Hungary-Croatia
Cross-border Co-operation Programme

Interreg
European Regional Development Fund
EUROPEAN UNION

RuRES
Renewable energy sources and energy efficiency in the function of rural development

RENEWABLE ENERGY SOURCES AND ENERGY EFFICIENCY FOR RURAL AREAS

HUHR/1601/3.1.1/0033

Interreg V-A Hungary-Croatia Co-operation Programme 2014-2020

Editors:

Topić, Danijel; Varjú Viktor; Horváthné Kovács Bernadett

Peer reviewer:

Németh Kornél (PhD) – energeticist, environmental expert

Marinko Stojkov (PhD) – full professor with tenure in electrical engineering

Lector:

Sandra Labudović (prof.) – professor of English and Croatian language

A cross-border region

where rivers connect, not divide

AUTHORS

Bálint Dóra – junior research fellow, MTA KRTK RKI DTO, Pécs
Bodor Ákos – research fellow, MTA KRTK RKI DTO, Pécs
Došen, Dario – senior laboratory technician, FERIT, Osijek
Fekete, Krešimir – assistant professor, FERIT, Osijek
Hajdú Zoltán – scientific advisor, MTA KRTK RKI DTO, Pécs
Horeczki Réka – junior research fellow, MTA KRTK RKI DTO, Pécs
Horváthné Kovács Bernadett – associate professor, University of Kaposvár
Klaić, Zvonimir – associate professor, FERIT, Osijek
Knežević, Goran – assistant professor, FERIT, Osijek
Kovács Sándor Zsolt – junior research fellow, MTA KRTK RKI DTO, Pécs
Mezei Cecília – research fellow, MTA KRTK RKI DTO, Pécs
Pelin, Denis – full professor, FERIT, Osijek
Primorac, Mario – expert associate, FERIT, Osijek
Šljivac, Damir – full professor with tenure, FERIT, Osijek
Póla Péter – research fellow, MTA KRTK RKI DTO, Pécs
Titov, Alexander – PhD candidate, University of Kaposvár
Topić, Danijel – assistant professor, FERIT, Osijek
Varjú Viktor – senior research fellow, MTA KRTK RKI DTO, Pécs
Žnidarec Matej – assistant, FERIT, Osijek

Editing of figures: Fonyódi Valéria, Szabó Tamás

Technical editor: Glied Viktor

Published by: MTA KRTK Institute for Regional Studies

Printing House: Kontraszt Plusz Kft. 7623 Pécs, Petőfi u. 48.

ISBN 978-963-9899-99-5 (Printed version)

ISBN 978-615-5949-00-5 (pdf)

Pécs, 2018

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CONTENT

1 INTRODUCTION

Danijel Topić, Bernadett Horváthné Kovács, Viktor Varjú

The European Union has recognized the enormous potential for the development in the field of energy efficiency and renewable energy sources. The EU 2020 and EU2030 goals (the increase of renewable energy share to at least of 27 % of the EU's energy consumption) and the Roadmap 2050 defined ambitious EU goals with respect to the increase of renewable energy use; however, they did not define a common policy for the member states. EU27/28 defined their own contributions and tools for supporting RES development.

According to the EU energy statistics (European commission, 2017), the share of renewable energy sources in final energy consumption at the end of 2015 was 29% in Croatia and 14.5% in Hungary, respectively. The national target accounting for RES in 2020 is set to 20% for Croatia and 13.0% for Hungary, respectively. Although Croatia and Hungary are RES overachieving country, it needs to be emphasized that the majority of RES in Croatia comes from conventional hydro power plants and wind power plants located outside the cross-border region, while biomass is used mostly for traditional heating while it comes mostly from traditional biomass in Hungary. On the other hand, the cross-border area of Croatia and Hungary has a great potential of RES, especially of sun, geothermal and biomass energy in rural areas that can be used for power and heat generation.

