012.

Figure 2.2.30 illustrates the percentage participation of individual subsectors in total EE traffic potential based on the use of new generations of more energy efficient and environmentally friendly vehicles. The basic problem for activating this potential is that its predominant part refers to the subsector of private and commercial traffic. Due to the large number of entities in this subsector and the right to freely dispose of vehicles in their ownership, insufficient awareness of the good and bad personal and collective effects, this subsector is more difficult to influence than the other two. Modern city development must provide adequate conditions for the life and functioning of citizens, but citizens, who actually make cities, must have a more humane attitude towards the city's values as a specific collective environment. To this end, public promotional campaigns are needed to raise awareness of the benefits of procurement and optimal use of energy-efficient vehicles, as well as various incentive measures towards greater use of public transport.

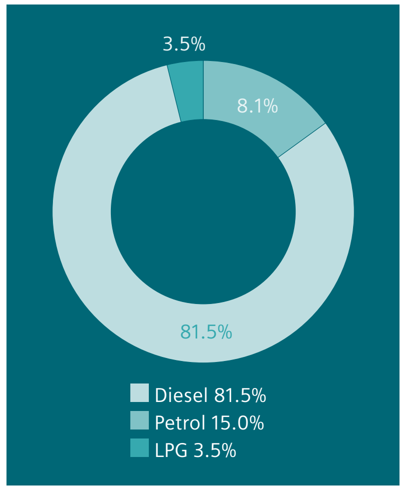


Figure 2.2.28 Participation (%) of energy products in the consumption of private and commercial vehicles in 2012

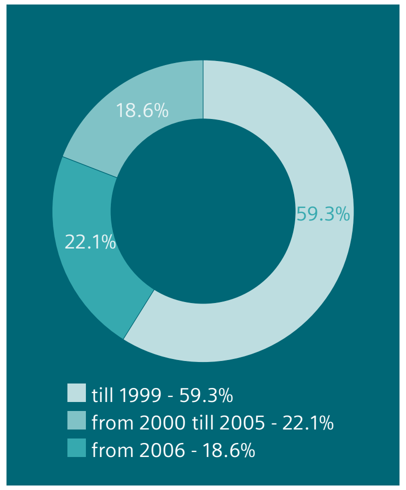


Figure 2.2.29 Structure of registered passenger cars in Montenegro according to year of production

Specific fuel consumption increases with frequent stopping and driving in the column. These phenomena can be reduced by appropriate traffic signals in urban environments, based on the number and speed of vehicle tracking, the intensity of traffic and, accordingly, the adjustment of the light signaling. Economic measures, with a time-defined road map in urban areas, are also recommended, which discourage the use of vehicles at the time of the biggest traffic jams and at the same time direct public transitions to public transport. In intercity traffic, it is possible to reduce the delay with the appropriate information support that informs the drivers of crowds, congestions, collisions, etc., so that the drivers will be able to choose an alternative route in a timely manner.

Also, a very efficient measure, aimed at renewing the fleet with more energy-efficient vehicles with lower specific consumption, and therefore even lower specific CO_2 emissions, is the introduction of a fee that is proportional to the prescribed fuel consumption. This measure involves paying higher taxes when buying a new vehicle with higher fuel consumption, which motivates the purchase of more energy efficient vehicles.

b. Other possibilities of increasing EE in traffic

The authors of this Study had the ambition to evaluate the indicators for the capital city at all three levels of EE (system efficiency, travel efficiency and vehicle efficiency, Table 2.2.5). However, despite efforts, it was not possible to obtain relevant data for the estimation of the passenger kilometer (pkm) and the tone-kilometer (tkm) that are the basis for the determination of the mentioned indicators. Only data of this kind have been published in the information of MONSTAT for Montenegro as a whole for the years 2005-2010. From this document, Table 2.2.10 is derived, from which, due to the growth of indicators, the so-called "building boom" in the south region of Montenegro and the capital city around 2008 can be recognized.

For illustration purposes, the EU Energy Efficiency Policy in Transport will be briefly mentioned. An EU policy review for achieving EE targets in transport suggests that a wide range of instruments is used in the Member States. The most common are fiscal measures that make up 28% of all measures and are applied in almost all Member States. In recent years (since 2008) there is a tendency to use less regulatory or normative measures, and more cooperative, such as voluntary agreements.

The most common aim of measures according to the review carried out at European level (Figure 2.2.31), and shown in the above figure, is to improve efficiency of passenger transport, mainly through improvements to the efficiency of cars or measures to increase the uptake of cleaner vehicles, but also through promoting modal shift. Measures are also beginning, but not predominantly, to tackle improving the efficiency of other modes, and encouraging modal shift of freight from road to other less energy intensive modes such as sea and rail.

These conclusions correspond to the review carried out by the European Commission in 2009, about the first National Energy Efficiency Action Plans (NEEAPS). A large number included technological measures to improve vehicle efficiency and fiscal incentives and subsides to encourage cleaner vehicles, but fewer had policies on other strategies such as modal shift and mobility management.

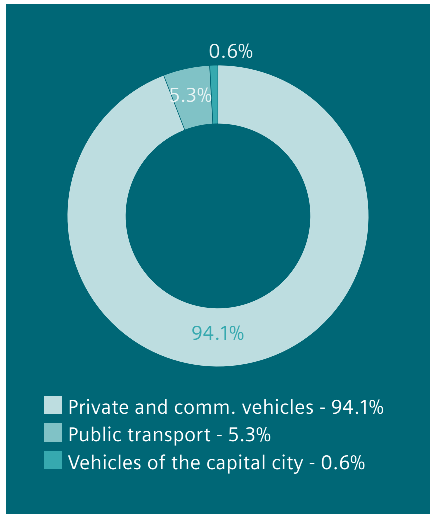


Figure 2.2.30 Participation (%) of the subsector in the EE traffic of the capital city using more efficient vehicles

Traffic	Indicator	2005	2006	2007	2008	2009	2010
Road	pkm	85	112	141	123	102	81
	tkm	61	73	92	139	179	167
Rail	pkm	123	132	110	125	99	91
	tkm	133	182	185	184	101	151

Table 2.2.10 Indicators pkm and tkm for road and rail transport in Montenegro, 2005-2010 (× 1000)

Since only a few member states have presented clear and consistent energy transport strategies, it is interesting to note the conclusions of the EU Commission which have insisted on more comprehensive strategic approaches that include technological, infrastructure, financial and behavioral measures (road and road) and spatial planning measures. For example, studies under the European Climate Program have shown that the appropriate modes and driving techniques (without sudden braking and acceleration, etc.) can increase EE 10 to 12% and reduce GHG emissions by 5 to 25%.

Also, transport avoidance measures include cycling and hiking. In urban areas there are often short distances which, instead of motorized vehicles, can be crossed on foot or on a bicycle. To increase the share of this mode of transport, an adequate traffic infrastructure is needed, which would, above all, enable bicyclists to increase the radius of movement as well as safer driving. Cycling reduces the density of traffic and congestion, as to the direct method allows the vehicle to the same period of time exceeds a greater distance.

These EU policies and concrete measures are very instructive and somewhat binding for Montenegro as a future Member State. According to these policies and measures, there is a significant additional potential on various grounds, illustrated in the previous picture, which may be at the level of the already estimated EE efficiency of transport means. This potential is difficult to quantify for certain urban areas. Its activation depends on national and local legislation, the quality of spatial plans, administrative and financial predispositions, and in particular of the general awareness and culture of citizens to accept and exploit contemporary sustainable development policies.

2.2.6.4 General recommendation

To achieve the full potential of EE and measures, it is important to appreciate the complexity of the transport sector. Single, uncoordinated measures can only have a limited success. A proper policy to enhance EE in the urban transport system must address all three levels of energy-efficient transport: system efficiency, travel efficiency and vehicle efficiency. Strategies and policy packages deliver that kind of mixed approach. Ideally, positive incentives (“pull” measures) need to be supported by disincentives (“push” measures).

A well developed and convenient public transport infrastructure can attract more passengers, but that is often not enough, in itself, to inspire a major shift from private car use to public transport. Underlying factors that sustain car use, such as convenience and status, continue to prevent people who can afford cars rather than using public transport. Therefore, steps have to be taken to overcome these factors, such as pricing measures that increase the cost of the car use, or parking restrictions that reduce the convenience. Generally speaking, these steps will prompt a more rapid shift towards energy-efficient modes of transport.

2.2.7 Municipal waste

2.2.7.1 Solid municipal waste

The collection, transport and disposal of municipal waste represent a public interest of special importance for the state of the environment of the capital city and are one of the more important conditions for the proper course of lives and work of citizens. The estimated amount of waste ranges from about 0.8-1 kg / day per citizen of the city, about 0.5 - 0.8 kg / day per inhabitant of urban settlements, below 0.5 kg / day per inhabitant of rural settlements and about 1.5 kg / day per tourist. In the capital city, a modern sanitary landfill “Livade” was built on Vrela Ribnička and created conditions for standardized sanitary-technical collection and disposal of waste. At this landfill, a regional recycling center and facilities for the treatment of vehicles out of use with a capacity of 90 000 t / year were built and put into operation. In this way, the capital city has solved the problem of landfilling and recycling of municipal waste and created conditions for its pre-selection at the place of formation and the treatment of vehicles out of use.

The quantities of municipal waste deposited at the third sanitary bath within the city landfill “Livade” are shown for 2015 and 2016. (Figure 2.2.32[15]).

Total collected quantity of all types of waste (municipal, vegetable, cabbage and other waste) in 2016 was 80 768 tons, an increase of 11.76% compared to the previous year (72 272 t). The amount of municipal waste disposed of in purpose-built containers in the territory of the city is 70 225 t, which is 6.4% more than in the previous year. In 2016, there were 3 706 containers on the premises of the capital city on 1 793 locations. At the end of 2016, 20 underground containers were installed at 18 locations, with a volume of 3 or 5 m³. In addition to disposing of municipal waste in containers distributed in the area of the city, certain types of household waste are deposited in five recycling yards.

For transport and waste disposal in 2016, 45 dedicated vehicles were used (27 trucks for discharging containers, 6 open vehicles - sculptors, 1 loader, 3 half-way pick-ups, 6 tractors, 2 vans) as well as 13 passenger vehicles. Diesel fuel was used for the propulsion of these 58 vehicles, but at the moment the used quantities are not available. These quantities, and even the savings potential, are cumulatively covered by the main city’s fleet, which was discussed in the previous section regarding traffic. From the mentioned source, it is known only that the cost of fuel and lubricants (including fuel for 6 auto-tanks) in 2016 is € 365,227, which is 11% lower than in 2015. If the quantity of waste transported is higher by 6.4%, then it can be concluded that the company Čistoća doo, whose founder is the capital city, has achieved significant savings in its overall energy consumption frameworks, thanks to the newly acquired vehicles, and possibly an improved organization of work.

Also, the data on energy consumption of the company “Deponija d.o.o” (presses, shears, conveyor belts, excavators, etc.) are not available, which is also cumulatively covered by the consumption of the capital city. Given that new, modern plants are in question, one can assume that they are very efficient. Otherwise, municipal waste will be treated as an energy resource in chapter regarding RES.

2.2.7.2 Wastewaters

The largest polluters of surface and groundwater in the area of the capital city are untreated wastewaters of settlements, that is municipal sewage. Namely, the current state of infrastructure equipment is such that the collector network continues to cover mostly only the central parts of urban settlements. Wastewater collected by the collector network, with a part of wastewater which, however, is treated on the existing waste treatment plant (PPOV) Podgorica, is discharged without purification into the recipient.

According to estimates, about 150 to 170 km of canalization network was built for collection and drainage of wastewater in Podgorica. A total of 137 791 m of pipelines and 4 311 manholes were recorded in 2010. The sewage system of Podgorica is separate, i.e. atmospheric and fecal wastewater is collected and drained separately. Virtually all wastewater is gravitated through the public sewage system to PPOV. Only used waters, sewage and industrial waters with pre-treatment are taken away by sewage network.

The current PPOV in Kruševac (on the right bank of Morača) has been in operation since 1978. It was designed and implemented for mechanical and biological wastewater treatment with a hydraulic load of 17 300 m³ / day

[15] ‘Čistoća” d.o.o. Podgorica, Work Report for 2016

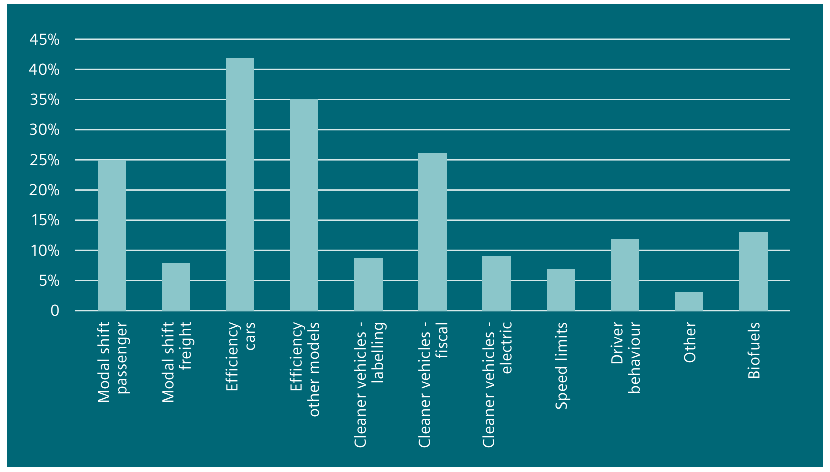


Figure 2.2.31 European measures for improving transport efficiency, declared objectives, 2008-2012

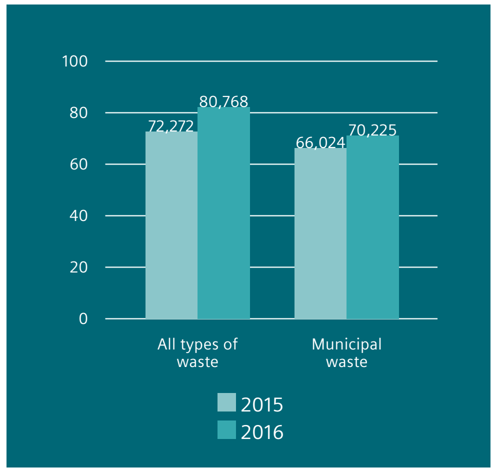


Figure 2.2.32 The collected quantities of all types of waste and municipal waste (t) in 2015 and 2016

Year	Electric energy			
	Active energy (kWh)		Reactive energy (kVArh)	
	High tariff	Low tariff	High tariff	Low tariff
2013	481,363.00	352,214.00	395,935.00	348,340.00
TOTAL (€):	65,971.17		5,877.65	

Table 2.2.11 Overview of consumption of active (kWh) and reactive (kVArh) energy of PPOV pumps in 2013

and an organic load for 55 000 equivalent inhabitants. About 85 000 inhabitants are connected to the city sewage system, which causes the overload of the plant, due to its insufficient capacity and inability to purify all the wastewaters. Since there is no possibility of further expansion at the mentioned location of the plant, the problem of wastewater treatment capacity is planned to be solved by the construction of a new PPOV at the site of the KAP.

The total annual electricity consumption of the three pumps in PPOV in 2013, as well as the consumption and costs for active and reactive energy is given in the following table (Table 2.2.11[16]), as well as the monthly active energy consumption diagram (Figure 2.2.33).

16 Energy Efficiency Improvement Program of the capital city for the Period 2017-2019, Podgorica 2016

From the previous table it can be concluded that, due to the large share of reactive energy, cos**φ**= 0.7 - 0.8, the cost of reactive energy is almost 6 000 € / year. This low cos**φ** can be raised to the desired value cos**φ** = 0.95 with the installation of capacitor batteries.

2.2.8 Water supply

2.2.8.1 Structure and functionality of water supply system

There are three water supply systems in the capital city area[17]:

17 Report on the work of the company "Water and Sewage" - Podgorica in 2013, Podgorica, March 2014

- Water supply system of Podgorica and Gornja Zeta villages
- Water supply system of City municipality Tuzi
- Water supply system of Dinoša.

The water supply system of Podgorica supplies with water the consumers of the Capital city (with suburban settlements), part of the City municipality of Golubovci and part of the Municipality of Danilovgrad. This water supply system consists of three springs: "Mareza 1 and 2", "Zagorič" and "Ćemovsko polje". The maximum capacity from all water sources is 61 800 000 m³ per year.

Water source "Mareza" is the oldest water source in the capital city. The "Mareza 1" pumping station is equipped with four pumps with a total capacity of 470 l/s. The modernization project of this pumping station was completed in mid-2016. The "Mareza 2" pumping station is equipped with seven pumps. The operating capacity is 960 l/s, and 1,600 l/s is installed capacity. Replacement of pump aggregates and electric motors in 2012 also solved the problem of increased vibration, which prevented the operation of pump aggregates at full capacity.

The water source "Zagorič" uses water from drilled wells, and its exploitation began 40 years ago. The capacity of this water supply is 400 l/s. Wells B1 and B2 are equipped with aggregates of older production (with long shaft), with capacity of 125 l/s. Wells B3 and B4 have submersible pump aggregates of recent production with capacity of 60 l/s and 90 l/s.

Water source "Ćemovsko polje" has 5 wells, with total capacity of 410 l/s. On this water source, 10 piezometer boreholes of profile 2" with depth of 60 m were built. The object was built in 1999. During the period from 1999 to 2005, the wells were commissioned successively. In 2012, new water automatic chlorination equipment and additional measuring equipment was installed in this water source.

The water supply system "Tuzi" supplies water to the City Municipality of Tuzi. The water uses the wells PS "Tuzi", PS "Milješ" and PS "Vuksanlekići" with a total installed capacity of about 135 l/s.

The water supply system "Dinoša" was commissioned in 2008. The water is used from the well with capacity of 28 l/s. The well is equipped with a pumping station facility with electro-mechanical and chlorine equipment.

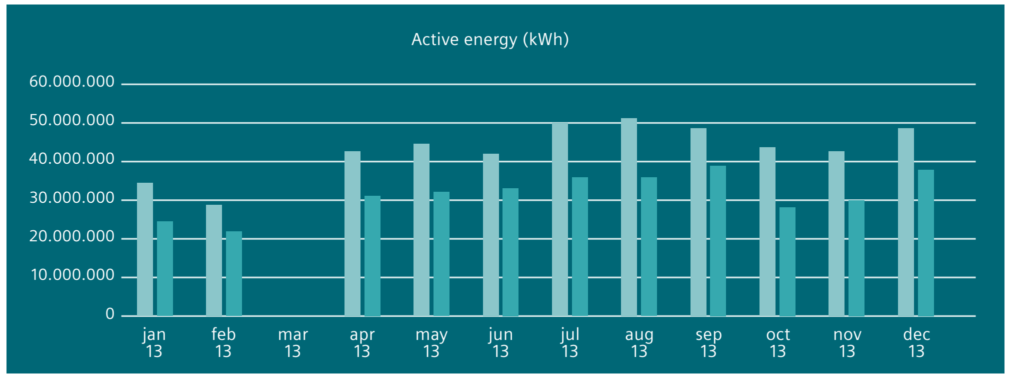


Figure 2.2.33 Review of monthly consumption of active electrical energy (kWh) of PPOV pumps in 2013

The unique water supply system of the capital city has tanks with a total capacity of 7,250 m³.

In addition to the aforementioned, there are several rural water supply systems on the territory of the capital city, built in the previous period without the corresponding project documentation. These are:

- water supply system of settlements Bioče, Vranjina, Lješanska Nahija, Komani – Bandići, Karabuško polje, Fundina;
- smaller water supply systems: Rijeka piperska, Duga, Selište, Peuta, Gornji Crnci, Okno.

The basic problem that is present in a certain part of the rural water supply systems is related to the part of the water supply system done in the previous period, and in which the equipment's aging (over 30 years) is very much present. This group includes: water supply of the Lješanska nahija, Bioče, Komani-Bandići, Zagarač and Piperi.

One of the basic preconditions for proper water supply is the adequate water supply network and its maintenance. The water supply network is divided into a primary network, which includes transport distributive pipelines, a secondary network used for supply of consumers, and a tertiary network that in most cases constitutes a connecting part of the pipeline from the secondary network to the customer metering point. The estimated value of the primary and secondary network lengths, through which water is distributed to consumers, is approximately 580 km of primary and 300 km of secondary network, while the length of the tertiary network is estimated at 370 km (37,000 connections, length to the 10 m connection). The total estimated length of the water supply network in the area of Podgorica water supply system is approximately 1,250 km.

The water supply network in Podgorica on the Google Earth geodetic surface is shown in the following figure (Figure 2.2.34).

The amount of 32,166,204 m³ of water was supressed from the water supply system in Podgorica, of which from: "Mareza" 21,557,016 m³, PS "Zagorič" 5,805,022 m³ and PS "Ćemovsko polje" 4,804,166 m³. Also, from the PS "Dinoša B2", for the needs of Podgorica, the amount of 991,703 m³ was suppressed, so the total amount of water in the Podgorica system amounted to 33,157,907 m³. In total, 17,233,254 m³ were invoiced, which meant that technical and commercial losses for Podgorica were 48% in 2013. In the following table, the data regarding suppressed and invoiced quantity of water, as well as losses in all three water supply systems in the capital city in 2013 are presented.

In 2013, the largest losses (74.3%) were recorded in the water supply system of Tuzi. Namely, the greatest technical losses of water from the system are realized in the secondary and tertiary network, and a significant part refers to illegal connections and water theft.

During 2013, 4,643 water meters for remote reading and disconnection were installed for the category of legal entities, which was about 78% of the total number of active consumers in that category. The installation of these water meters significantly increased the level of collection rate, which was 98% for legal entities at the end of 2013.

2.2.8.2 EE potential of water supply system

Pump stations are significant consumers of electricity, so it is necessary to regularly monitor the mode of operation of pump aggregates and the degree of their utilization. This approach can affect the reduction in the consumption of electricity.

The characteristic of the capital city's water supply system is the relatively high specific water consumption. In relation to the amount of suppressed water, the average specific consumption is about 500 l/capita per day. Given that, due to losses in the network, the invoiced amount is about 50%,

Figure 2.2.34 Water supply network of Podgorica

Water supply system	Supreessed (m³)	Billed (€)	Losses (%)
Podgorica	33.157.907	17.233.254	48,03
Tuzi	1.781.460	457.871	74,30
Dinoša	85.504	71.939	15,80
Total	**35.024.871**	**17.763.064**	**49,29**

Table 2.2.12 Supressed and billed quantity of water per water supply systems in 2013 (m³)

it follows that the average consumption of water is about 250 l/inhabitant per day. About 70% of the mentioned m³ corresponds to households, or 175 l/inhabitant per day. For comparison, in developed countries, daily consumption of drinking water per capita ranges from 120 to almost 300 liters. The USA is leader of the countries with the highest daily consumption of drinking water - up to 295 liters of water per day per inhabitant, while in Germany the average daily water consumption is 130 liters.

Taking into account these indicators of average invoiced consumption, it follows that there is room for savings of 15-20%. However, the greatest potential is to reduce unacceptably large water losses in the secondary and tertiary network (about 50%). In Europe, average losses are around 30%, and the goal is to reduce water losses to 15 %. Naturally, the reduction of these losses requires investments for the reconstruction of the water supply network, as well as the intolerant attitude towards illegal consumers and theft of water. Reducing losses is important for the conservation of natural resources, as well as due to the proportional decrease of electricity cost.

[18] A primer on energy efficiency for municipal water and wastewater utilities, Technical Report 01/12, ESMAP, 2012.

Large seasonal unevenness of consumption is also expressed as a result of the use of water for irrigation of the garden, agricultural and green areas in the summer months. The following figure shows the monthly suppressed water (Figure 2.2.35). In 2013, the amount of total suppressed water from all sources was 2.47% less compared to the previous year, which was achieved by the appropriate selection of the pump aggregates regime.

In 2013, the amount of 12,988,320 kWh of electricity was spent, so, according to the available data, compared to 2012, the consumption of electricity at the pumping stations decreased by 285,850 kWh or 1.86%. Figure 2.2.36 shows the consumption of pump electricity consumption in kWh for 2013.

It is now possible to determine the values of specific electricity consumption in kWh/m3 for the suppressed and invoiced quantities of water in 2013. According to the above data, it follows that the specific electricity consumption for suppressed water is 0.37 kWh/m3, and for the billed water 0.73 kWh/m3. For example, the specific consumption of electricity per m³ of invoiced drinking water in the New York state[18] amounts to 0.158 - 0.285 kWh/m³, while the indicator for USA is 0.370 kWh/m³. It should be emphasized that this indicator is very dependent on the type of water supply system. For gravitational water supply, which is the dominant case in the state of New York, it is natural that this indicator is much lower than for a system with pumping aggregates for which operation electricity (or some other energy resource) is required.

According to the above mentioned, if the losses in water supply networks were reduced by 30%, and with the possibility of 3% saving in electricity consumption of pumping motors, the total energy savings potential would be 4,286,145 kWh/year with respect to the level of consumption from 2013.

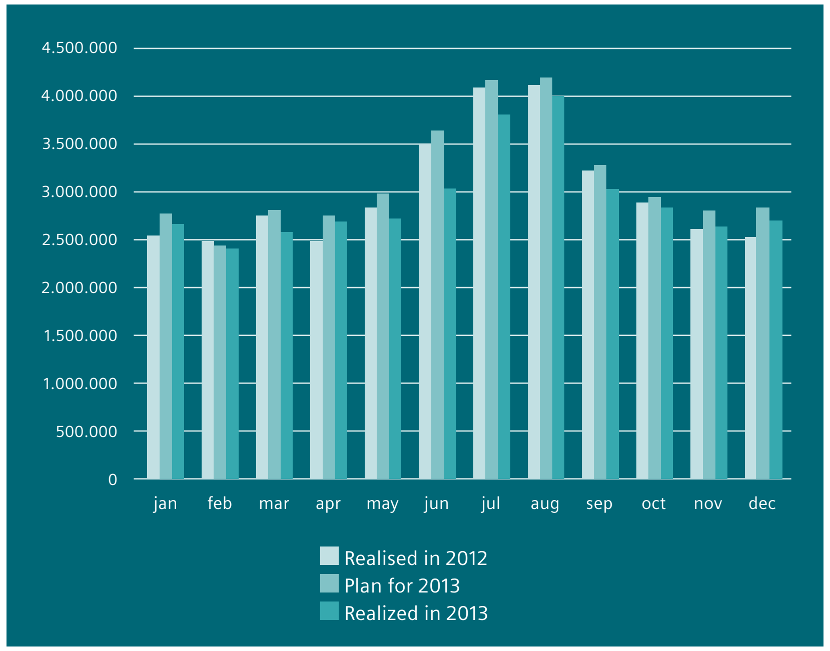


Figure 2.2.35 Suppressed water per month in 2012 and 2013

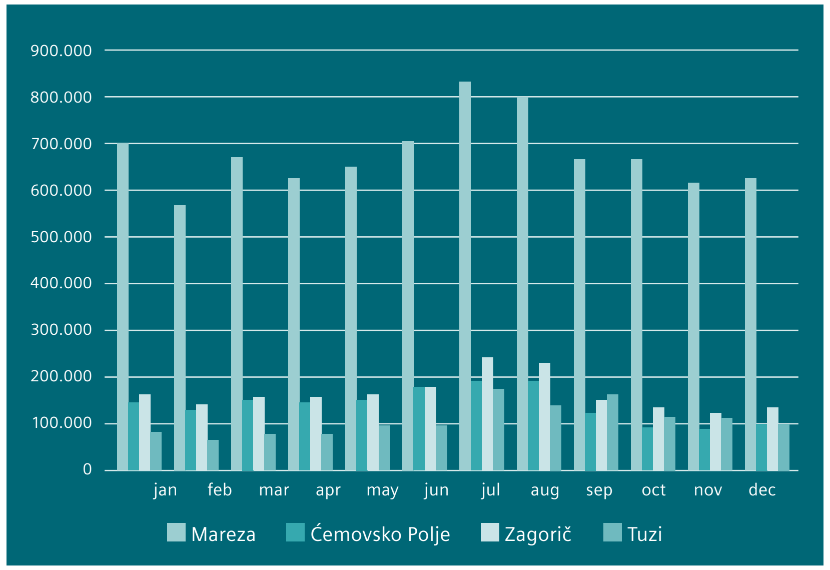


Figure 2.2.36 Electricity consumption of pumping stations in kWh, 2013

2.3 Renewable energy sources (RES) potential

2.3.1 Previous note

First of all, due to various and sometimes confusing definitions of distributed energy sources, and for the purpose of correct processing in further analysis, firstly, a few general headings regarding the topic in the title are listed.

The most acceptable definition of distributed generation is that it is a production system of electricity that is directly connected to the medium voltage or low voltage distribution network, or connected in the installation from the consumer side. Also, the distributed sources include autonomous sources (stand-alone) and backup supplies for consumers in the distribution system.

Distributed sources, according to the type of primary energy source, are divided into:

- Renewable (wind power plants, solar power plants, small hydropower plants, biomass and biogas power plants, geothermal power plants and power plants using sea energy (tides and waves);
- Non-renewable (fossil fuel power plants: coal, oil and natural gas and fuel cells).

According to the installed power, the distributed sources are divided into: micro, small, medium and large sources, as illustrated (Figure 2.3.1).

Finally, for precise purposes, the division of distributed sources according to the functional role is stated:

- Distributed sources for backup supplies (standby): diesel-electric aggregates, fuel cells and rechargeable batteries;
- Autonomous sources (stand-alone): diesel-electric aggregates, PV systems, wind turbines and hybrid systems;
- Distributed sources for supply of remote and rural consumer centers (rural and remote applications): small hydropower plants, biomass power plants, wind and diesel aggregates;
- Sources for combined production of heat and power (CHP): thermal power plants, diesel generators, fuel cells, geothermal power plants, small household cogeneration;
- Peak load shaving sources: fast micro turbine power plants, accumulation small hydropower plants;
- Base load sources: small hydropower plants, wind farms, solar power plants, etc.

Some of these distributed sources will be elaborated in more detail below.

2.3.2 Hydropower potential

2.3.2.1 Hydropower potential

Previous research and various energy programs at the national and local level have shown that regarding RES, the Capital City of Podgorica has significant hydroelectric potentials, a very generous resource for solar energy, and preliminary possibilities for using the wind have been examined by installing the test wind turbines. It has also been noted that both biomass and municipal waste are a significant resource.

Hydroenergy represents the most rational RES, the most manageable and environmentally the friendliest, and opens the space for economic development in the catchment area. Potential hydroelectric plants are located at the territory of the capital city: Zlatica, Milunovici, Raslovici on the main stream of Moraca, Prifta on Cijevna, then Opasanica, Krusevica, Nozica and Brskut (State Water Management Basis, Hydro Energy Development Strategy, Energy Development Strategy, etc.) on the same watercourses. Table 2.3.1 gives the hydroelectric characteristics of these power plants, and Figure 2.3.2 gives a graphic representation of the available potential for the watercourses of Montenegro.

From the above table, and from the graphic illustration of the longitudinal hydropotential (potential proportional to the width of the blue corridor), the previous statement about the great potential of this quality resource (819 GWh/year) is

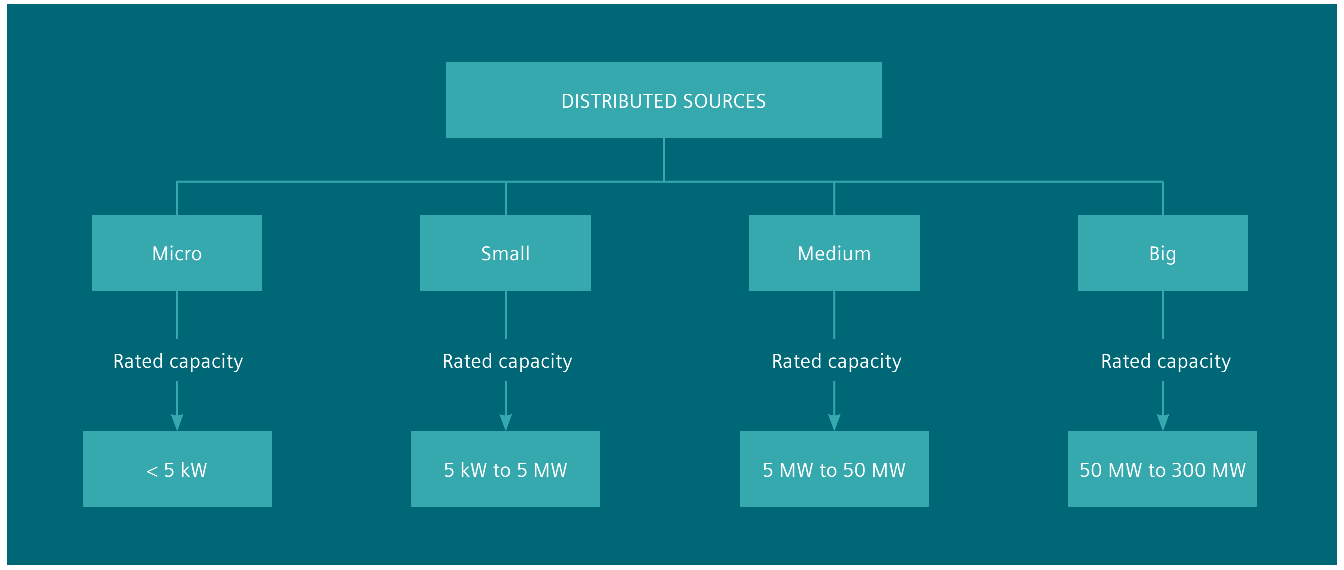


Figure 2.3.1 Classification of distributed sources according to installed power

obvious, with the possibility of multipurpose use of individual accumulations of a total volume of 362.2 hm³.

The construction of the above mentioned HPPs on the Morača River (including the HPP Andrijevo, which is the first in a row, located in the territory of the municipality of Kolašin) has been planned in various strategic documents over the past 100 years, and during the 80's of last century, the main projects were also made. Other HPPs were analyzed at the level of conceptual solutions. The accumulation of the HPP Zlatica represents a compensatory pool of upstream hydroelectric power plants and, beside electricity, it would also have water management, tourist and other importance.

Watercourse	Accumulation position	Dam height (m)	KNU (mnm)	Volume (hm³)	Power (MW)	Production (GWh/god)
Opasanica	Opasanica	110	1.160.0	45.0	10	43.0
Kruševica	Kruševica	-	1.036.5	-	19	32.0
Nožica	Nožica	154.0	948.5	17.0	14	26.7
Brskut	Brskut	64.9	785.0	11.2	74	141.9
Cijevna	Prifta	98.0	200.0	180.0	82	193.0
Morača	Raslovići	36.0	155.0	28.0	37	120.1
Morača	Milunovići	38.0	119.0	68.0	37	120.1
Morača	Zlatica	38.5	81.0	13.0	37	155.7
Total				**362.2**	**310**	**819.5**

Table 2.3.1 Hydropower potential of the capital city

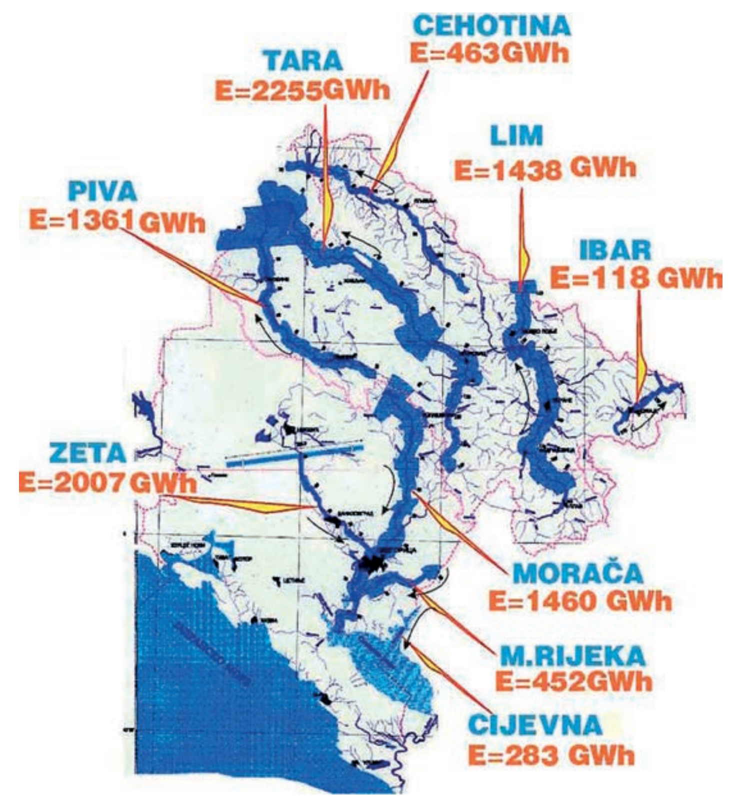


Figure 2.3.2 Available hydropower potential of Montenegro per watercourses

2.3.2.2 Solar energy

In order to specify some of the concepts that often interfere with solar energy, a brief overview of the basic concepts, technical solutions and terms in this domain is given.

There are two basic ways to use solar radiation energy: thermal and photovoltaic (PV) conversion. Thermal conversion involves conversion of solar energy into heat, which is later used for heating water, rooms, greenhouses, etc. PV conversion, however, implies direct transformation of solar energy into electricity through a photoelectric effect. The mentioned transformations are illustrated below (Figure 2.3.3).

The heat energy obtained by conversion from a solar is used for:

- Heating of sanitary water in apartments, houses, hotels, restaurants, sports facilities, etc.;
- Heating of sanitary water in settlements that have the distribution of hot water from city heating plants in periods when the heating plants do not work;
- Heating of water in swimming pools (private and swimming pools in sports and recreation centers);
- Heating water or other fluids in industrial processes;
- Heating of greenhouses in agricultural production;
- Drying of agricultural products;
- Distillation of water for industrial purposes;
- Warming up space as a complementary tool in periods when there are plenty of sunny days;
- Production of electricity based on heat conversion of solar radiation (steam turbines);
- In processes for space cooling.

The thermal conversion of solar energy takes place on the entire sun-exposed surface. In order to direct the Sun's energy and use it for specific purposes, it is necessary to have an appropriate receiver or collector as the most important part of the solar thermal conversion system.

Under the PV conversion, the direct transformation of solar energy into electricity by photoelectric effect is implied. PV systems are systems used for the supply of consumers with DC and AC current. PV systems can be divided into two basic groups:

- PV systems that are not connected to the grid (off-grid), or stand-alone systems;
- PV systems connected to the public electricity network (on-grid).

A more detailed division of the PV system is shown schematically in the following figure (Figure 2.3.4).

Independent PV system is an excellent source of energy for distant homes, catuns, caravans, telecommunication facilities, boats and sailing boats. Figure 2.3.5 shows a standalone PV system for consumers operating on a DC current with the indicated basic components. For this PV system, two basic processes are present:

a) the transformation of the Sun's radiation, that is, the light energy into the electric, necessary for the operation of consumer and;

b) transformation of electricity into chemical and, vice versa, chemical in electrical, due to the need to store energy in the battery.

It should be noted that there are so-called hybrid PV systems using a combination of PV and other energy sources (aggregates for diesel, gas or petrol, wind turbines or small hydrogenerators). With these systems, electricity produced in solar modules or wind turbines is supplied to consumers, and the surplus energy is stored in the so-called solar batteries. In the absence of conditions for the production of electricity by solar modules or a wind turbine, the power source for DC or AC consumers will be a battery. If the battery does not have any more energy to power the consumer, the generator powered by diesel or biodiesel fuel takes over the supply of consumers.

PV systems connected to the public grid (Figure 2.3.6) via a home installation belong to a distributed electricity generation. They are connected mainly to the low voltage distribution network.

The PV system, connected to the public grid over DC/AC inverter (5), delivers the surplus of electricity to the grid, and in the case of insufficient solar energy, the needs of the consumer are satisfied using the energy from the grid. Measurement of produced (surplus) or consumed electricity is done using a meter (7).