The usage of RES and EE measures in a rural area is very important in achieving these targets. RES can be used for both heat and power supply of consumers not connected to an energy grid instead of using fossil fuels. RES can be used for electricity and heat supply of small agricultural economies and other objects in the rural area often not connected to energy grids or lacking economic sustainability regarding rising energy costs. The usage of RES and EE measures can help directly in CO2 emissions reduction replacing fossil fuels and lowering energy consumption.

The Faculty of Electrical Engineering, Computer Science and Information Technology Osijek (FERIT) and Hungarian Academy of Sciences, Institute for Regional Studies, Centre for Economic and Regional Studies (MTA KRTK) have already successfully implemented the REGPHOSYS project whose objective was to find an optimal configuration of PV systems for the cross-border Croatia and Hungary area according to regional technical, economic and meteorological conditions. Cooperation of these two institutions has been established through the successfully implemented REGPHOSYS project and substantial research in the field of RES in the cross-border region has been conducted and published. The idea is to continue this cooperation through the RuRES project and extend the research to including a new partner, Kaposvar University. RuRES has included research in the field of RES and EE aiming to study rural development in the cross-border region. Introducing a new partner Kaposvar University, additional knowledge and experience is available and the team of experts are expanded. The Kaposvar University project team will help with research in the field of biomass and waste management, usage for energy purposes and development in the rural area. According to PV GIS, 2018, there is a significant solar energy potential with global irradiation on optimally inclined surface of approx. 1,400 kWh/m2 yearly. Geothermal temperature gradient in the Pannonian basin is significantly higher (approx. 0.049 K/m) than the world average with hot dry rocks and geothermal reservoirs present. The elaborated survey (Ivanović & Glavaš, 2013) indicates a significant potential of the biomass waste usage in the cross-border area of Croatia. A similar survey needs to be done for the cross-border area of Hungary. Since there is a great RES potential in the rural area of the cross-border region that has still not been used enough, it is important to investigate ways of RES usage in rural areas, develop typical energy system related technical solutions for specific conditions in rural areas, investigate how the use of RES and EE can influence rural development and study economic, social and environmental impacts.

The aim of this project is to undertake scientific research and propose RES and EE measures for rural development in the cross-border region.

There are three overall objectives of the project:

1. develop a typical RES system for energy supply in the rural areas;
2. provide a set of recommendations for EE improvement and waste management in the rural area;
3. investigate economic, social and environmental impacts of RES and EE in the rural area of the cross-border region.

A short-term perspective is to disseminate information on RES, EE and waste management in the rural areas of the cross-border region. A long-term perspective is to increase RES usage, improve EE, sustainable waste management as well as reduce fossil fuels usage, CO2 emissions and energy cost. The specific objectives are to expand cross-border innovation and a research network, develop typical RES systems for energy supply in the rural areas for specific conditions and foster cooperation between institutions engaged in the project.

The expected results of the project are as follows:

- a model developed for stakeholders/local governments which demonstrates their RES and EE potentials and provides suggestions for further development;
- newly purchased equipment settings and a simulator which can help demonstrate how to build a small-scale proper RES system in the rural area;
- a website where stakeholders can be informed on the most recent results of our measurements and research to be used for their purposes;
- a trilingual book summarizing the most important project results for the scientific audience and stakeholders;
- the final conference where the results will be discussed with both the scientific audience and stakeholders and research findings disseminated;
- trainings for local stakeholders in the rural areas, namely one in Osijek-Baranja County, one in Baranya County and one in Somogy County.

This book aims to summarize the main results of the RuRES project using a multidisciplinary approach. In addition to elaborating on the measuring results in the rural areas, the chapters provide an overview of the given and researched area taking into account the geographical, social and economic conditions analyzing the perspectives, attitudes and potential behaviors of everyday people. The book also gives a review of the potential impact of renewable and energy efficiency investments in a rural area.