PV systems are not installed only on buildings or in their immediate vicinity, but also on free surfaces, and they are connected directly to the power system by constructing a part of the connection network. The described type of PV system is called solar or PV power plant. The production of electricity by solar power plants takes place in the

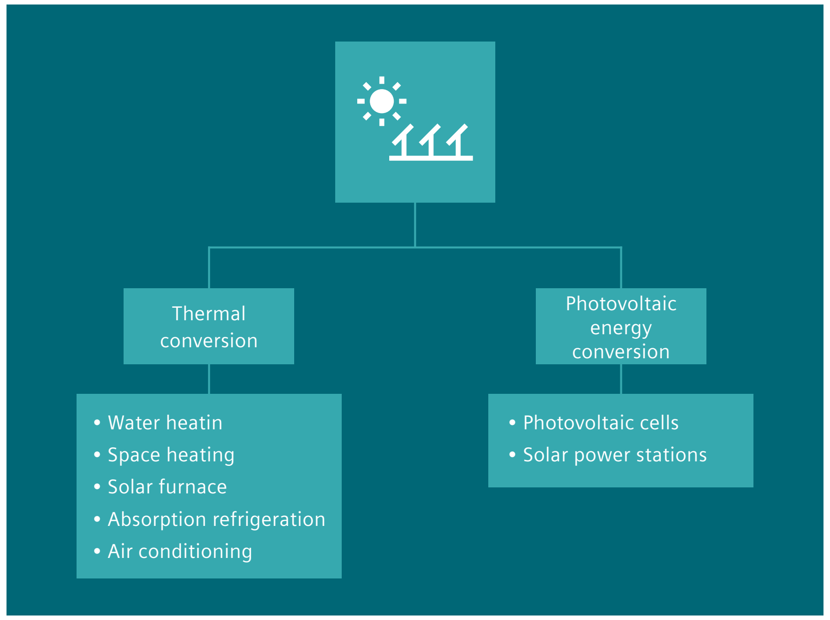


Figure 2.3.3 Possible use of solar energy

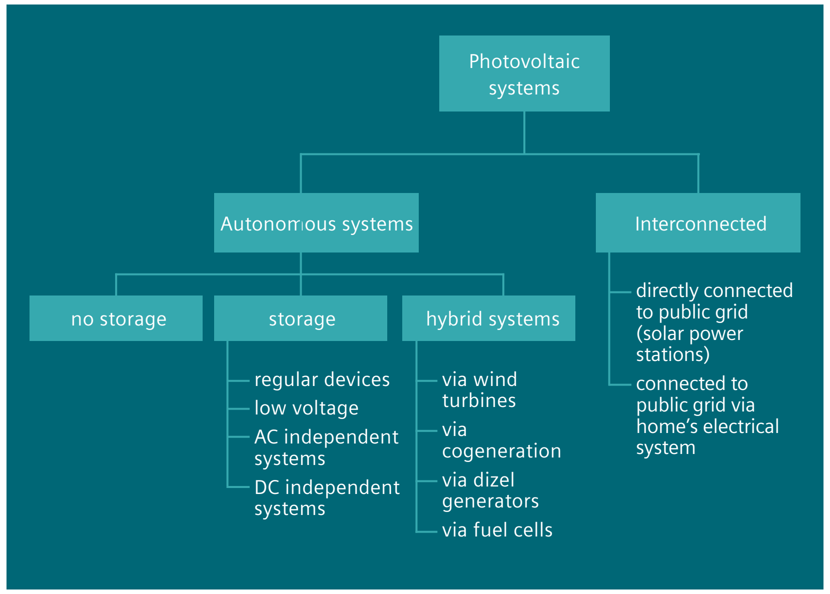


Figure 2.3.4 PV systems types

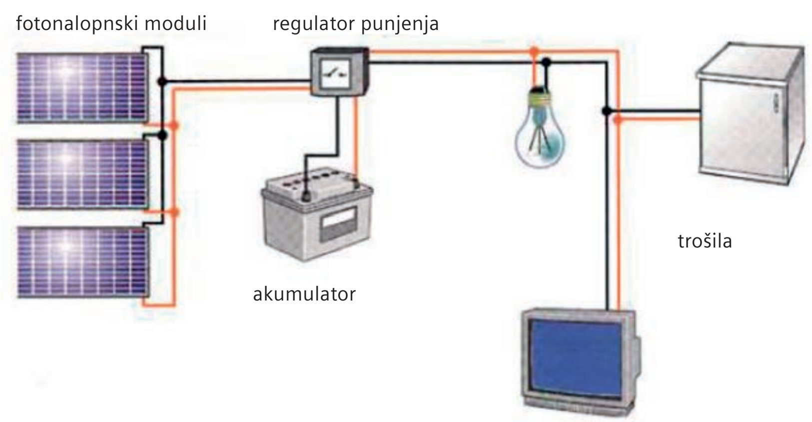


Figure 2.3.5 Standalone PV system with DC current consumers

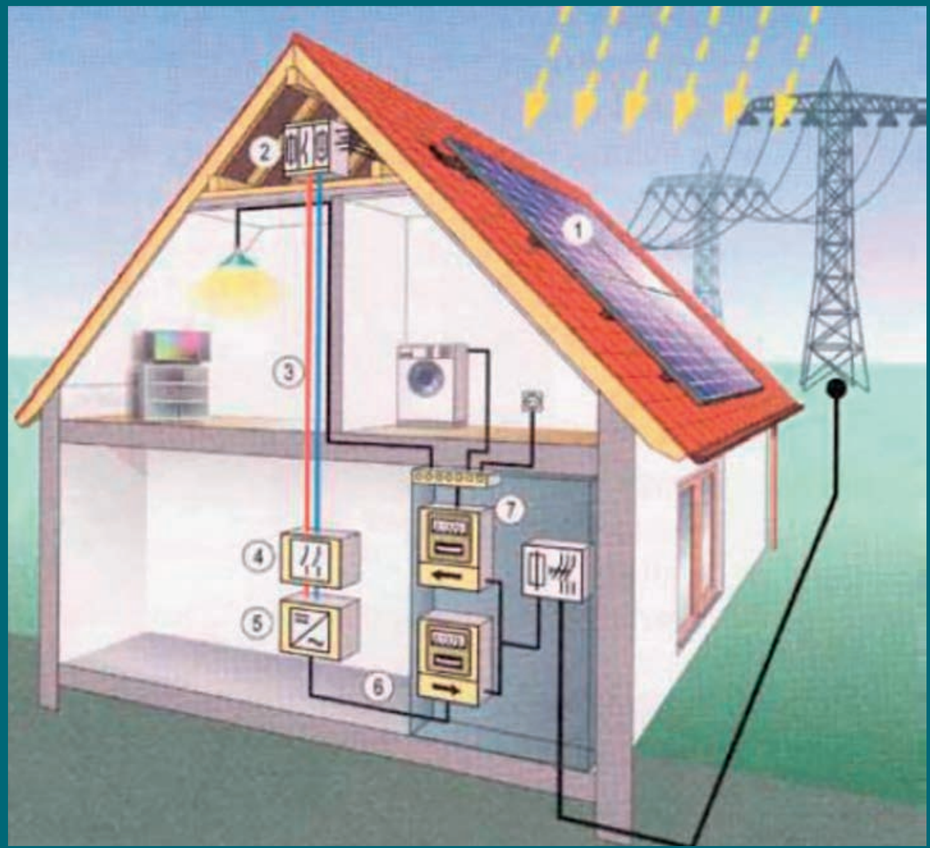


Figure 2.3.6 Basic components of PV system connected to the public electrical grid

Figure 2.3.7 An example of solar power plant with central tower

following order: energy of the Sun → concentration of heat energy on the working medium → steam generation → mechanical energy in the steam turbine → electricity.

Solar power plants deliver all electricity produced to the power system. They have higher power and are mostly installed on larger areas, often in the deserts. They are characterized by their efficiency in the range of 20% - 40%. Due to the need for high temperatures, almost all types of solar power plants have to use some form of concentrating the solar rays from a large area to a small surface. Given the diversity between mirrors (heliostats) and the overall system performance, solar power plants are divided into:

- power plants with parabolic (distributed) collectors;
- power plants with central receiver (solar towers);
- solar panels.

Which of the above solutions is the most suitable for possible zones in the territory of the capital city, should be thoroughly analyzed in feasibility studies. The first two types require significant space, with the other being able to relocate in the hilly terrain, while the third is more demanding in terms of continuous monitoring and maintenance. Due to the relief configuration of the rural areas for the Solar Power Plant in the capital city, a variant with a solar tower could be an optimal choice (Figure 2.3.7).

Montenegro has great potential for the development of solar energy systems, since total insolation time for most of the territory of Montenegro is over 2,000 hours a year and more than 2,500 hours per year along the coast. Podgorica has a higher annual amount of solar energy (1,602 kWh/m²) compared to other cities of South-Eastern Europe, such as Rome or Athens.

The data of the Hydrometeorological Institute of Montenegro (HMZ) show (Figure 2.3.8) that the highest annual average of solar radiation was recorded in the southernmost coastal areas (Ulcinj and Bar), and the smallest in the interior of the state (Pljevlja). Maximum monthly values were recorded in the town of Bar for the month of July (7,680 Wh/m²/day), and the lowest in Pljevlja in December (864 Wh/m²/day). The highest values of solar radiation were recorded in July for all locations, and the annual survey shows the negative asymmetric curve of solar radiation, where the averages in August are the same as in June, and then there is a relatively sharp fall in autumn and early winter.

The highest average monthly value of solar radiation in Podgorica, recorded in July, was, in the same observation period, 6,669 Wh/m²/day. It is evident from the figure that among the eight observed municipalities only the lower values with respect to Podgorica were recorded in the northern municipalities of Pljevlja and Zabljak (Figure 2.3.8).

As will be seen in section 2.3.3.1, in the document "Strategy for the Valorization of Spatial Planning for Renewable Energy Sources and Demonstration Pilot Projects"[19] for the territory of the capital city, 17 urban zones with a total area of 84.87 ha and 7 rural areas 225.59 ha were analysed for possible construction of PV power plants. The solar potential of urban areas is estimated at 21.22 MW, and the rural ones are at 56.41 MW, or 77.63 MW in total.

Podgorica, as a city with a large number of sunny days, should give solar energy more importance when it comes to EE (use in housing and economy), and it is also worth examining the possibility of producing solar collectors and other elements. Measures to promote low-energy buildings and the application of RES in buildings (especially active and passive solar systems) should be enabled. Also, research and evaluation of spatial-planning documentation for the development of PV systems needs to be carried out. When issuing urban-technical conditions for construction objects, it is mandatory to provide guidelines for EE and use of solar and other forms of RES.

[19] Strategija valorizacije prostora u cilju proizvodnje energije iz obnovljivih solarnih izvora i demonstracioni pilot projekti, IBI GROUP, oktobar 2011.

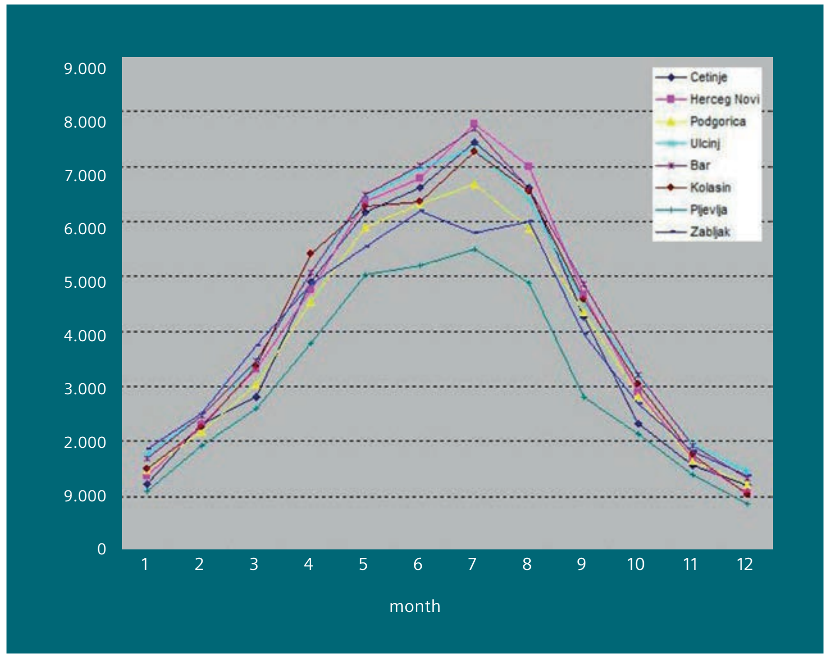


Figure 2.3.8 Average monthly values of solar radiation (Wh/m²/day) for the period 2004-2010

2.3.2.3 Wind energy

High wind speeds in the area of the capital city allows the wind generator to be installed. According to the PUP, the construction of a wind farm at Stijepova, northeast of the river Cijevna, is planned. Suitable areas for wind energy use are also Radovce, Trmanje, Stravče and Kučka Korita. There is no data regarding the precise locations, so the data from the study "Assessment of the potential of renewable energy sources in the Republic of Montenegro" from 2007 can be used for this occasion[20]. According to the analytical maps of the Study it can be estimated that the average wind speed is in the range of 5.5 - 6.5 m/s. Typical values of the actual energy potential of the wind are 100-300 W/m^2, while in the most winding regions, on the slopes and peaks of the mountain wreaths, the actual energy potential of the wind reaches values of over 400 W/m^2.

[20] Procjena potencijala obnovljivih izvora energije u Republici Crnoj Gori, CETMA, februar 2007.

2.3.2.4 Biofuels potential

Thermal and/or electrical energy can be produced using biomass (forest residue, firewood, fruit-growing vineyard remains). Firstly, it should be noted that the total consumption of fire wood in 29,463 households of Podgorica in 2011 amounted to 142,686 m^3, as well as certain smaller quantities for the thermal needs of the commercial sector, which was discussed in greater detail in chapter 2.2.3.

The fruit and vineyards remains of the Plantation "13 July" amounted to 6,206 t in 2008[21]. With an energy density of 3000 kWh/t and a humidity of 25%, the energy potential of the biomass of the fruit and vineyard remains in the state-owned plantation was 18,618 MWh. In addition to this, there is a significant potential of the fruit and vineyard remains from private plantations, which, at the level of the capital city, is difficult to estimate due to low data availability.

[21] B. Glavonjić, Trenutni status korišćenja drvnog otpada za proizvodnju energije u Crnoj Gori i komercijalne mogućnosti, 2010.

The capital city possesses good soil conditions for plantation, fast growing tree species, for energy needs. The most suitable premises for such dedicated forestry production are the coastal area of the Donja Zeta and the coast of the Skadar Lake area of 10,000 ha, which cover a space between 5.5 and 10.44 m above sea level. At 50 m^3/ha, the annual amount of fast-growing biomass can be estimated at 500,000 m^3. A detailed feasibility study would point to more concrete technological solutions for raising intensive rapid-growing plantations in order to produce energy biomass.

The company "Deponija d.o.o.", whose main activity is the collection, disposal and further treatment of municipal waste, has carried out a feasibility study for the production of electricity and hot water from the landfill and sanitary facilities 1, 2 and 3. The study has determined the amount of biogas that arises and the methane content, which is represented by more than 50%. The amount of biogas that could be produced in sanitary tubs 1 and 2 is 400 to 450 m^3/h. Based on the above data, it was concluded that it is possible to produce 900 kW of electricity per hour.

2.3.3 Feasibility of distributed RES expansion

In addition to other factors, the feasibility of the distributed RES expansion is conditioned by certain technical problems of integration of these sources in the power system:

- *the criterion of the allowed power* of a small power plant, defined by the short circuit power at the point of connection to the grid and the type of generator;
- *flicker criterion* evaluated by perturbation factors induced by long-lasting flicker (over two hours);
- *the criterion of allowable high harmonic currents*, which is evaluated on the basis of the value of the higher harmonic current that is normalized with respect to the short-circuit power at the connection point;
- *three phase short-circuit current* criterion (if the condition is not fulfilled, the three-phase short circuit current limitation is performed or replacement of the switchgear and other equipment has determined, change of the connection point, etc.).

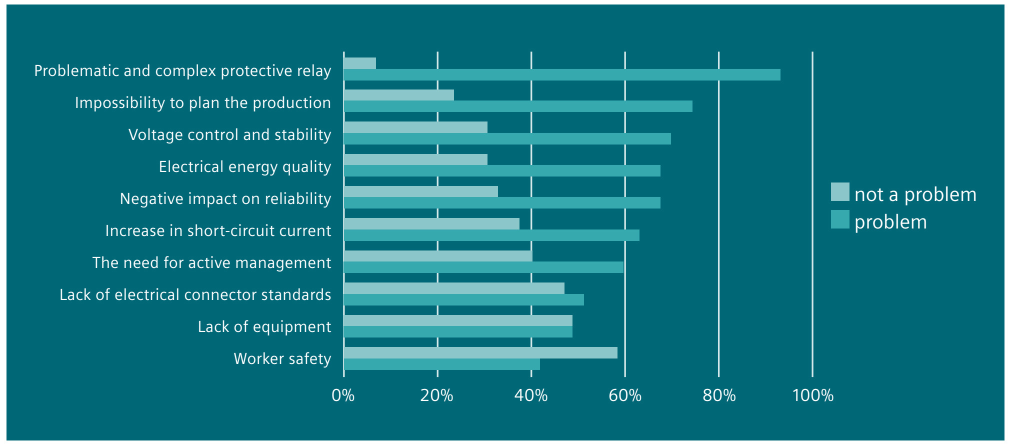


Figure 2.3.9 Participation (%) of negative and positive aspects of RES integration in power systems

There are also additional positive and negative aspects, some of which are listed in the following figure, which must be taken into account in the option of integration of RES into the power system (Figure 2.3.9). Also, there are often negative reactions of the local population to the construction of RES, and depending on the type of power plant (solar, wind turbines, biomass, etc.) there are more or less pronounced associated negative environmental impacts. The above factors should, before construction, be analyzed and documented for each individual case.

For the improvement of EE, a whole set of EU legal acts (Directives 2002/91/EC, 2006/32/EC and 2005/32/EC, etc.) contains many elements related to the promotion of EE and the greater use of RES. Thus, in the construction of new larger facilities it is necessary to provide at least 20% of the required energy from alternative sources, taking into account the ambient and landscape characteristics of the surroundings of future facilities.

As it was emphasized in chapter 2.2, energy and environmentaly sustainable construction includes:

- Reduction of heat losses from the object by improving the thermal protection of external elements and favorable relationship between the base and the volume of the building;
- Increase of thermal gain in the object by favorable orientation of the building and using solar energy;
- Use of RES in buildings (biomass, sun, wind, etc.);
- Increase of EE of thermal power systems.

As it is pointed out in the LEP and other planning documents of the capital city, the geothermal energy of the abundance of groundwater and the heat pump system should be used for air conditioning. The architectural design of objects (roofs, facades) requires the integration of installations for the exploitation of solar energy. The best way to integrate these installations is to place the collector on a sloped roof if the roof is oriented to the south, with a deviation of ± 30 °. The most suitable type of buildings for such integration are residential buildings, either for collective or individual housing. In the case of flat roof objects, the optimal solution is to install a solar installation on the construction that guarantees optimum inclination of the collector.

2.3.3.1 PV power plants

In the document "Strategy of Valorization of Space for the Purpose of Production of Renewable Solar Energy Sources and Demonstration Pilot Projects"[22] from October 2011, by analyzing all influential parameters, urban and rural areas of the capital city were identified, which could be used for these purposes. Figure 2.3.10 shows the locations of PV power plants (zones with thick red borders).

[22] Strategy for the Valorization of Space for Production of Renewable Sources of Energy and Demonstration Pilot Projects, IBI GROUP, October 2011

The above document highlights the conditions for setting up the PV system. Their installation has to be in balance with the protection of significant natural, cultural and other values, and in accordance with other development projects and infrastructure. Physical, relief and climate parameters of

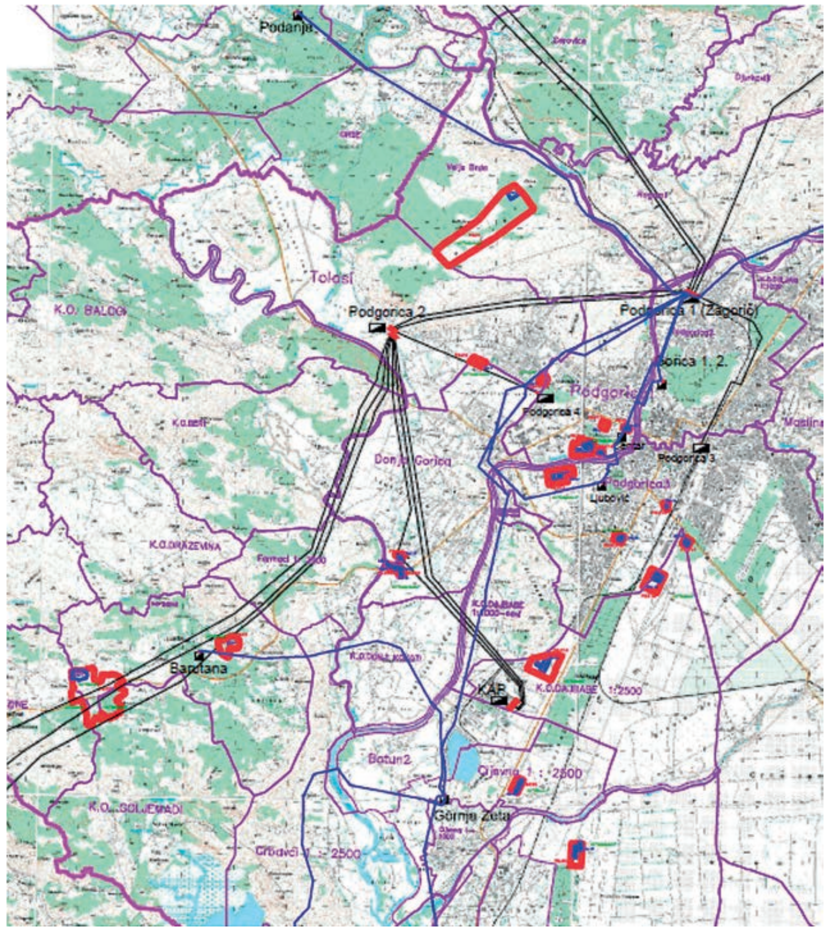


Figure 2.3.10 Segment of the capital city territory with zones for solar power plants

potential locations for the installation of solar projects are defined, as well as the identification of those in which it is prohibited (protected natural assets). Environmental impacts, economic benefits, etc. have also been considered. All future objects will be built to combine energy-efficient design and technology for the production from RES in order to achieve the level of buildings with zero net energy consumption.

a. Zones in the rural area:

- Zone PG-Z1 - in the southern part of the territory of the capital city, at the location of Velje brdo north of the settlement Tološi. The area is 97.91 ha;
- Zone PG-Z2 - in the southwestern part of the territory of the capital city, between the settlements Kornet and Gornji Kokoti. The area is 9.95 ha;
- Zone PG-Z3 - in the southwestern part of the territory of the capital city, between the settlements of Brezina and Barutana. The area is 72,28 ha;
- Zone PG-Z4 - in the eastern part of the territory of the capital city, southwest of Ubli village, and north of the settlement of Medun. The area is 16.21 ha;
- Zone PG-Z5 - in the southeastern part of the territory of the capital city, at the Kaljturk site, and southeast of the urban area Tuzi. The area is 6.93 ha;
- Zone PG-Z6 - in the southeast part of the territory of the capital city, at the site of Kolj Ljekaj, and southeast of the urban area of Tuzi. The area is 14.58 ha;
- Zone PG-Z7 - in the southeastern part of the territory of the capital city, at the location of Kolj Ljekaj, and south-east of the urban area of Tuzi. The area is 7.71 ha.

b. Zones in the urban area:

- Zone PG-Z8 - in the southern part of the territory of the Capital City of Podgorica, at the site Momišićko polje, and in the settlement Tološi. The area is 2.89 ha;
- Zone PG-Z9 - in the southern part of the territory of the Capital City of Podgorica, in Block VI, and east of the settlement Tološi. The area is 2.21 ha;
- Zone PG-Z10 - in the southern part of the territory of the capital of Podgorica, at the site Krusevac. The area is 1.40 ha;
- Zone PG-Z11 - in the southern part of the territory of the Capital City of Podgorica, at the site Krusevac, and on the right bank of the river Moraca. The area is 0.70 ha;
- Zone PG-Z12 - in the southern part of the territory of the Capital City of Podgorica, at the site of Kruševac. Area of the zone is 10.95 ha;
- Zone PG-Z13 - in the southern part of the territory of the Capital City of Podgorica, at the site of Kruševac. The area is 0.87 ha;
- Zone PG-Z14 - in the southern part of the territory of the Capital City of Podgorica, at the site Zabjelo and on the left bank of the river Moraca. The area is 12.18 ha;
- Zone PG-Z15 - in the southern part of the territory of the Capital City of Podgorica, at the site Zabjelo. The area is 2.57 ha;
- Zone PG-Z16 - in the southern part of the territory of the Capital City of Podgorica, on the Tusk road and near the railway line Podgorica-Bar. The area is 0.87 ha;
- Zone PG-Z17 - in the southern part of the territory of the Capital City of Podgorica, on the Tusk road and near the railway line Podgorica-Bar. The area is 1.86 ha;
- Zone PG-Z18 - in the southern part of the territory of the Capital City of Podgorica, south of the Tuski road and east of the railway line Podgorica-Bar. The area is 11.16 ha;
- Zone PG-Z19 - in the southern part of the territory of the Capital City of Podgorica, in the KAP complex. The area of the zone is 19.80 ha;
- Zone PG-Z20 - in the southern part of the territory of the Capital City of Podgorica, at the location of Donja Gorica, and along the left bank of the river Sitnica. The area is 1.20 ha;
- Zone PG-Z21 - in the southern part of the territory of the Capital City of Podgorica, at the location of Donja Gorica, along the left bank of the river Sitnica and along the main road M 2.3 Budva - Cetinje - Podgorica. The area is 2.47 ha;
- Zone PG-Z22 - in the southern part of the territory of the Capital City of Podgorica, at the location of Donja Gorica, near the left bank of the river Sitnica and along the main road M 2.3 Budva-Cetinje-Podgorica. The area is 0.77 ha;
- Zone PG-Z23 - in the southern part of the territory of the Capital Cityof Podgorica, at the site Bjelastavica, and northeast of the settlement of Srpska. The area is 3.71 ha;
- Zone PG-Z24 - in the southern part of the territory of the Capital City of Podgorica, at the airport "Golubovci". The area is 9.18 ha.

The most promising locations include the location located in the southern part of the territory of the capital city, on the left bank of the river Morača, as well as the location in the city center. Locations are roofs of buildings in complexes "Hemomont" d.o.o. and former factory "Titeks", as well as PV power plant of installed capacity of 130 kW on the roof of the UN Eco-building, near the Millennium Bridge. Most buildings have a ground floor and a shed roof. There is a wheeled approach with asphalt or concrete pavements of at least 5 m width to all buildings in complexes. The nearest substation station 35 kV is located east of the site at a distance of about 890 m.

At the end of this section, some of the main advantages and disadvantages of PV power plants are outlined, as well as the approximate cost per installed kW for the three types of solar power plants mentioned above.

Advantages of solar power plants:

- produce clean energy, virtually no pollution;
- have high reliability;
- have small running costs.

Disadvantages of solar power plants:

- have high investment costs;
- require large areas for accommodation;
- their production depends on sunshine.

The approximate prices per installed kW of electric power are:

- Solar power plants with distributed collectors: cca. 1 300-2 500 €/kW;
- Solar power plants With central receiver: cca. 2 000 €/kW;
- Solar power plants with panels: cca. 1 700 -4 200 €/kW.

These elements should be taken into account with care when developing a feasibility study for each concrete project for the construction of PV power plants in the territory of the capital city.

2.3.3.2 Biomass powered plants

The term biomass includes a wide range of residues of plant crops and biological materials. Solid biomass is biodegradable material derived from forest waste (branches, bark), wood industry (sawdust, shavings), the rest of agricultural crops (fruit-growing vineyard, straw, plow), dedicated energy plants. Biomass is the first and oldest source of energy that people have used, which is widely used today to obtain both heat and electricity, thus contributing to the conservation and protection of the environment.

Depending on the type, moisture and volume of biomass, the technologies of its preparation and combustion - that is, the types (constructions) of the combustion boilers. For combustion, classical combustion technologies on the grid (mainly immobile, moving, sloping and stepped) are dominantly used.

The production of thermal energy from biomass has a number of specifics that must be taken into account when designing thermal power systems, selecting equipment and during exploitation. Due to developments in electronics and its increasingly affordable prices, the regulation of operation should be automated to the greatest extent possible, which would enable their energy, economic and ecologically efficient operation, as well as a significant increase in the level of reliability. The lifetime of the biomass plant has been estimated on over 20 years. Biomass boilers are used to generate heat for industrial processes, or for the heating of residential and commercial buildings.

Recently, biomass has been used for cogeneration, i.e. for the simultaneous generation of heat and electricity (Figure 2.3.11), which is achieved using the Organic Rankin Cycle (ORC) already applied in Europe, in a wide range of obtained power from 0.2 to 5 MW and more. The implementation of this system is the most cost-effective in areas that are rich in forests, where the necessary biomass would be produced at the same time. ORC uses a thermal circuit of the thermal oil that serves as a medium for transferring heat from flue gases to a working fluid which, in this case, is not water but an organic fluid.

The advantages of the ORC system are high degree of cycle efficiency (especially in the case of cogeneration applications), flexibility and system inertia, automatic and safe control, lower boiler pressure, high turbine efficiency (up to 85%), low mechanical turbine stress, no turbine blade erosion, very long service life (no erosion and corrosion of pipelines, valves, turbine blades), no water purification system, simple START-STOP procedure and quiet operation is required.

Given the flexibility, this cogeneration system is used in various applications such as central heating (heating plants), pellet production, sawmills (and similar industries that have biomass as a by-product), trigeneration systems with absorption chillers, etc.

Montenegro and even the capital city have biomass resources to implement such systems, but it is necessary to educate farmers and agrocomplexes, to present corresponding advantages and benefits and to provide wider support from local governments and the state itself.

2.3.3.3 Heat pumps

Heat pumps today are among the most efficient heating and cooling systems. Of the 100% energy generated by the heat pump 75-80% is free because it comes from

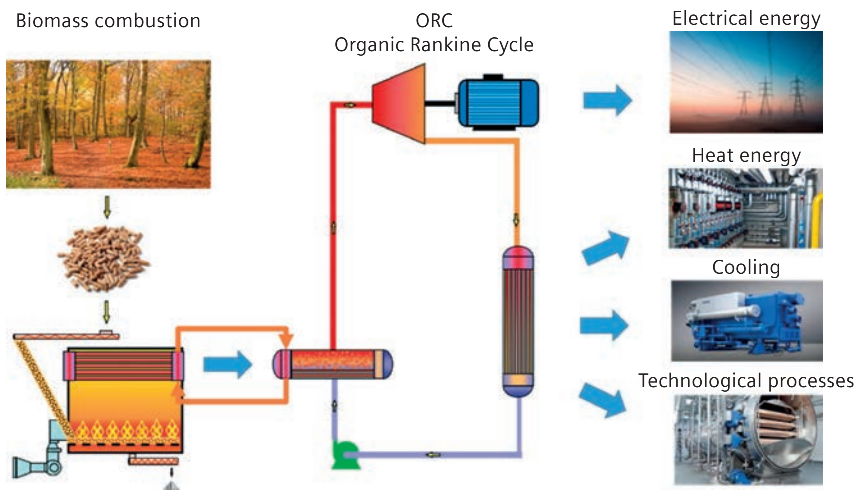


Figure 2.3.11 Combined heat and power generation from biomass[23]

[23] http://www.esco.rs/biomasa.html

the surrounding environment, and only 20-25% of the energy comes from the electric sources that are being paid. Heat pumps are thermal machines that operate in a thermodynamic cycle, draining the heat (cooling effect) from the source of lower temperature and delivering heat (heating effect) to the higher temperature sink with minimal work consumed (Figure 2.3.12). The capacity of the heat pumps ranges from 5 kW to several tens of MW.

The same principle of operation applies to refrigerating appliances (refrigerators, air conditioners). The basic difference between them and the heat pumps is in the effect that you want to achieve. In the case of cooling devices, the goal is cooling, or taking heat from a room or medium (heat source), and in the case of heat pumps, the goal is to heat or heat a room or medium (heat sink).

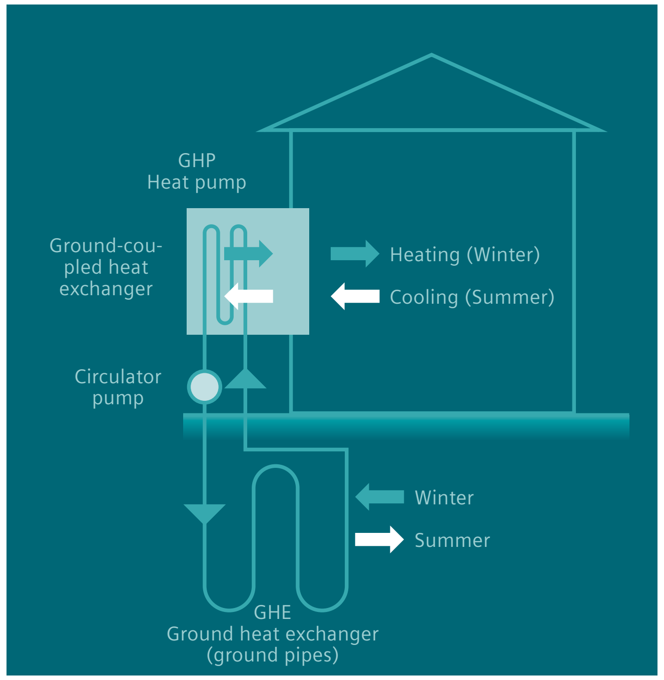


Figure 2.3.12 Thermodynamic cycle of a heat pump

In principle, two types of geothermal energy should be distinguished (GTE):

a) High-Temperature (HGTE), formed as a result of creating a water vapor under high pressures in the Earth's interior

b) Low-Temperature (LGTE) which is a result of the absorbed solar energy in the ground.

In the text below, geothermal energy (GTE) will mean LGTE, that is, renewable energy generated in the ground due to the influence of the Sun.

As a heat source for heat pumps, ground, groundwater, geothermal water, surface water (larger rivers, natural or artificial lakes), water and sewage networks, as well as waste heat from various industrial processes (use of air from rooms or industrial wastewater). The nature and characteristics of heat sources and sinks have a significant impact on the design, construction and method of fitting the machine into the energy flows of the given object.

Heat pumps have wide application in the building industry (heating, cooling and hot water preparation) and in the industry for various technological processes (cooling and heating of products, achieving higher temperatures in the technological process). The advantage of heat pumps is the ratio of energy input and energy, ranging from 1:3 to 1:5. This means that for an investment of 1 kWh of electricity you can get 3-5 kWh of heat, depending on the type of heat pump, type of heating system and heat source from the

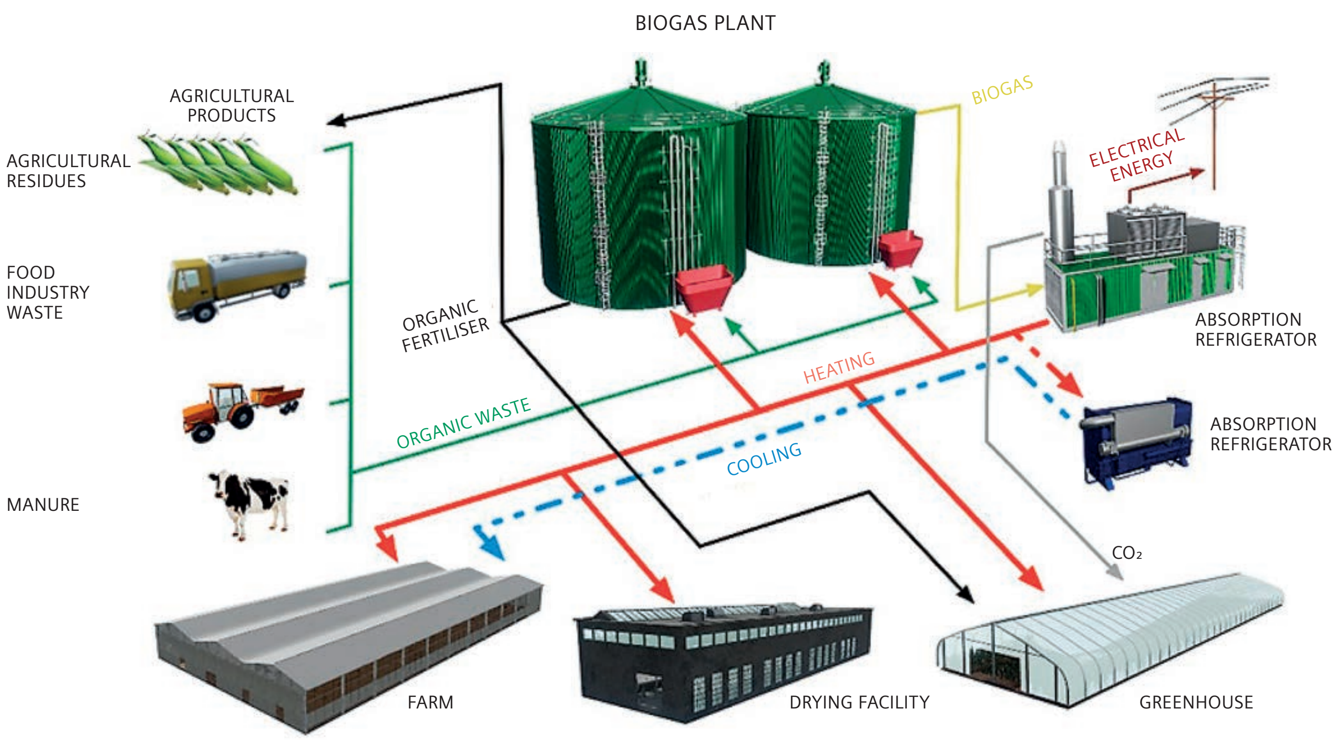


Figure 2.3.13 Cogeneration plant using biogas as a fuel

nature. In order to install a heat pump, it is necessary to fulfill some of the conditions, such as: sufficiently high and constant temperature of the heat source for a long time, a small distance of the heat source and the sink, a heat sink of moderate temperature, as well as a large number of hours of use during the year which enables higher profitability.

2.3.4 Biogas plants

Unlike fossil fuels, biogas is a permanently renewable fuel, since it is produced from biomass which, in fact, is a living storage of solar energy through photosynthesis. The use of biogas helps to improve the energy balance of the country and contributes to the preservation of natural resources and environmental protection. Although CO_2 also occurs when burning biogas, the main difference with respect to fossil fuels is reflected in the fact that carbon in biogas is recently absorbed from the atmosphere in the photosynthesis process. The carbon cycle closes in a very short time - from one to several years. Production of biogas reduces GHG emissions from untreated animal fertilizers. These are methane (CH_4) and nitrogen-suboxide (N_2O) that have a 23 and 296-fold stronger greenhouse effect than CO_2.

Biogas is a combustible gas that mostly consists of methane (CH_4) and carbon dioxide (CO_2). It occurs in a biochemical process called anaerobic digestion, in which complex organic matter (organic substrates) decomposes in the absence of oxygen. Biogas is used for the production of heat, combined production of electricity and heat (in a cogeneration plant), or combined production, electrical, heat and cooling energy (trigeneration).

Different types of organic substrates can be used for the production of biogas, and most commonly they are:

- liquid and solid manure;
- degradable organic waste from the food and agro industry (animal or plant origin);
- organic fractions from municipal waste and catering;
- dedicated cultivation of energy plants.

The rest of anaerobic digestion can be used as high-quality fermented biofuels, or as biomass (after pre-drying and/or palletizing).

The configuration of the biogas production plant depends largely on the type and characteristic of the used substrates (Figure 2.3.13), although numerous combinations of equipment can be considered for the given combination of substrates. The configuration of the equipment affects the quantity and quality (percentage of methane) of biogas. The substrates can be divided into liquid (which can be pumped) and solid substrates. Liquid substrates, after temporary storage in the tanks, are subjected to pasteurisation and sent to the digester. The hard substrates are stored in a "trench" silos or underground concrete tanks (biological waste from the food industry) and they are transported to a digester after the previous manipulation and preparation.

Developing and implementing a biogas production system, based on national and regional biomass resources, increases the security of energy supply and reduces dependence on imported energy sources. At a time when we are increasingly faced with the problems associated with excessive waste production and its disposal, biogas production in anaerobic digesters is an excellent way to reduce the amount of municipal waste and activate valuable resources at the same time. Since biogas production requires labor for the production, collection and transport of substrates, for the production of technical equipment and, ultimately, for the installation, management and maintenance of biogas plants, this means that the development and application of this technology contributes to the creation of new enterprises, the increase in income in rural areas and opening new jobs.

Since biogas is a very flexible fuel, it can be effectively used for the combined production of electricity, heat and/or cooling energy, pumped into a natural gas network or used as a fuel for the propulsion of motor vehicles. Biogas technology should show how agricultural individual farms, large agricultural producers and local communities can be less energy dependent, while at the same time ecologically clean. On this basis they can increase the competitiveness of their products and provide higher revenues.

The new Law on Energy of Montenegro, adopted in December 2015, defines privileged producers of electricity and heat with the right to appropriate subsidies and privileges, while meeting the requirements regarding energy efficiency and environmental protection.

2.3.5 Micro RES installations at households

Micro-generating or micro CHP (micro combined heat and power) is the name for a distributed energy source used in households, or small generation units. At the micro CHP system, heat and electricity are simultaneously produced with power smaller than 5 kW. Most importantly, the micro CHP, instead of the conventional boiler in the central heating system, uses a small gas engine that powers an electric generator. Possible motors for cogeneration can be a combustion engine, a Stirling engine, a steam engine and fuel cells. The engine's waste heat is used in the primary circuit of the heating system, while the generated electricity is used in the household, or the excess is transferred to the electrical network (Figure 2.3.14, Figure 2.3.15). It has the same efficiency of converting gas into heat as a conventional gas boiler and is about 80%. Unlike large CHP plants, the primary production for micro CHP is the heat energy production.

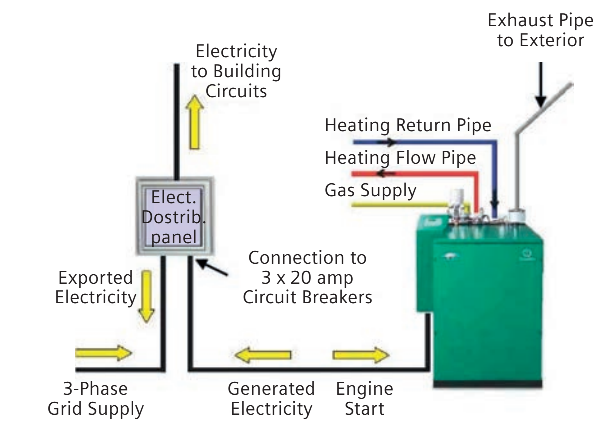


Figure 2.3.14 Micro CHP house system

The most of installed micro CHP systems are in Japan (estimated at over 50,000) and most of them have a Honda MCHP engine. Since 2002, there are about 1000 of them installed in the UK and thet mainly have Whispergen Stirling engines and Senertec Dachs piston engines. About 3000 micro-generating systems have been installed in Germany.

Figure 2.3.15 shows a schematic representation of one micro-CHP system (ecoPOWER), of German production, present in our and regional markets. This is the first micro cogeneration in the market, which is certified according to the strict European Gas Appliances Directive (90/396/EEC). The system has a gas-driven gas engine with variable speed (1,200 - 3,600 rpm), generating an electric power of 1.3 to 4.7 kW and a heating power of 4.0 to 12.5 kW. The connection to the public electricity distribution network is necessary.

The total efficiency of these systems is constant and amounts to over 90%. It is characterized by low GHG emissions and a sound level of 56 dB (A) at a distance of 2 m. For this type the dimensions (height/width/depth in mm) are 1,080/740/1,370, it has a mass of 395 kg, and the outer appearance (Figure 2.3.16) is aesthetically adapted to most home appliances.

However, the costs for a 1.2 kW electrical power system and 11,000 Btu/h (3.22 kW) heating capacity are twice the cost of conventional heating equipment. The price of the system from 2 to 6 kW is from 8.500 to 17.000€. The installation cost is also slightly higher than for the conventional heating system due to additional requirements for gas connection ventilation and measuring connections to the distribution network. For new housing objects, it is around 3.400€ for a system whose electrical power varies between 2 and 4.7 kW. In addition to investment, there are administrative barriers in procedures for obtaining approval for the use of these systems, which is why they have not yet found a more significant application in our households.

2.3.6 Solar water heaters usage expansion

Today, the heat conversion of solar energy is mostly used for heating of sanitary water in residential buildings (dominantly houses), as well as for space heating. The principle of exploitation of solar energy for this purpose is shown in the figure below. Part A refers to the heating of the sanitary water, and part B to the heating of the space.

Namely, the principle is as follows: The solar rays heat the liquid medium in the collector (1). The medium heated to 90 °C circulates between the collector and the storage (2). In a heat exchanger, the medium heated by solar radiation heats the water (3). The storage accumulates the heat that is available at night, as well as on cold days.

For the sake of remembrance, in today's Podgorica, former Titograd, 35 years ago, the idea was developed that solar energy through solar collectors was used to obtain warm water. In that time, such collectors were produced by an Israeli collector factory that sold the license for the production of collectors to the company "Elastik" in Titograd. Due to the fact that the complete technical documentation for the production of these collectors had been obtained, the company "Elastik" managed to not only win such production but also seriously prepare for the placement of collectors especially on the Montenegrin coast. The first large installation of the collectors was carried out at the hotel "Plavi horizonti" near Tivat, which at the time had 600 rooms to accommodate its guests from the then Czechoslovakia. The installation of solar collectors has continued in other hotels on the Montenegrin coast and other locations in the coastal cities of Montenegro. The demand for solar collectors was also present in other parts of the former SFRY, especially in the Republic of Croatia. Unfortunately, however, this production was extinguished during the 90s and "Elastik" experienced the fate of most other industrial capacities in transition in our country and in the wider region.

Solar collectors for sanitary water are used in domestic sanitary water systems as well as for pool heating. The swimming pool covers are also used to maintain heat whenever possible, such as, for example, preheating sanitary water for hotels, villas, pool water, agricultural greenhouses, etc.

Considering the possibilities in the part of the use of RES, the proposed activity of placing solar collectors on residential buildings owned by the Capital City of Podgorica is proposed. In connection with this, a pilot project for the installation of solar collectors for six residential buildings with a net surface of 6,303 m2 was designed. Solar collector type systems (plate or tubular) are planned and they would serve primarily for sanitary hot water heating. They can also be used as an additional segment in the heating system, for example in combination with a heat pump. According to the results achieved, the mentioned activity would include a higher number of residential buildings owned by the capital city in the following phases. The goal of the project is to reduce the consumption of electricity for heating space and sanitary water in buildings, which will serve as a benchmark for identifying the advantages and benefits of applying these technical solutions.

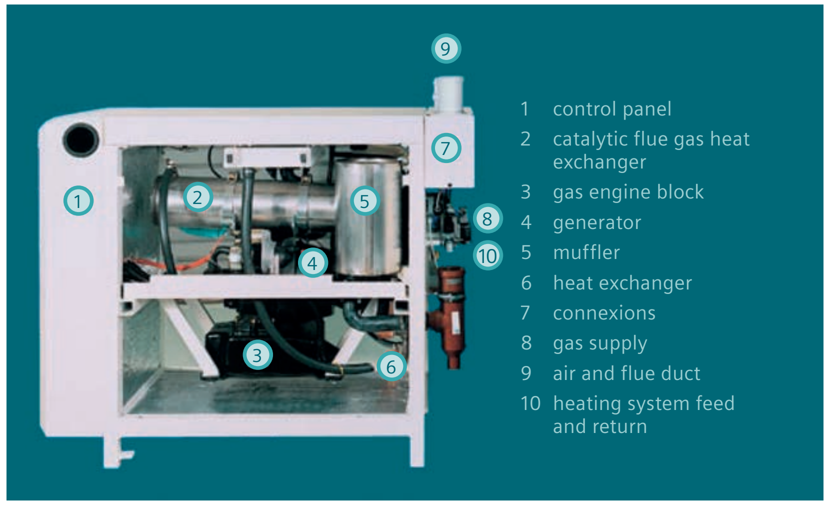


Figure 2.3.15 Schematic representation of ecoPOWER aggregate

Figure 2.3.16 Micro CHP (ecoPOWER) aggregate – appearance

In addition to the installation of solar collectors in residential buildings in the ownership of the capital city, the city plans also envisage the use of collectors for the thermal needs of the following objects: "Ekoplant" - Tolosi, Elementary School "Radojica Perovic", Donja Gorica - Central Activity Zone along Cetinje Road, "Titex" - Zabjelo, Agro-industrial zone, Service-warehouse zone with marshalling station, Service-warehouse zone, KAP and Airport building.

2.3.7 Usage of biomass for supply of heat demand

As noted above, by using biomass (fuel wood, forest residue, fruit and vine residue), heat and/or electricity can be produced.

In addition to the use for household heating, the residue from pruning is used for the production of briquettes at the plant "PlantOMP" located near Podgorica on the plantations of the company "13 July"[24].

The planned capacity of the factory is 5000 tons of briquettes per year, and according to plans, over 95% of production will be exported, while the remaining 5% will be placed on the domestic market. The main purpose of this briquette is for grilling purposes, although the dimensions in which it is produced do not exclude the possibility of its use for the needs of heating (in the appropriate combustion equipment). The factory started operating in the second half of 2011, but it had a number of technical problems and operates in a certain capacity, but full production has not yet been established.

The capital city possesses good soil conditions for plantation of fast growing tree species, for energy needs. The most suitable premises for such dedicated forestry production are the coastal area of the Donja Zeta and the coast of the Skadar Lake area of 10,000 ha which covers a space between 5.5 and 10.44 m above the sea level. A detailed feasibility study would point to more concrete technological solutions for raising intensive rapid-growing plantations in order to produce energy biomass.

Here, a very important energy-ecological project of the system for collecting, draining and burning of landfill gas from sanitary tubs within the "Livade" landfill was launched in 2008. The collected landfill gas is combusted at the so-called "torches" (gas burning tower) with continuous measurement of the amount of gas to be burned. In the first half of 2014, the replacement of the existing torch with a capacity of 150 Nm3/h with a new one with a capacity of 800 Nm3/h was made, due to the increase in the amount of biogas that would be aspirated from the two sanitary tubs.

The company "Landfill" also implements activities aimed at the construction of a plant for the production of electricity and hot water from the landfill biogas obtained from the sanitary tub. The same entity plans to produce electricity from solar panels installed on the roofs of the municipal waste treatment facilities. In this sense, a project proposal for the construction of the mentioned facility was developed, which was applied for the provision of funds from international funds. One of the main goals of the project is the combustion of gas for energy purposes, while achieving economic profit. Realizing it also means reducing the use of fossil fuels, as well as significant economic savings. Also, the maintenance of the necessary equipment is not financially demanding, which enables the directing of funds to solve other current issues.

The construction of a power generation plant by combustion of landfill biogas involves multiple components, so that its purpose can be observed from several aspects. First of all, in this way the issue of biogas is resolved and it establishes the system of functioning of the landfill according to international standards. The purpose of this project is also the possibility of

[24] Akcioni plan korišćenja drvne biomase u Crnoj Gori, FODEMO Project Office, 2014.

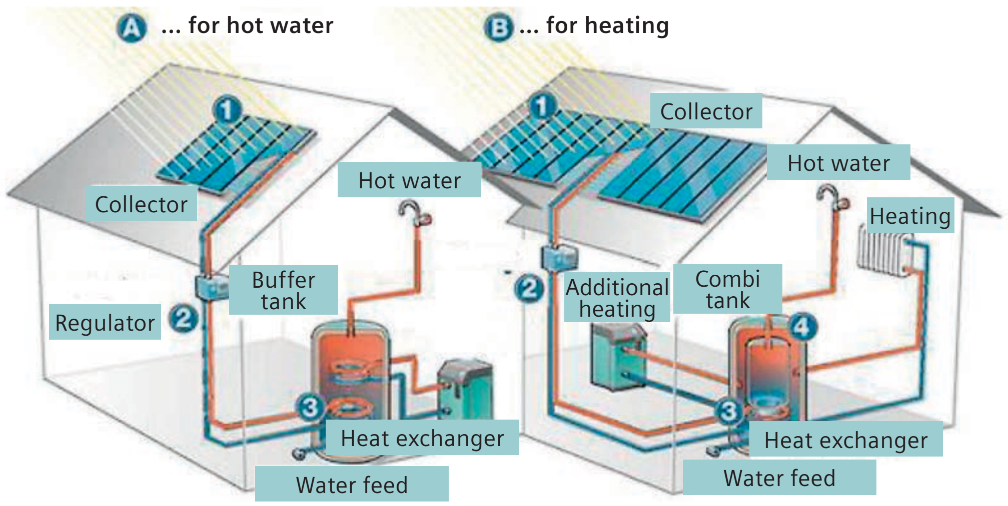


Figure 2.3.17 Principle of using solar energy for heating of space and sanitary water

using electricity for the production of sanitary hot water, which will be used for the heating of residential buildings planned near the location of the plant, which in itself represents an improvement in the quality of life of citizens and a number of other benefits.

2.3.8 Potential usage of geothermal energy

As it is stated in the chapter 2.3.3.3, in order to use the heat energy within the ground, which is at relatively low temperature (+10 °C to +15 °C), it is necessary to lift it up to a higher temperature which exists in the distribution system of the object (around +50 °C). Since the heat in question, by thermodynamic laws, cannot be transferred from lower to higher temperature by itself, some sort of a pump is needed (like in hydraulics when pumping water from lower to higher level), which will, using electricity, "pump" the heat energy from +10 °C to +50 °C. This kind of device is called „geothermal heat pump" (GHP).

Systems with geothermal heat pumps can be divided in 3 categories depending on the heat source/sink. These are: (a) underground waters, (b) surface waters and (c) ground. For the capital city area, due to great availability of underground waters, the first category is especially interesting.

Systems that use underground water are often called "open cycle systems" or "open systems"[25]. The main advantages of open systems are: relatively low installation cost, simple design and small needed ground area with respect to other geothermal systems. Drawback is that in some regions, underground waters are not available in the needed amount or periodically disappear, and their low chemical quality can be also a problem. Also, proper dimensioning and usage of as efficient as possible submersible pump is very important for the total efficiency of GHP installation, especially in the case the water level is at the depth of more than 30 m.

[25] N. Kažić, E. Tombarević, Priručnik za upotrebu geotermalne energije u Crnoj Gori, www.gbc.me

Although GHPs operate with the same principle as "air" heat pumps (AHP), they have better efficiency, which is especially evident if they are used for cooling. This is the fact because the ground and underground waters are warmer during the winter and colder during the summer than the outer air. According to available research, GHPs are more efficient than GHPs for about 25% - 50%, depending on the climate conditions and operating regime.

The area of Podgorica represents a special curiosity because below it there is a "real river" of quality drinking water which flows at speed of 1.5 x 10-5 m/s. Depth of the underground water level during the hydrological minimum amounts to:

- about 24 m in the vicinity of the University of Montenegro;
- 18-20 m in the area near the watercourse Morača, between bridges "Millennium" and "Union Bridge";
- about 35 m in the area near the wells in Stari aerodrom;
- about 15 m in the area of KAP (Aluminum smelter company).

Average well depth during the drought period is about 35 m.

There are several objects in Podgorica that use geothermal energy for space heating and cooling needs. One of the business objects (ATLAS Center) includes a residential part. Within the objects of ATLAS Center, and EUROPOINT, GHP systems are supplied with water from wells of 35 m to 40 m depth and of 200 mm diameter. After the water traverses the installation, it flows out to shallow wells. The temperature of underground water lies in the range 12 °C to 14 °C during the year, and exits the system with a temperature changed for ± 5 °C to 10 °C.

Generally, the impact of these systems on environment is problematic although it is the most economical from the energy point of view. Namely, these systems consume relatively large quantity of water (150-200 l/h per kW), which, for the case in question, represents the important resource of drinking water of outstanding quality. Greater use/pumping of underground waters may lead to the decrease of their level within ground and weakening of this important drinking water resource. Currently valid regulation refers only to usage of waters that are public good. In this case, according to present legislation, it is necessary to ask for a concession if the amount of water greater than 86 m³/day (1 l/s) is pumped out. In the case that well is located on a private property, a concession is not needed although the water exceeds the boundaries of the property. However, it is to be expected that with the increase in use of underground waters an appropriate legislative will follow, which will limit unsustainable exploitation of underground waters. In each case, it is necessary to research appropriate and economically sustainable areas and estimate potential for geothermal energy exploitation within the capital city.

Smart technologies in traffic and communal services

3.1 Traffic

3.1.1 Trends of traffic development in the world

The development of the transportation system in the developed industrial world has enabled an extremely high degree of mobility of people. The development of mobility was primarily based on measures that encouraged the use of individual vehicles. This has enabled comfort, independence, access to work, health services, education and social interactions. Technological improvements regarding vehicles and the accompanying traffic infrastructure have further contributed to the development of mobility, which has also affected the affordability of transportation vehicles and all other attributes of their attraction [3].

Such a development of people's mobility on the other hand has influenced the unpredictable growth of external ecological and economic costs. Within ecological costs, costs arise from excessive noise, air pollution and greenhouse gas emissions. Degradation of urban space, time delays in traffic congestion and traffic jams, traffic incidents fall within the framework of socio-economic factors.

Taking into account these consequences, the developed countries of the world are turning to the approach of sustainable mobility, which, within the framework of sustainable urban development, connects the use of space more as a system of activities with the overall traffic system. In promoting sustainable mobility, it is necessary to emphasize the turning to the values traditionally inclined by the majority of inhabitants and through which the promotion itself is easier to achieve: a healthier way of life, with reduced exhaust gases and an increase in the activity of the inhabitants with the use of non-motorized transport modes, reduced negative impacts on the environment and health.

Part of this approach is also implemented by the EU with a strategy to limit CO_2 emissions in traffic. It is necessary to develop cycling and pedestrian traffic, to encourage and improve mass public transport, to coordinate the use of land, to improve the management of urban cargo and stationary traffic, to perform efficient transport charging (parking fees, fees at the center...), implement measures to reduce traffic, to develop more acceptable forms of transport, to restrict access to vehicles that pollute the space in which we live and encourage the use of cleaner and quieter road vehicles.

The goal of sustainable mobility planning is to meet the needs of the inhabitants for movement without endangering the health of people and ecosystems. In that sense, it is important to harmonize traffic planning and spatial planning. In doing so, the key factor is the limitation of individual car traffic and the development of alternative forms of traffic [3].

Transport infrastructure in European cities is developing primarily in the direction of moving transit traffic to city by-passes, as well as toward public transportation and non-motorized traffic.

The construction of city by-passes reduces the traffic flow density of the most loaded roads that transit traffic through the city, as well as negative emissions to the environment.

To reduce the negative emissions that emerge as a result of traffic flows in European cities, an active traffic policy is also important. It is aimed at encouraging the use of public transportation with the appropriate public transport offer. Daily migration of the population should be redirected as far as possible to the public transport that must be competitive from the point of view of price, travel time and comfort. By limiting individual road traffic in the city core, consequently there are several infrastructure surfaces for the development of other sustainable forms of traffic (e.g. cycling routes). A high quality public passenger transport system and the development of non-motorized forms of transport are areas that need to be paid attention regarding the effective fulfillment of the criteria of sustainable development [3].

Changes of transport modalities, along with the introduction of new technologies, can be achieved with appropriate measures of traffic policy, with the reduction of traffic speed in settlements, with greater restrictions on the access of individual vehicles to the city center, road taxes and the increase in the speed of public transport of passengers. This promotes the development of non-motorized forms of travel and the use of public forms of transport at the expense of the use of individual vehicles.

One of the recognizable solutions for establishing sustainable mobility is the construction of the "Park and Ride" system ("P+R") on the periphery of the city, so that the daily migrants from the region on their way to the settlements will take a more organized public transport of passengers. Passengers park their own vehicles on the "P+R" checkpoints and continue their journey to the city with public transport vehicles, because these locations or points are effectively connected to the city.

3.1.2 Overview of traffic in Podgorica

The largest traffic generators in Podgorica are industry and tourism. The impact of tourism on transport is very high and has a significant seasonal component.

Podgorica has its tourist potential and the possibility to enrich the tourist content of Montenegro through business, transit, excursion, recreational - resort, hunting and sports tourism. It has a significant place in the increasingly frequent tourist traffic of the wider area. A good infrastructure connection with the coast as well as with the northern part of Montenegro put Podgorica in the ranks of Montenegrin towns for which a large number of tourists decide. A special attraction is the vicinity of Skadar Lake National Park. Twenty minutes away from the Skadar Lake National Park, an hour and a half from the ski resort in Bjelasica, and forty minutes away from the sea - Podgorica is an excellent location from which you can go on a tour of the whole of Montenegro. Not far from the city itself, there are the ruins of the ancient city of Duklja, medieval Fortress Medun, and in the very center of the city there are settlements Castle of Nemanja, Old town and many other sights.

In addition to tourism, a significant part of the traffic flows is generated by industry. About 30% of the total registered enterprises in Montenegro are located in Podgorica [3]. A large number of business entities is an indicator of the development of the economy in Podgorica and its strategic importance for the whole country. The largest number of companies is in the field of trade, transport, utilities, construction, and manufacturing. A significant number of businesses is registered in the category of hotels and restaurants.

The analyses carried out in 2010 show that the number of passengers in the direction to the Podgorica exceeds 50,000 / day. The most intensive urban traffic flows are in the direction to the center of the city from suburban areas and towards the southern part of the city, where there is a higher density of workplaces [3].

Forecasts by 2025 show that traffic flows of passengers in Podgorica outside the main tourist season will be in the order of more than 3600 passengers / day from the direction of Bijelo Polje, while from the direction of Nikšić there will be more than 24,000 passengers / working day. From the direction of Bar, the demand for passengers will be greater than 9000 and from the direction of Cetinje 6600 passengers / business day. In total, the number of passengers in the direction to Podgorica will exceed the number of 80,000 / day [3].

The growth of traffic with individual vehicles, the relatively inadequate system of public transportation system and transport subsystems with great negative impact on environment are the goal areas that need to be taken into consideration during modification process of existing transport system in the Podgorica. The main problem is the transport of passengers with individual vehicles which is reflected in traffic congestion, non-competitive public transport due to the low performance of this system and functional disconnection, the transit of cargo traffic through the wider city center, which further weakens the quality of life in Podgorica and prevents the activation of development potentials of the city.

3.1.3 Possibilities for improvement of traffic in the city of Podgorica

The purpose of sustainable mobility in Podgorica is the development of a traffic system based on meeting the criteria of sustainable development. As part of sustainable development, it is necessary to enable harmonious development of sustainable mobility with spatial development. Sustainable transport is defined as the ability to create conditions for free movement, with free access, communication and connectivity without sacrificing other important human or environmental values today and in the future.

The basis of this concept is [3]:

- Moving transit traffic from the city with the construction of the city bypass and connecting to the highway network;
- Modifications of the modalities of the traffic with measures for improvement of the public transport system (bus and rail);
- Defining areas of different traffic arrangements to improve the quality of living in the city with the increase of areas for pedestrians and bikers at the expense of surfaces for individual vehicles;
- Creation of an intelligent traffic center.

3.1.3.1 Moving of transit traffic from the city

Transit traffic represents passenger and cargo traffic flows. Such flows represent a major traffic burden for the city and its inhabitants. City by-passes generally provide transfer of transit from the area of city center. In the example of cargo traffic, the solution needs to be upgraded with the concept of a logistics center, which unites the road and rail terminal with additional logistical services.

Transit traffic through the city center increases traffic congestion and this is another reason more for the downtimes that occur, especially in the summer months. In addition to the lost time in traffic, consequences are also emissions that pollute the environment. This creates high economic costs both at the level of the society and at the level of households. Therefore, transit traffic is a threatening factor for the environment, taking into account the volume of traffic, the possibility of occurrence of negative phenomena, which are accompanied by traffic (noise, air pollution, dust, etc.). Moving this type of transport or relieving the city center of heavy cargo transport, as well as reducing the risk of possible accidents during transportation, should be one of the priorities in the organization of traffic.

3.1.3.2 Modifications of the modalities of the traffic

The great traffic problem in Podgorica is the pressure of daily migrants, who drive with individual vehicles to the wider city center. Reduction of this pressure would partially be mitigated with city bypasses, which would be in the function of scheduling traffic on the city peripherals for the purpose of shorter trips within the city of Podgorica. Another measure to reduce this pressure on the city is to change the mode of transport of daily migrants by increasing the number of users of public transport (PT). To accomplish this, it is possible to carry out the following activities:

- Improvement of the PT system by: integrating city and suburban bus transport and increasing the accessibility of citizens to PT, introducing new lines and stops, increasing frequencies of lines;
- introduction of auxiliary road lanes for PT vehicles
- introduction of the so-called "Park and Ride - "P + R" parking lots i.e. "P + R" along of the city entrance main roads and so on.

3.1.3.2.1 Improvement of the PT system

Improvement of the PT system can be carried out by:

- Introduction of a tramway PT - the advantages of this type of transport can be identified through reduced emissions of pollutants, lower noise levels, adequate capacity for passenger transport and easier manipulation due to less space occupancy of the streets. Also, maintenance requirements are much lower in relation to buses;
- Introduction of buses powered by biodiesel or another type of alternative fuels, hybrids and electric vehicles in PT;
- Integration of all systems and carriers of suburban and urban PTs with the introduction of a unique ticket: A single ticket for the payment of individual travel or in the function of the monthly ticket should be introduced. A unique ticket is an electronic card with a chip (standard banking card), to which the funds are deposited;
- Increasing the accessibility of citizens to PT system by introducing new lines and stops (special attention should be paid to shopping centers, city center, etc.);
- Increasing the accessibility of citizens to PT system by increasing the frequency of PT vehicles on the lines.

3.1.3.2.2 Introduction of auxiliary road lanes for PT vehicles

The justification for the introduction of auxiliary road lanes for buses depends on the transported number of passengers with PT system on a business day. These auxiliary lanes can also be used in emergency situations for vehicles with the right of passage priority.

3.1.3.2.3 Introduction of the "Park and Ride - "P + R" parking lots

The capacity of "P + R" parking lots and traffic modalities, which connect at one point of intersection, depends on the existing and planned supply and demand for public transport. When establishing a parking lot "P + R" it is necessary to:

- Determine the correct location;
- Identify potential groups of users and their accessibility needs (older, disabled, students, daily migrants, low income people, parents with children's strollers, passengers with heavy luggage, foreigners) and include them in the planning process;
- Determine technical requirements and elements and integrate them with spatial requirements;
- Design an appropriate architectural solution of the parking lot;
- Establish a visible and clear signaling, which simplifies the traveler's choice of the trip within the point of intersection;
- Provide an appropriate information system - good information regarding PT services, departure times, delays, purchasing tickets, traffic announcements and availability of information over the Internet or mobile telephony as well as current passenger information through monitors, maps and information points;
- Include the possibility of additional informing - e.g. providing information on the chosen destination of travel (cultural events, tourism, service activities, etc.);
- Provide security and surveillance and design solutions for the safety of passengers and prevention of physical attack, car theft, bicycle, vandalism, etc. (patrols, video surveillance...);

The concept of P+R parking lots is given in Figure 3.1.1.

Figure 3.1.1 Concept of P+R parking lots

Figure 3.1.2. Examples of P+R parking lots

Parking capacity, parking security, comfort, speed and reliability of alternative transport should motivate people to use public transport. Additional motivation is achieved with the appropriate parking policy. Parking in the city center should be limited, primarily parking on the streets. Some parts of the city should be completely closed for the traffic of individual vehicles. In this way, more areas for non-motorized traffic and pedestrian paths are released, while at the same time more space is provided for parking in the city.

A limited number of parking in the city should also be introduced with a stricter policy of charging, i.e. by charging a parking fee at a higher price, differentiated by location and time of day (higher parking fees in the city at the time when the intensity of traffic is greatest).

It is necessary to regularly inform or notify about the possibilities of parking to "P + R" outside the city and about the use of PT system. This part must be very well organized, in order to provide quick access to all locations in the city, especially those that are not accessible to an individual vehicle.

3.1.3.3 Areas with different traffic arrangements

Following the example of European cities and for the purpose of protecting and preserving the city core (buildings, promenades, parks), some areas in cities and town centers should be accessible only with public transport and non-motorized forms of transport. In order to successfully implement such solutions, it is necessary to prepare appropriate measures in advance and to work together to find new solutions.

The measures of restriction or the complete closure of the city traffic center have numerous positive as well as negative consequences. Positive include: positive impact on air quality in the city, regeneration of the city core and service activities, development of non-motorized traffic and greater safety of pedestrians, etc. The negative consequence of the closure of the city core is the decline in traffic and visitors, unless there is adequate access to the PT system.

It is necessary to provide access to vehicles that supply the closed part of the city with passes for the needs of the shops, restaurants, shops and the availability of residents of this area in case of emergencies.

3.1.3.4 Intelligent Traffic Center

Intensive urban traffic flows and vehicle speeds require better control, greater safety and more efficient centralized traffic management. Proper management and control of traffic flows becomes a concern of many European cities. Considering the increasingly important traffic functions in Podgorica, it is also necessary to develop Intelligent Traffic Center.

The Center would manage and supervise the performance of traffic in the Podgorica. At the same time, it would offer traffic information for public and individual traffic. It would serve as a basis for expanding the ability to flexibly streamline traffic in terms of capacity expansion and load reduction. It would collect all information about the state of traffic in the city (statistical and existing) on the ground - by sensors, drivers, AMSCG, police, freight forwarders, those who maintain roads and others. The Center would integrate all data from existing sources related to traffic and even information on current construction works, public events, i.e. data regarding all current events on the city's traffic infrastructure. The Traffic Center would inform the participants in the traffic and provide comprehensive information to all participants.

The example of Intelligent Traffic Center cockpit is given in Figure 3.1.3.

Intelligent traffic system includes the following subsystems for:

- Measurement of traffic parameters;
- Control of traffic light signaling (traffic light and variable traffic signs);

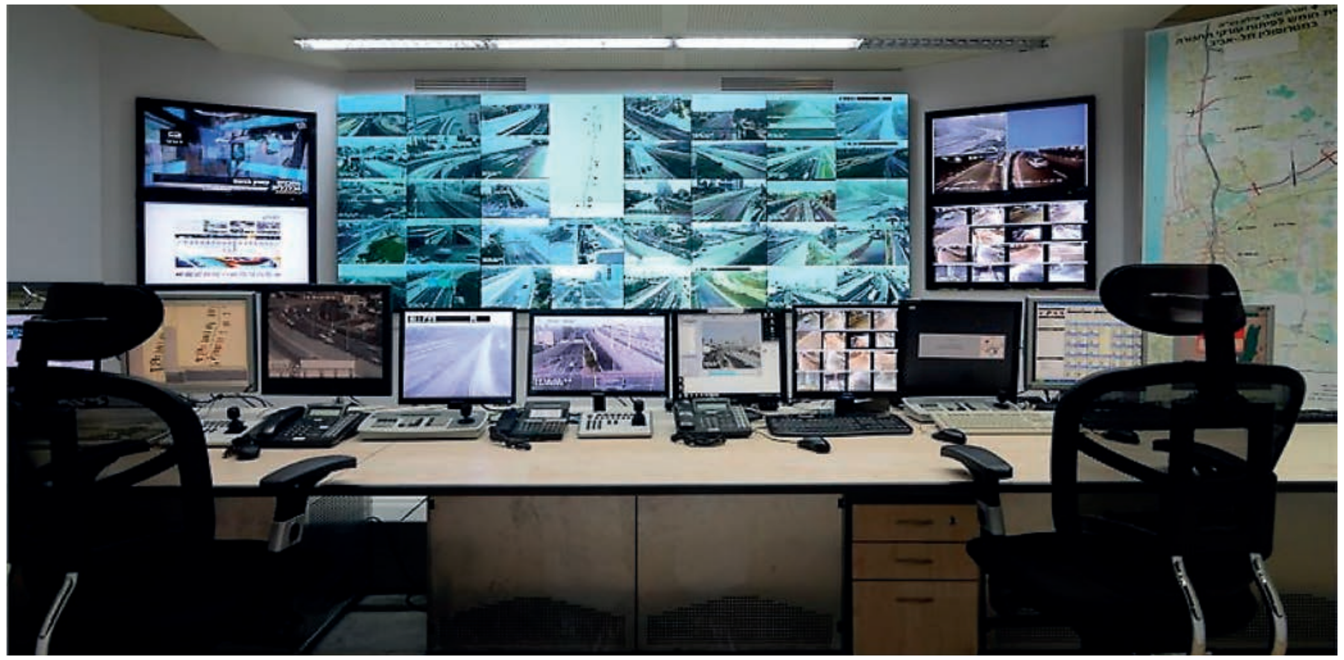


Figure 3.1.3. Example of Intelligent Traffic Center cockpit

- Automatic vehicle license plate recognition;
- Parking management;
- Notifications of the current state of traffic;
- Estimation and prediction of traffic intensity.

Each of these subsystems includes a complex infrastructure consisting of a number of sensors, communication systems and control units in which information is collected, processed, analyzed and, on the basis of specialized algorithms, certain management actions are made. In this sense, each of these subsystems can be implemented as a separate system.

3.1.3.4.1 Measurement of traffic parameters

The basic subsystem of an intelligent traffic system that needs to provide the necessary input data and information for other subsystems is the measurement of traffic parameters. Traffic parameters that are important for all analyses in real time and offline are:

- number of vehicles;
- speed of vehicles;
- spatial distribution of vehicles on roads;
- announcement of pedestrians to cross over a pedestrian crossing etc.

There are numerous solutions that enable the determination of these parameters: inductive loops, cameras, sensors to audio or video signals, etc. Modern sensors also allow determining the type of vehicle as well as detection of pedestrians. The announcement of pedestrian crossing over a pedestrian crossing is provided by pressing the appropriate button on the traffic lights.

All information collected can be made available to other subsystems through appropriate communication infrastructure, while archived data can be used for simulation, analysis and development of non-real time simulations and algorithms.

3.1.3.4.2 Traffic light signal control

Traffic congestions are inevitable feature of major cities around the world. There are many management strategies that are designed to reduce the intensity and duration of traffic congestion, and the best results are achieved by control of the traffic lights, so called coordinated operation of the signal in the context of traffic management on the corridor.

The main advantages of coordinated signal mode are:

- Higher level of service is ensured due to reduced number of stops and higher speeds;
- Higher capacity is ensured, as the available time is more efficiently used;
- The speed of the vehicle's flow is evener, because they move in a wave;
- The number of accidents decreases because time is strictly divided between pedestrians and vehicles;
- Negative environmental impacts have been reduced.

Existing solutions in this area involved adjusting the fixed duration of the signal, the value of which was determined on the statistical processing of data on the number of vehicles in certain parts of the day, defined by the fixed speed of vehicle movement, experience, etc. In general, such solutions can be applied only on a certain number of roads, and the actual state of traffic is largely not in line with the planned solution.

Modern and advanced solutions in this area include two segments: active traffic signal control and variable traffic signs management. Although they can be viewed separately in certain scenarios, they should still be considered as a single system.

3.1.3.4.2.1 Active traffic signal control

Active control of traffic signals is an optimal control of traffic signals in real time. This contributes to the improvement of traffic flow in order to reduce number and duration of traffic congestions, which contribute to increasing the capacity of roads, shorter duration of travel and less pollution of the surrounding environment by the exhaust gases of the vehicle. Optimal control of traffic signalization in real time implies optimal coordination of signal time duration at traffic lights based on the current state of traffic. Information on the current state of traffic is obtained from the subsystem for measurement of traffic parameters. On the basis of the obtained information and certain optimization algorithms, the operation of the signal on the traffic light signalization is coordinated in real time. This system should incorporate the following scenarios:

- Pedestrians crossing – pedestrians crossing should be realized with a variable frequency with prior announcement. Information is obtained from the subsystem of measurement of traffic parameters;
- Emergency or incidental situations in which cases the passage of vehicles with the right of priority is provided.

3.1.3.4.2.2 Variable traffic signs management

Variable traffic signs management allows the remote changes of traffic signs and/or traffic notifications regarding available parking spaces, cost of parking during specific period of day, billing in the city center, etc. This segment can be connected to the active traffic signal control in order to improve the effects of reducing traffic congestion (e.g. by determining the allowed speed of movement, diverting traffic to alternative routes, etc.), to facilitate faster roadway depletion due to emergency or incident situations, etc.

Figure 3.1.4. Examples of variable traffic signs

3.1.3.4.3 Automatic vehicle license plate recognition

The system for automatic vehicle license plate recognition should enable the realization of the following services:

- Payment of access to certain (central) parts of the city;
- Traffic violation detection (exceeding the allowed speed, passing through the red light, passing through unauthorized zones according to a restricted traffic zone, etc.).

This system consists of a recording camera, digital image processing software for license plate recognition and a database for archiving (Figure 3.1.5).

3.1.3.4.4 Parking management

The parking management system is explained in a separate chapter of this Study.

3.1.3.4.5 Notifications about the current state of traffic

Information collected, systematized and analyzed by the previously described subsystems can be transmitted through appropriate communication media (radio signal, variable traffic signs, mobile phone applications) in the appropriate notification form for the users. In addition, information on current construction works, public events, or information on all current events in the city's traffic infrastructure can be forwarded. Examples of these notifications are:

- recommendations for the use of alternative routes in case of blockage of certain roads and / or congestion on roads;
- free parking spaces;
- Payment of access to certain traffic zones or use of certain roads.

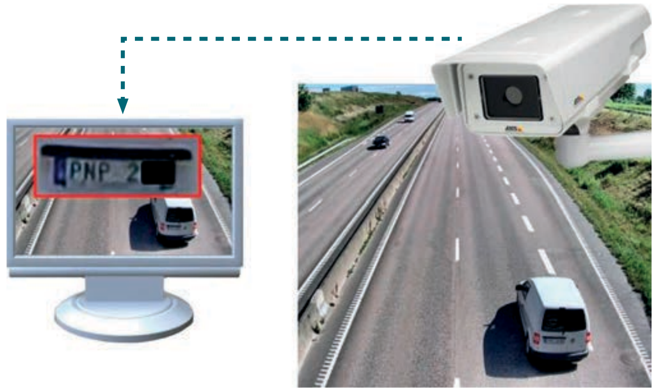


Figure 3.1.5. Automatic vehicles license plate recognition

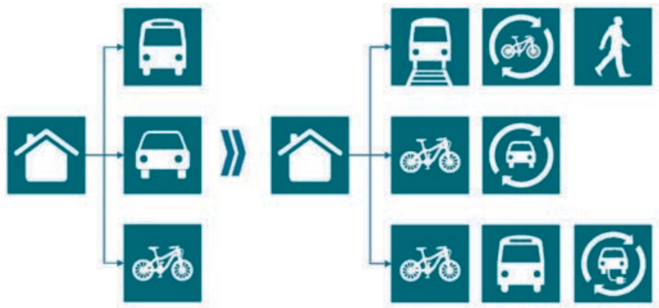


Figure 3.1.6. Examples of multi modal transport [4]

A special notification system can be generated for multi-modal transport or the so-called: Smart Mobility [4]. Smart Mobility means transformation from a mono-modal transport system to a multi-modal transport system. Namely, the customary way of traveling predominantly meant the use of one means of transportation - the so-called monomodal transport system. Research has shown that optimization of costs and time of travel (direct benefit for travelers), as well as reduction of gas emissions, increase of efficiency of services and transport of goods can be achieved by applying multi-modal transport system. A multi-modal transport system involves finding the optimal mode of transport (using different modes of transport) from the aspect of travel time and / or traveling costs, which depends on the current state of traffic and its prediction for the estimated time of transport. An example is given in Figure 3.1.6. Individual users, depending on their trip starting and end-points, can obtain possibilities of multimodal transportation through applications for computers or mobile phones that, based on optimization algorithms, determine the types of transport according to one or more criteria.

3.1.3.4.6 Estimation and prediction of traffic intensity

Equipping all roads with systems for measuring the parameters of traffic is a great investment, so it is therefore expected that all roads will not be covered by the mentioned equipment, at least in the first stages of implementing the intelligent transportation system. However, estimation models can provide an approximate expected state on a certain number of traffic routes using measurement data. In this way, the range of traffic monitoring in certain zones can be expanded analytically.

Statistical data of measured traffic parameters archived in databases can serve for different types of analyses. The obtained results, coupled with the planned events at a certain time interval, can be used to predict the traffic intensity and to prepare the necessary measures in advance.

3.1.4 Possibilities for use of electric vehicles in public transportation

Limited oil reserves, increased prices, highly developed awareness of the harmful effects of exhaust gases, pronounced noise are reasons that slowly but surely affect the world of oil and oil derivatives becoming a past. This is also supported by the decision of EU countries to gradually and finally stop using fossil fuel vehicles in the near future.

Different solutions appear as an alternative: the use of vehicles on other types of fuel (e.g. biodiesel, hydrogen...), hybrid vehicles and electrically powered vehicles.

Of all these solutions, electrically powered vehicles have the highest number of advantages:

- do not emit exhaust gases;
- have low noise levels;
- maintenance costs are much lower compared to internal combustion engines due to a smaller number of moving parts.

The disadvantages of electric vehicles on the current development of technology are:

- Relatively low autonomy with one battery charge and its dependence on external conditions (outside air temperature, cabin air conditioning, operation of other electric vehicle consumers, etc.);
- Relatively short battery life;
- Relatively high battery prices.

Other obstacles to the greater use of electric cars are the lack of public and private infrastructure and the fears of drivers from missing energy before reaching their destination due to the limited reach of existing electric cars.

For all of the above reasons hybrid vehicles are used as transient solution, which in the event of lack of power from electric batteries have the possibility of starting over a diesel or gasoline engine.

The use of hybrid buses and electric buses combines the benefits of the vehicles themselves and the positive effects from redirection of passengers to greater use of public transport (PT). Analyses have shown that most favorable approach for charging batteries of PT vehicles is the so-called "opportunity charging". This approach implies the installation of fast charging stations at both ends of the bus line. The batteries are charged for a short time, enough to be able to power electric motors and other bus consumers until they reach the charge station at the other end of the line. An example of such a charge is given in Figure 3.1.7.

Opportunity charging has a number of advantages:

- Requires lower capacity batteries;
- Charging takes place during the day when part of the necessary electricity can be produced from alternative sources (e.g. from the Sun), which additionally has a beneficial effect on reducing the emission of harmful gases;
- The charging of a larger number of buses is not at the same time, thus relieving the network from simultaneous load.

The more intensive use of individual electric vehicles is primarily conditioned by the development of the appropriate infrastructure. It implies:

- Development of a power distribution network;
- Installation of slow charging station for batteries charging overnight;
- Installation of fast charging station for batteries charging as needed.

The development of a power distribution network capable to supply new loads due to

Figure 3.1.7. Fast charging station at the end of bus line

Figure 3.1.8. Connection of vehicles to chargers at parking lots

Figure 3.1.9. Connection of vehicles to charger in garage

battery charging is a prerequisite for the expansion of the use of electrically powered vehicles. Development should be directed both at higher voltage levels (by providing the appropriate level of reliability), and at lower voltage levels by designing and constructing appropriate installations that will ensure battery charging.

Installation of slow chargers for charging batteries during the night will be the biggest challenge, especially in residential parts of the city with a high population density. In this situation, it is necessary to find a suitable technical solution that will provide the possibility for an appropriate connection for each parking place (on roads and underground garages) in order that each parking user has the opportunity to charge the batteries at night.

Installation of fast chargers is necessary for recharging batteries during the day. These chargers have a significantly higher power than those intended for slow charging, and therefore their installation is more expensive and technically demanding both in terms of the devices themselves and in terms of power from the distribution network. Such charging station should be installed at places of former petrol stations, near shopping centers, sports facilities, administrative buildings, etc.

Figure 3.1.10. Public fast charging station at the place of previous petrol station

Figure 3.1.11. Public fast charging stations near public objects

3.2 Improvement of public utilities using smart technologies

3.2.1 Water and wastewater management

The application of smart technologies in the field of water supply and wastewater treatment includes smart meters, water loss sensors, pressure sensors, flow meters and water quality sensors.

All data obtained from the sensor is forwarded to the control center for analysis in real time and offline, and for the creation of management actions (SCADA system).

Expected benefits from the application of smart technologies in water supply activities are:

- Monitoring of the current state for preventive maintenance. By analyzing the obtained data, the status of water pipes can be assessed and, according to their state, it is possible to define the strategies for repair or replacement of existing pipes;
- Measurement of water pressure in the pipes enables the implementation of corrective actions in order to reduce stress on the pipe, avoiding defects and prolonging the working life of pipes and related equipment;
- Measurement of water flow allows monitoring of consumption in normal conditions, as well as determining the leakage of water due to the failure of pipelines and associated equipment. Sensors and gauges allow the detection of leakage of water from water pipes due to failures before their escalation and the appearance of water on the surface. In addition, it is possible with a certain degree of precision to determine the location of the failure in order to send the team for repairs. Also, by automatically activating the valves, water losses, floods and additional damage can be minimized;
- Monitoring of water quality allows early warning and automatic control actions by closing the valve to prevent the spread of infected water;
- Water consumption meters allow end users to monitor consumption in real time to conserve water and make it more efficient. Also, by analyzing these data, combined with hydro and meteorological measurements, water supply companies can get better predictions of water demand requirements for planning dispatching of pump operations, pool reservations, water supply network loads, etc;
- Analyses of measured data can play an important role in future planning of water supply network development and decision making.

Similar solutions can be implemented in the wastewater system, regardless if it is a separate or combined system of sewage systems and atmospheric precipitation systems, as well as with wastewater treatment plants.

3.2.2 Waste disposal

The increase in the number of inhabitants in cities is not a challenge only from the aspect of providing transport services, energy supply, public security and other utilities, but also waste management.

Smart technologies can also be implemented in this area, thus allowing utility companies to manage municipal solid waste in an efficient and sustainable way. As in other areas of responsibility of city administration, information and communication technologies (ICT) are launching many of these new solutions, especially in the area of waste collection.

Solid municipal waste refers to solid materials that are no longer needed or their primary use is complete. In more developed countries, recycling, composting and energy transformation programs are already redirecting significant amounts of municipal waste from landfills. However, the analysis suggests that the total amount of municipal waste continues to grow.

3.2.2.1 Importance of solid waste management

Cities must effectively deal with solid waste for several reasons:

- Protection of public health. First of all, cities manage waste to mitigate the impact on public health. As a propagation medium for bacteria, insects and pests, accumulated waste is associated with the spread of diseases that are transmitted by air and water. The industrial revolution and the mass movement of workers into cities have prompted the first rigorous efforts in addressing and improving urban sanitation. These efforts included the systematic collection of waste through separate combustion plants and landfills;
- Environmental protection. The environmental impacts of traditional methods for waste disposal - and their impact on public health - have begun to be observed after World War II. Gases at the landfill sites are produced by decomposition of organic materials. They contain carbon dioxide, methane, volatile organic compounds, hazardous air pollutants and unpleasant compounds that can adversely affect public health and the environment. There are also significant emissions of carbon that are released when transporting municipal solid waste;
- Cost control. Solid waste management can be a significant part of the municipal budget. For cities in poor countries, garbage collection and disposal is often the largest budget item;
- Promoting sustainability. The practice of waste management is becoming more and more related to the sustainability goal. Programs that encourage the prevention, recycling and recuperation of materials directly support new sustainability goals by reducing resource and energy requirements and the need for creation of new landfills.

The "zero-waste" approach is even more pressing from the sustainability perspective. This movement aims not only to eliminate waste through preventing the generation and recycling of waste, but also restructuring the production and distribution system in order to restore everything - theoretically eliminates the need for landfills and incineration completely. This approach of product design in the way that their materials can be constantly returned to the production process is the basis of what is called a circular economy. Numerous cities in the world and the region officially adopt zero waste as a goal.

3.2.2.2 Consideration of waste as asset

A search for sustainability is a change in thinking about existing waste management practices. Namely, waste should be considered as a source of funds for the renewal of materials and energy. The first message to municipalities that discusses best practices for waste management is to shift from the point of view of discarded materials as waste and responsibility, to point of view according to which each waste is potential asset that needs to be recovered and returned to the market. This focus on widespread recovery of waste components aims to reduce the amount of waste going into problematic landfills and incinerators. But it also introduces the idea that waste represents a source

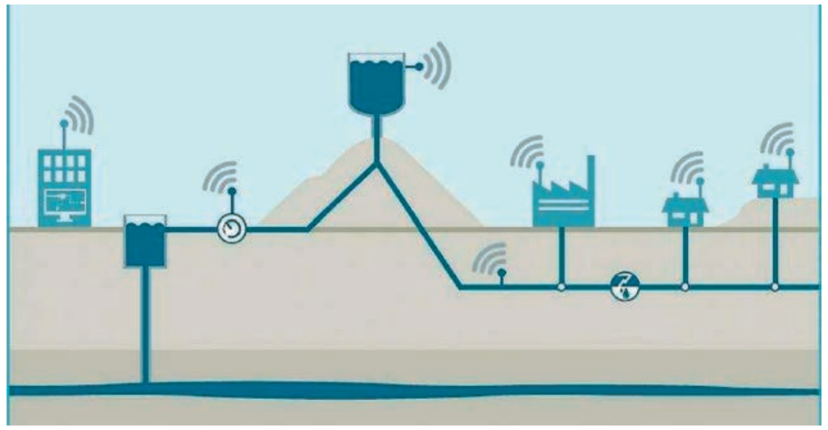


Figure 3.2.1. The principles of application of smart technologies in water supply networks

of revenue. Cities now have the opportunity to sell their waste streams to companies that sort, redirect, and process waste into products that have a new market value.

3.2.2.3 Determination of waste characteristics

For cities that start new waste management initiatives, it is first necessary to determine the characteristics of waste. Municipalities need to understand the nature of waste generation in their community, including what is in it, where it comes from and how much of each type is present. Waste characterization studies include urban demography, land use and business data. Using GIS data can help to plot the physical location of waste generators, while useful analytical tools help city management to determine where there are concentrations of large volume generators of certain types of waste.

3.2.2.4 Application of smart technologies in waste management

Smart waste management technologies can be considered through the following phases:

- Waste collection;
- Recycling of waste;
- Transformation of waste into energy;
- Waste disposal.

Waste recycling technologies, transformation of waste into energy, and waste disposal are technological operations in which the impact of smart technology is largely reflected in the application of sensory techniques that enable process optimization. For this reason, they are not the subject of this Study.

3.2.2.4.1 Waste collection

Collecting solid waste in the municipality is a relatively expensive activity that also has a polluting effect on the environment. In general terms, the collection of waste requires a large number of employees (physical workers and drivers) who operate trucks that emit exhaust gases into the environment.

Smart waste collection solutions can eliminate the unnecessary departure of waste trucks to locations where there is not enough waste, which directly reduces fuel costs and the effect of exhaust gases, while reducing related operational and maintenance costs regarding the collection vehicles.

3.2.2.4.1.1 Sensors in waste containers

Fixed discharging schedules for waste containers according to specific times and pathways dissipate both time and fuel when trucks arrive at some empty containers in the collection schedule. In order to better determine when the waste containers really need to be emptied, utility companies can install micro sensors in them that determine the status of their occupancy and forward this information to the central data center. The operating principle and the example of the sensors are given in Figure 3.2.2.

In cooperation with the company "Čistoća d.o.o.", the possibility of using these sensors has been analyzed and a proposal has been made for the sensors to be installed in underground containers with volumes of $3m^3$ and $5m^3$, with well-designed software using GIS technology.

Garbage sensors can also be installed in combination with trash compactor containers and / or waste bins. This increases the capacity of containers and further reduces the number of required journeys of waste trucks.

Figure 3.2.2. Examples of sensors in waste containers

Figure 3.2.3. Example of trash compactor bins

Trash compactor waste bins have the ability to compress mixed or specific content (plastics, paper, etc.) using built-in mechanical compressors, thus increasing the capacity of the bucket and reducing the need for its frequent discharge. Consequently, the costs are reduced and operation of the utility is optimized. These bins for their work use electricity that can be obtained from its own source through solar cells and small batteries for the accumulation of electricity. An example of such buckets is given in Figure 3.2.3.

3.2.2.4.1.2 RFID tags on waste bins and recycling bins

In some cities, Radio Frequency Identification (RFID) systems for waste collections are being developed. Labels are associated with a particular resident or address and, similar to a bar code, can be read by equipment on vehicles for collection. Collected RFID information is sent to a city database where it can be analyzed to help cities in several ways. For example, RFID allows trucks to record weight and filling capacity (Figure 3.2.4). Analysis of these data enables utility companies to optimize the routes and collection schedules. The result is a smaller number of trucks that operate less often, and the results reduce emissions of exhaust gases and air pollution. The European Commission's technical study on the use of RFID in the recycling industry shows that the use of an RFID system can reduce waste collection costs by up to 40% due to reduced fuel consumption and air pollution [5].

Another use of RFID tags is the monitoring of residents habits regarding recycling. Cities could then direct educational programs to those who do not participate in recycling, provide incentives for people who recycle, and so on.

This technology can also be used to develop a pay-as-you-throw system (PAYT), by which each user of the utility company's services is charged as much as the waste they produce and throw.

The proposal by company "Čistoća doo" is that RFID tags would be most relevant in recyclable yards, which are also located on the territory of the capital city, where citizens would receive identification cards. These cards would contain evidence of the number of citizen's visits to recyclable yards and the amount of disposal waste, which would then affect the reduction of their monthly bill for the removal and disposal of municipal waste.

3.2.2.4.1.3 GPS truck tracking

Use of the Global Positioning System (GPS) has proved useful for optimization of waste collection routes, improvement of driver behavior and reduction of operating costs.

3.2.2.4.1.4 Route planning based on GIS

The Geographic Information System (GIS) can be used to create, record, analyze, manipulate and display geographic information. GIS technology is now starting to play an important role in modern solid waste management practices. This can help with waste collection planning routines, as well as the thoughtful location of recycling centers, material recovery facilities, warehouse waste yards and landfill sites. This system is already in use in the city company "Čistoća d.o.o." and proven to be an effective type of control.

3.2.3 Parking service management

Due to the intense increase in the number of private vehicles, especially during the tourist season, as well as the lower number of parking spaces, one of the biggest problems in city centers are free parking spaces. Studies show that in large cities:

- 1/3 traffic in the narrow city core is caused by the search for free parking places [6], [7];
- 4.5 km is the average length of the additional traveled road during search for a free parking space [8], [7];
- Individual car is parked almost 23h daily in average (especially during working days), which makes difficult to find free parking places [9], [7].

Figure 3.2.4. Reading RFID label of container

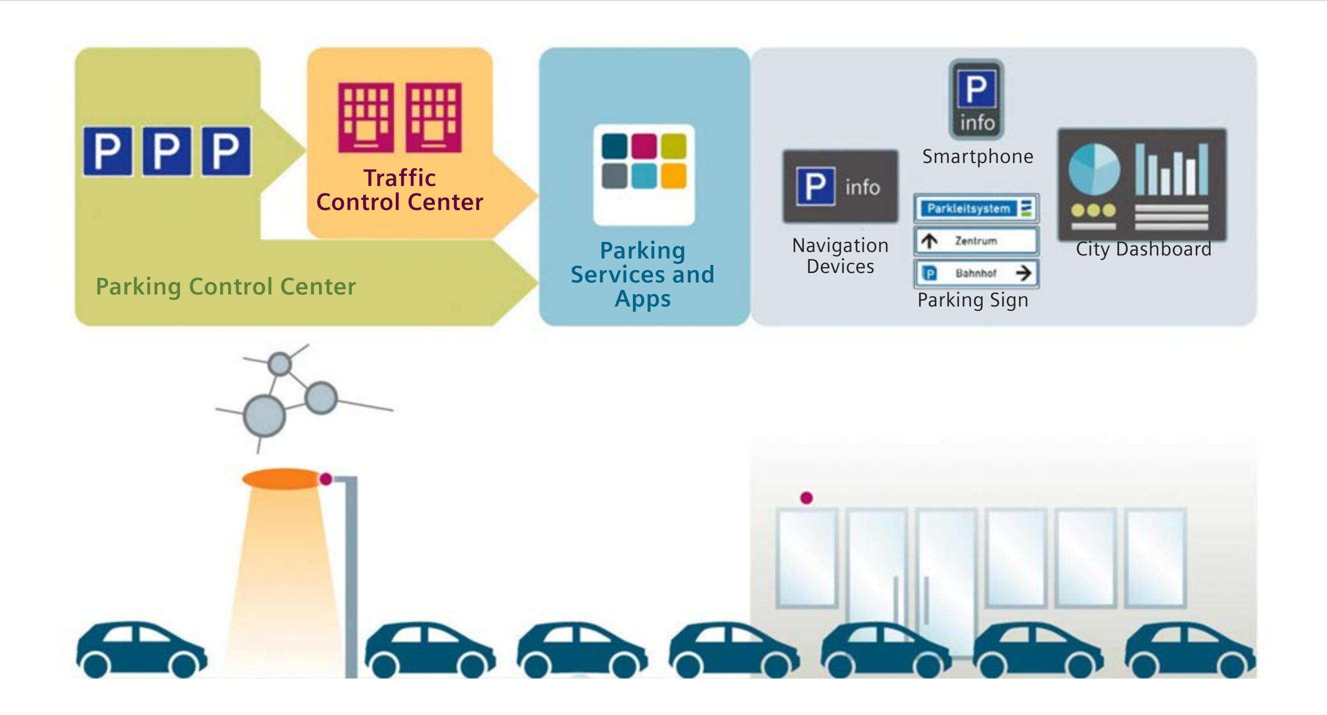


Figure 3.2.5. Principles of parking management system [7]

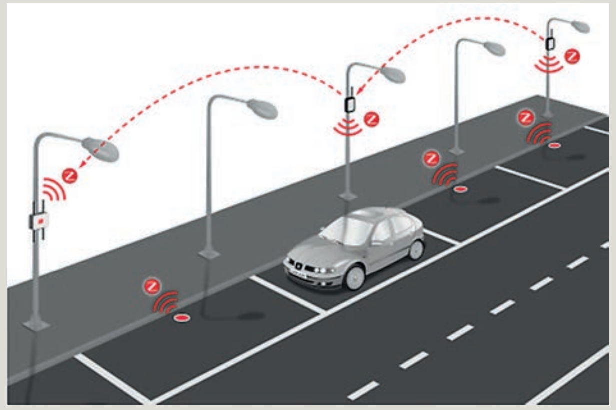


Figure 3.2.6. Examples of sensors locations

Figure 3.2.7. Example of sensors located on existing objects

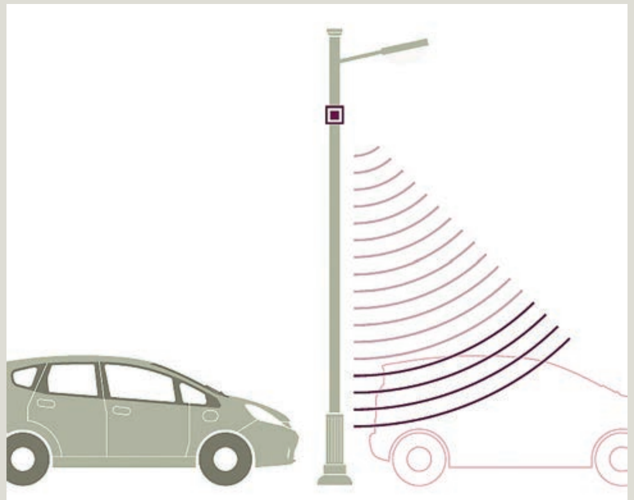


Figure 3.2.8. Sensor mounted on lighting pole [7]

All this points to the necessity of appropriate parking management system. Studies show that use of such systems can [8], [7]:

- Reduce the search time for free parking places by about 43%;
- Reduce the distance traveled for free parking space by around 30%;
- Reduce congestion in traffic by 8%;
- Reduce the emissions of greenhouse gases.

3.2.3.1 Parking places on public spaces

In general, the parking space management system for public surfaces consists of an appropriate solution for identifying free parking spaces, a central control unit with parking management software and ancillary communication networks and information exchange applications. Possible implementation of the system is given on Figure 3.2.5.

Recognition of free parking spaces should be realized using sensor technology (without the use of cameras) to protect the privacy of people. It is possible to use combinations of sensors placed on the ground (recognizing only one parking place) and / or sensors located at high altitude objects (public lighting poles, buildings near the street, etc.). Examples are given in Figure 3.2.6 and Figure 3.2.7.

The sensors installed on existing objects (example is given in Figure 3.2.8) have a number of advantages over the ground sensors:

- There are no significant investments in infrastructure;
- Power supply and signal transmission can be provided by using existing installations;
- Better coverage of parking spaces with fewer sensors than the sensors on the ground (which can provide coverage of only one parking space);
- They can be used for other purposes such as monitoring traffic speed, breaking parking rules, etc.

The information obtained from the sensor is transmitted in the appropriate format to the central control unit via the appropriate communication medium (optics, Wi-Fi signal, GSM / GPRS signal). This information can be used for:

- the driver assistance system for finding parking spaces (applications for phones or navigation systems);
- the driver notification system for the availability of parking spaces in a particular zone for the purpose of selecting another mode of transportation (applications for phones);
- light traffic signs with information on the number of free parking spaces;
- control of traffic in the appropriate traffic zones.

3.2.3.2 Parking places in the public garages

The parking management system can be significantly improved by linking with systems in garage parking facilities. Such objects may be equipped with a system which:

- Transmit information on the number of free parking places in the garage facility to the central control unit;
- Allows the user to book a free parking space through an application which helps drives to directly go to the reserved location.

3.2.4 System for notifications related to city services information

The citizen notification system on service information should provide access to information via easily accessible media (today, mobile applications are the most suitable). Through the application following information should be published:

- All news related to the utility system, development projects, modernization, announcements of works to be carried out throughout the city, as well as announcements of events that will take place in the city;
- Information on modifications of the traffic in parts of the city where the works are carried out, as well as information of public importance;
- Information on public transportation timetables and their changes;
- A list of all citizen services phone numbers;
- A list of all taxi association numbers, etc.

In addition to the aforementioned information, modern systems for informing citizens about service information should provide opportunity that users can report problems either through the application or through a phone call. A citizen should have the possibility to report a communal problem from the site, with a photo of the problem, which is immediately sent to the application database and forwarded by the operator to the responsible service. The citizen who has reported the problem in the shortest time should be contacted by operators for possible additional information. When a response from the service responsible for the problem is received then the user of the application is informed by phone about the response.

Similarly, citizens should have the opportunity to be informed immediately after the filing of a complaint about the possible intervention of the Municipal Police, and especially about its jurisdiction over the complaint. If the complaint is not within the competence of the Municipal Police, it should be forwarded to the competent authority, about which the user should be immediately notified.

The advantages of this approach are as follows:

- recording of telephone conversations, which will avoid all confusion related to receiving;
- forwarding applications to the competent services for a short period of time;
- faster communication with citizens regarding the services of public utility companies and other entities to which the city has entrusted the performance of utility activities;
- electronic records of received applications, etc.

Available EU funds for project financing

The classical approach to municipal project financing is using the state government financing. However, since this is no longer available in significant volumes to the municipalities, they cannot continue to depend on state budgets to sustain the renovation of their infrastructure. This is especially the case for energy related projects (energy efficiency related projects are the most obvious examples), which are usually overlooked when budgeting funding for reconstruction or renovatio, and have to compete with other funding priorities such as road construction (which is among the most popular municipality projects). It should be pointed out that, until there is a legal framework enabling energy-cost savings, resulted by the project implementation, to be reinvested or used to pay for new projects, it can be difficult to attract investors to energy related projects.

Experience suggests that even in countries where the local financial market has sufficient size and liquidity, consumers and investors may have limited access to local institutions due to perceptions of high risk, high transaction cost, lack of institutional infrastructure and project development capacity, or lack of awareness regarding technologies and their technical and financial performance characteristics. Supporting financial intermediaries and providing risk-sharing instruments to financial institutions (credit risk guarantees and other contingent finance instruments) can be cost-effective ways of addressing these barriers. Microcredit, commercial loan guarantees for ESCOs and revolving loan funds have all been successfully demonstrated in many EU countries.

While both external and internal financing is often used for financing a municipal energy project, internal financing relies mainly on the municipality's own equity, and external financing deals with borrowed funds or increase of debt. Though in general at least 20 percent of the total project costs must come from internal financing, it is usually difficult for municipalities in countries with economies in transition to put up enough internal funding to enable implementation of a sizeable project which would generate return on investment quickly enough to make the project bankable and ensure adequate external borrowing. There are many reasons for this: for example, ambiguous and poorly defined ownership rights and responsibilities, low municipal revenues due to high unemployment and low salaries, limited local budget authority and borrowing limits placed on municipalities. A project heavily financed with internal equity might restrict municipal utility infrastructure growth and improvement, while too much external funding might make the project risky. External financing can be realized with bank loans, bonds, leasing and state subsidies.

Though a variety of financing instruments exists, local financial markets still have limited capacity and are unable to provide adequate financing of municipalities' projects. In theory, the municipalities should aim at attracting not only domestic, but also international financial markets for project funding.

Experience to date shows that the majority of water and wastewater, heat supply and street lighting projects have been financed through funds from international donors and IFIs. These international development institutions typically use grants or loans to demonstrate how energy-efficiency projects generate cost savings to finance the improvements. Soft loans are common in such projects, which often aim to attract commercial finance. More innovative approaches unique to energy efficiency are revolving funds and performance contracts, and international partners often encourage demonstration of how such funds and contracts work in the local setting. Vendor credit is also becoming more popular in emerging market economies.

It is necessary to mention that it is crucial for the municipality to work on project design, conduct energy audits, set energy savings targets, prepare a feasibility study, draft a project proposal and estimate cost and resource savings prior to seeking financing. Often a municipality will secure the services of a private sector firm to assist with this, such as an ESCO or other energy efficiency service provider. It is advisable to seek co-financing from several sources. For example, the municipal budget spending can be used for project preparation, energy audits, feasibility studies, interest payments and project management, while borrowed equity or grants can be used for project implementation.

The common steps for financial sourcing can be expressed as the "3Cs" of finance: character, cash flow, and collateral:

- Character is a determination of the applicants' credit history and credit worthiness – past loans, repayment timeliness and current ability to pay. Establishing character is difficult in cases where the applicant has not had the opportunity to earn credit;
- Cash Flow essentially involves establishing technical and financial baselines, and the savings that will result from the project in order to evaluate feasibility and the existence of a positive cash flow. This can be difficult when metering is insufficient to measure both production and consumption of energy, non-payment is common, and accounting systems are not transparent;
- Collateral is established by the security of the asset, where the loan is typically less than the value of the asset that is pledged to the lending institution in the event of default. In general, energy efficiency projects tend to be more distributed, thereby more difficult to collateralize. In addition, a difficulty in transitioning economies is determining the true value of a commodity or property, and whether the legal and political systems will allow the lender to seize assets in order to recover an unpaid loan. This often results in vendors unwilling to finance investments and lenders requiring a guarantee.

South East Europe requires several billion euros of investment in renewable energy sources and tens of billions of investment in energy efficiency and transmission infrastructure over the coming decade. The region's energy markets are not sufficiently developed or competitive. Political risks and regulatory discontinuity impede private ownership and financing. Regional banks, project investors and local authorities lack the experience required to develop bankable renewable energy and energy efficiency projects. Lack of regional cooperation in energy sector planning increases overall investment and financing requirements. There are various financial mechanisms available for financing of energy related projects:

- Municipal/State General Budgetary Funds – independent decision-making power, but limited funds availability; may not be available for large scale projects;
- Special Purpose Funds
  - Grants – generally, the most popular financial instrument since there is no repayment necessary. They are accessed through Government, donors and state banks. Grants are usually related to specific development assistance programs, like technical assistance for project development. The availability of grants depends on the project type, quality, as well as the policy of potential donors. The Global Environment Facility (GEF) is a resource that should be considered. UNEP, UNDP and World Bank are serving as implementing agencies;
  - Revolving Fund – requires only a one-time initial investment, assuming it is managed properly to accumulate adequate savings to sustain future financing. In order for the revolving fund to be sustainable, it is necessary to ensure that metering and monitoring of energy savings is accurate and systematic. This may be a challenge for municipalities which are not equipped with energy information system;
  - Guarantee Facilities for Commercial Bank Loans – Usually, if a municipality's credit rating is unsatisfactory due to lack of previous financing experience, credit guarantees can be obtained from special guarantee facilities established by international donors and international financial institutions (IFIs) to lower barriers to commercial financing;
  - Municipal Bonds – makes the most sense when the size of the municipality is significant enough to attract the attention of investors. Issuing municipal bonds requires lengthy and expensive preparatory work that consists of analyzing and forecasting the municipality's financial resources, and launching a procedure for obtaining a credit rating from an international credit agency. Bond financing is beneficial when the revenue from bond issuance is eligible for tax breaks or tax exemptions. The downside to bond financing for municipal energy efficiency is that bonds' maturity date is not correlated to the financial savings from the energy efficiency project, which can create cash-flow issues. However, if the project has a good payback, this problem is negligible;
  - Joint Implementation – is regulated by internationally agreed procedures, which state that the project developer must document that the project will result in emission reductions that would not have occurred without the project. When a municipality selects a project, it can work closely with project developers, designated operational entities, and the host country government (the designated National Authority, DNA) in preparing the Project Idea Note (PIN) and Project Design Document (PDD). If the PIN is approved and the PDD is developed, the municipality can play an important role in organizing stakeholder consultations and providing its support for the project, particularly if it includes municipal assets or enterprises.
- Third Party Financing
  - Leasing – A lease is essentially an agreement to either enable temporary use of equipment without purchas-

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ing, or to acquire equipment by paying for it over time. It is beneficial for small municipalities who are very limited in their financing options due to lack of credit history or are unable to obtain co-financing from grants or bank loans;

- Vendor Credit – Through an agreement between a vendor and the municipality, the vendor sells equipment to the municipality under a repayable loan. The terms for the loan are agreed upon between the municipality and the vendor and are usually short-term. Though vendor credit is a readily available financing tool that enables municipalities to obtain equipment as a low cost, due to the underdeveloped tendering procedures in many CIS countries, it can result in ambiguous quality of financing and equipment. Another problem with this method is that the projects tend to be small;
- Performance Contracting – performance contracting (PC) is applicable when energy-cost savings are an inherent result of a project. A PC is a contract between the municipality and the energy efficiency service provider, which is an energy service company (ESCO), private consultancy or NGO. Goods and services associated with the project are paid for with the energy-cost savings accrued from it, allowing the municipality to finance improvements without incurring any upfront costs. In order to initiate a dialogue with an ESCO or another type of organization, a municipality must first have an energy audit conducted by a reputable source that lays out the different EE measures possible and the savings expected from them. ESCO's typically provide the following services: investment grade energy audits, calculation of baseline energy consumption, identification of energy saving measures, design of energy saving projects, installation and maintenance of new energy efficient equipment, training of technical personnel in a facility and monitoring resulting energy savings. However, the role of an ESCO should not be limited to providing technical services needed to optimally design and implement an energy efficiency project. An ESCO should conduct analysis and generate information that financial institutions require in order to evaluate projects' financial viability. Sometimes ESCOs are able to finance the improvements internally, offering a full range of services under one roof. However, it is more common for an ESCO to arrange for a third party financing from a commercial bank or other financial institution;

- Soft loans – special loan programs with low interests targeted at energy related projects.
- Commercial bank loans – standard loan procedure.

Against the mentioned background, international sustainable energy financing facilities are very important. Through these facilities, the European Union, International Financial Institutions (IFIs) and bilateral donors finance energy efficiency and renewable energy projects for private and public sector clients. The most important IFIs and donors in the region include:

- EBRD – European Bank for Reconstruction and Development;
- EC – European Commission;
- EIB – European Investment Bank;
- GIZ – German association ("Gesellschaft für Internationale Zusammenarbeit");
- KfW – German government-owned development bank;
- USAID – United States Agency for International Development;
- WB – World Bank;

These institutions and donors provide financial assistance in four different ways:

- Regional or country-specific IFI loans, or credit lines to local banks, often with grants or subsidies;
- Regional technical assistance funds generally provided by bilateral donors;
- Country grant funds which aim to promote energy efficiency (EE) investments;
- Country guarantee funds provided by donors which leverage loans from local banks.

Financing for renewable energy investments is usually provided through financial intermediaries such as local banks. Various forms of financing can be packaged together to reduce the risk of the investment and make it more feasible for the borrower. Credit lines to local banks using funding provided by IFIs at lower interest rates are the most common. Local banks then on-lend these funds to private sector clients (households, small and medium enterprises and industrial companies). This does not mean the funds are necessarily cheaper than ordinary loans, but the end user and local bank can often avail themselves of consultancy services and training to develop feasible projects. This helps to reduce the risk to the local banks, making them more willing to lend, and also improves the overall effectiveness of the investment.

In many cases, there are also grants, subsidies or incentives that reduce the amount that must be borrowed, sometimes by up to 20 percent. In other cases, guarantee schemes are available to local banks to cover losses and thus reduce their risk, helping to lower interest rates.

Some of the available funding possibilities are:

- WEBSEDFF – http://www.websedff.com
- CIVITAS – CIVINET http://www.civitas.eu/
- WB Global Infrastructure Facility (GIF) (http://www.worldbank.org/en/news/press-release/2014/10/09/world-bank-grouplaunches-new-global-infrastructure-facility)
- KfW Carbon Programme II (http://www.climatefinanceoptions.org/cfo/node/211)
- EBRD SEI (Sustainable Energy Initiative)
- German International Climate Initiative http://www.international-climate-initiative.com/en/about-the-iki/iki-funding-instrument/
- Global Environment Facility (https://www.thegef.org/gef/climate_change)
- WEBSEFF – http://www.webseff.com

Barriers to development of financial mechanisms can be divided in three groups:

- Financial
  - Lack of credit guarantee mechanisms;
  - Insufficient transparency of financial transactions;
  - Low activity of existing lending institutions in EE area;
  - Incongruous municipal financial policies;
  - Weak lending institutions;
- Legal
  - Lack of clear and transparent ownership rights within the existing legal framework;
  - Weak legislative structures that are unable to enforce existing laws;
  - Absence of mandatory medium-term budget forecasting prevents long-term service agreements and deters involvement of ESCOs.
- Institutional
  - Lack of monitoring of data;
  - No single energy management office in municipalities;
  - Absence of energy procurement practices for municipalities;
  - Underdeveloped ESCO market;
  - Lack of experience in project financing, managing budgets, assets, debt;
  - Inadequate managerial and technical expertise on municipal level in designing and implementing bankable EE projects;
  - Inadequacy of information about the financial markets and services available to regional and city administrations.

A general conclusion regarding ensuring the project financing is that, in spite of evident numerous barriers of financial, legal and institutional character, a project feasibility study that is well prepared, with clearly demonstrated results that are measurable (reliable data regarding energy savings, environmental impact estimation and cash flow analysis), will surely find a financing mechanism (one of the mentioned or their combination) which is acceptable for municipality.

List of priority projects

Energy efficiency

1. Energy audits of buildings owned by the capital city

The implementation of energy audits of public buildings is an obligation defined by the Law on Energy Efficiency. Energy audits of buildings are an inevitable step in definition of the appropriate energy efficiency measures, and thus a basic prerequisite for applying for any of the available funds for financing projects in the field of energy and environmental protection. In order to more efficiently realize the project, it is good to first perform energy audits in buildings with greater potential for energy efficiency, so that through the implementation of the selected measures and savings that would be generated, finance of energy audits in the remaining buildings would become easier. Taking into account that these are technical analyzes, financing of this project is possible through some of the EU funds for technical assistance (GiZ has funded similar projects in the previous period), but also from state funds intended for achieving the goals of the Energy Action Plan efficiency.

2. Development of an information system for reliable monitoring of energy consumption

Reliable monitoring of energy consumption is a requirement that must be fulfilled to enable successful implementation of projects in the field of energy efficiency. It is one of the main prerequisites for available funds and ESCO companies when they are considering projects that should be accepted for funding. The existing information system for monitoring energy consumption is not at a satisfactory level and it represents the basic barrier for activation of funds for project financing, i.e. practically for the implementation of projects taking into account the limited resources within the municipal budget. The development of the information system can be carried out in several stages, depending on the availability of funding. Namely, through organizational measures and procedures, in the first phase, it is possible, with the available staff, to create a system for monitoring energy consumption, and then in the second phase to include software solutions available on the market or develop specialized solutions tailored to the needs and opportunities in the capital city.

3. Development of an energy management system

Experience and research in the area of energy efficiency have unambiguously confirmed the positive effects that the establishment of an energy management system has on the use of energy (higher efficiency, sustainability, positive environmental impact), as well as on enabling the implementation and monitoring of the effects to the municipality, which are consequence of projects in the field of energy. The ISO 50001 standard provides guidelines for the establishment and operation of the energy management system. This project implies, in the first phase, the development of a road map for the establishment of an energy management system, and then monitoring the implementation and the trial run of the system. After the expiry of the probation period, the employees in charge for the system obtain complete independence in the management and monitoring of the system itself.

4. Establishment of a fund for energy efficiency and sustainable development

This project assumes preparation of a feasibility study for the establishment of an energy efficiency fund within the capital city, which would be filled out with savings that projects in the field of energy efficiency generate. The Fund would greatly facilitate the constant improvement of energy performance, i.e. the implementation of new projects in the field of energy and environmental protection, not only for buildings owned by the capital city but also, depending on the available funds and for households that represent the greatest potential for improving energy efficiency. It is necessary to find and verify the feasibility of additional options for filling this fund, beside funds from the savings generated by energy efficiency projects, such as, for example, cooperation with donors or creating favorable arrangements with financial institutions.

5. Connection of public lighting in the computer-controlled network

Connecting a public lighting lamp to a computer-controlled network opens the door to a wide range of innovative possibilities which save energy and improve the performance of the lighting system. In addition to these applications, there are wider possibilities for the application of non-lighting solutions in the communication network, which makes its platform for all city applications. Enabling the connected network simultaneously with the upgrade of public lighting reduces costs and eliminates the need for other installations.

Public lighting management at the initial level offers basic functions such as remote switching on and off, controlled lighting and planning of controlled lighting. In addition to its basic functions, there is also a wide range of functions, such as: monitoring energy consumption, monitoring the quality of the system's operation (warning of the location of a faulty lamp), adjusting the color of light, adaptive lighting and emergency response related to the public lighting system.

Renewable energy sources

1. Development of a feasibility study for the construction of solar PV systems on buildings owned by the capital city

Significant solar potential in the area of the capital city should be put in place for the purpose of developing the city. The Government of Montenegro promotes and supports the use of renewable energy sources. Through the development of a feasibility study, it is necessary to define locations and prepare conceptual solutions for projects for the possibility of producing electricity at a privileged price, as well as for installations according to the principle of energy exchange with the network. Also, it is necessary to analyze the possibility of a private-public partnership for the realization of projects for the construction of solar power plants on the roofs of buildings owned by the city.

2. Preparation of a feasibility study on the use of geothermal energy in the capital city area

It is necessary to define concrete locations for the use of geothermal energy in the territory of the capital city with the follow-up analysis of profitability taking into account the best available technologies on the market. Previous studies that investigated the general potential of geothermal energy have pointed out to the existence of significant potential, so it is necessary to make the next step in identifying specific locations and compare them with the energy needs.

Communal utilities and services

1. Development of a traffic center

The traffic center would integrate all data from existing sources related to traffic and even information on current construction works, public events, or data on all current events in the city's traffic infrastructure. The Center would manage and monitor the traffic in the capital city, inform the traffic participants and provide comprehensive information to all participants.

Benefits: A traffic center with its subsystems (light signaling (traffic lights and variable traffic signs), automatic plate recognition, traffic alerts) is the basis for better control, greater security and more efficient centralized traffic management. At the same time, it would offer traffic information for public and individual traffic. It would serve as a basis for expanding the ability to flexibly streamline of traffic in terms of capacity expansion and load reduction.

2. Development of a free parking spaces management system

This system should enable the automatic identification of free parking spaces on public surfaces and provide information about the number of places in a particular location (through applications for mobile phones, variables, etc.).

Benefits: reduction of the time required to find a free parking space, decreasing of traffic congestion, reduction of emissions of exhaust gases.

3. Study of the possibilities and prerequisites for the development of a power distribution network from the aspect of the greater expansion of electric vehicles

One of the obstacles for greater use of electric cars is the lack of public and private infrastructure for vehicle charging. Due to the relatively large electric powers required by charging stations for electric vehicles, especially those for fast charging, it is necessary to analyze the possibilities and capacities of the existing power distribution network in time, and anticipate the necessary activities for its improvement, in order to adequately prepare the network for the expected future expansion of electrically powered vehicles.

4. Application of hybrid buses and electric buses

The use of hybrid buses and electric buses combines the benefits of the vehicles themselves (less or zero environmental impacts) and the positive effects of greater use of public passenger transport.

5. Developing a system for informing citizens about service information

The system for informing citizens about service information should enable access to information for interested users through easily accessible media. The system should provide news related to the utility system, development projects, modernizations, announcements of works to be carried out throughout the city, as well as announcements of events that will take place in the city; information on modifications of the traffic regime in parts of the city where the works are carried out, as well as information of public importance; information on timetables and changes in the routing of urban, suburban and intercity public passenger transport, etc. In addition to the aforementioned information, modern systems for informing citizens about service information should enable the possibility that a citizen reports problems either through the application or by phone call.

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List of abbreviations and acronyms

AC	Alternating Current
APEE	Energy Efficiency Action Plan (Akcioni plan energetske efikasnosti)
ASI	Avoid-Shift-Improve
ATP	Air heat pumps (Toplotne pumpe na vazduh)
BAC	Building Automation Control
B-AWS	Building Automation Control Advanced Workstation
BMS	Building Management System
CHP	Combined heat and power (Kombinovana proizvodnja toplote i električne energije)
COP	Coefficient of Performance (Koeficijent grijanja)
DC	Direct Current
DNA	Designated National Authority
EC	European Commission
EE	Energy efficiency (Energetska Efikasnost)
EED	Energy Efficiency Directive
EES	Electric power system (Elektroenergetski sistem)
EIB	European Investment Bank
ELAS	Energy long-term assessment of population structures (Energetska dugoročna procjena naseljenih struktura)
EN	European Standards
EP	Energy policy (Energetska politika)
EPBD	Directive on Energy Efficiency of Buildings (Direktiva o energetskoj efikasnosti zgrada)
EPCG	Montenegrin electric power company (Elektroprivreda Crne Gore)
ESCO	Energy Service Company
ESP	Energy Service Provider
EU	European Union (Evropska Unija)
EZ	Energy Community (Energetska zajednica)
GEF	Global Environment Facility
GHG	Green House Gas (Gasovi sa efektom staklene bašte)
GIS	Geographic Information System
GIZ	German association ("Gesellschaft für Internationale Zusammenarbeit")
GPS	Global Positioning System
GTE	Geothermal energy (Geotermalna energija)
GTP	Geothermal heat pump (Geotermalna toplotna pumpa)
GUI	Graphical User Interface (Grafički Korisnički Interfejs)
GUP	Main Urban Plan (Glavni Urbanistički Plan)
HE	Hydro power plant (Hidroelektrana)
HGTE	High temperature geothermal energy (Visokotemperaturna geotermalna energija)
HMZ	Hydrometeorological Institute (Hidrometeorološki zavod)
HVAC	Heating, ventilation, and air conditioning systems
I-C	Originally Targeted (izvorno ciljni)
ICT	Information Communication Technologies
IEA	International Energy Agency
IFI	International Financing Institution
ISO	International Organization for Standardization
ITU Study Group on SSC	ITU's Telecommunication Standardization Sector (ITU-T) - Studijska grupa za pametne održive gradove (SSC - Smart Sustainable Cities)
JPP	Public passenger transport (Javni putnički prevoz)
JUS	Yugoslavia standard (Jugoslovenski standard)
KAP	Aluminum Plant Podgorica (Kombinat aluminijuma Podgorica)
LED	Light Emitting Diode
LEP	Local Energy Plan
LGTE	Low temperature geothermal energy (Niskotemperaturna geotermalna energija)
NEEAP	National Energy Efficiency Action Plan
NVO	Non-governmental organization (Nevladina organizacija)
NZEB	Near Zero Energy Building (Gotovo nulte energetske zgrade)
OECD	Organisation for Economic Co-operation and Development
OIE	Renewable energy sources (Obnovljivi izvori energije)
ORC	Organic Rankin's Cycle (Organski Rankin-ov Ciklus)
PAYT	Pay As You Throw
PDD	Project Design Document
pkm	passenger kilometer (putnički kilometer)
PNS	Process network synthesis (Procesna mrežna sinteza)
PPEE	Energy Efficiency Improvement Program (Program poboljšanja energetske efikasnosti)
PPOV	Wastewater treatment plant (Postrojenje za prečišćavanje otpadnih voda)
PUP	Spatial Urban Plan (Prostorno Urbanistički Plan)
PV	Photo-Voltaic (Fotonaponski)
RFID	Radio Frequency Identification (Radio Frekventna Identifikacija)
SAD	United States of America (Sjedinjene Američke Države)
SCADA	Supervisory Control And Data Acquisition
SEAP	Sustainable Energy Action Plan
SEE	Energy Efficiency Strategy (Strategija Energetske Efikasnosti)
SPI	Sustainable Process Index (Ekološki otisak)
SRE	Energy Development Strategy (Strategija razvoja energetike)
STV	Sanitary Warm Water (Sanitarna Topla Voda)
TE	Thermal power plant (Termoelektrana)
tkm	tonne-kilometer (Tonski kilometar)
TNG	Liquefied petroleum gas (Tečni Naftni Gas)
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development

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