2 RURAL AREAS IN A CHANGING WORLD – GEOGRAPHICAL ANALYSIS OF THE RESEARCH AREA

Dóra Bálint, Réka Horeczki, Zoltán Hajdú

2.1 Introduction: definition of the rural areas

In this chapter, we will summarize the most important viewpoints of a complex term rurality based on the literature. Then we will analyze the research area recent environmental and socio-economic situation with the help of quantifiable indicators.

The function and image of rural areas have undergone huge changes in the last 50 years. The traditional role of a village has been formed by processes like modern agricultural mass production, changed market relationships, suburbanization and the formation process of peripheries (ageing, depopulation). The biggest problem, according to the researchers reporting on this topic (Csatári, 2011), are the processes which were not foreseeable in the region; the depreciation of the countryside and decrease of the bearing capacity, which contributed to many negative trends, like social, economic and environmental problems. To review the concept, we have two different conceptions evident from the literature. In the first case, the concept of rurality is defined by quantifiable, objective numbers. In the second case, the existence of rurality, countryside and "separate quality" from the urban areas was questioned. The definition can be changed so researchers use geographical, social, economic or cultural indicators (Maácz, 2001). In the European Union, problems related to the special developmental need of the rural areas originate from the late 1980s (EC, 1988). The European Charter for Rural Areas (1996) adopted by the Council of Europe, defined the rural areas as territories where agriculture, forestry and fishing mainly appear, population has special economic, cultural activity, recreation, environmental protection and the postmodern way of life related to the social needs is also highlighted. The novelty of the definition comes from the rural = "not urban" wording (Arcaini et al., 1999). The European Spatial Development Perspective (EC, 1999) consider rural areas as complex economic-environmental-cultural territories which do not make a homogenous unit. It can be characterized by different limiting factors. Understanding urban-rural areas helped the studies under the ESPON 1.1.2. project. The research drew attention to the importance of connections and their intensity and direction, namely structural (land use, settlements system) and the differences between functional connections (production-consumption-communication formations). The European Union does not apply a unified capped system for rural areas; however, every member state has its own system based on some other socio-economic characteristic. It takes into account the settlement system, land use, economic functions but the most accepted indicator is population density. That being said, the method of OECD (1994), which uses population density to distinguish between rural and urban areas, is of vital importance. The method of OECD uses a two-step evaluation of a territorial level - on a local level (LAU2-settlements) where a threshold number of rural settlements are under 150 inhabitants/km^2 and on a regional level (NUTS3), the proportion, which shows the given administrative or functional unit proportion of inhabitants who live in rural areas, is used. The three basic types are predominantly rural areas, where the proportion of inhabitants living in rural areas is more than 50%, typically rural areas (intermediate), where the number of inhabitants living in rural areas is between 15% and 50% and predominantly urban areas, where the proportion of inhabitants living in urban areas is less than 15% (Eurostat, 2007). In 2010, with the help of new methods and GIS systems[1], the rural typology has been clarified. The new method takes into account the variable spatial sizes and the problem of metropolitan areas. 56% of the European Union territory is predominantly a rural area; in the case of Hungary, 66.1% of the country is a rural area and 47.9% of inhabitants live in rural areas. In Croatia, the numbers are different - 26% of the country is a rural area and 53.4% of the inhabitants live in rural areas. The Hungarian concept of rurality was first used in the law No 21/1996 (National Agrarian Structure and Rural Development) where rural areas were distinguished from the terms of agricultural, less developed regions and villages. Researchers, like Kovács (1998), used a different approach with the following main indicators of rural areas - the proportion of active workers working in the agriculture in 1990 was more than 20%; a minimum of 120 primary users per thousand people; a minimum of the population living in settlements with less than 120 people/km^2; the population density less than 80 people/km^2 in the region.

According to the Ministry of Agriculture (1997), a rural area is a place where the agricultural activity, green cover (forest, natural landscape) and settlements system are mainly dominant in small villages with the specific low rate of built-up areas and population density. Dorgai (1999) says that settlements are rural areas which do not have an urban status with residential population being less than 10,000 and dwellers of the rural settlements proportion being more than 15 %.

Csatári (2000) attempts to rank the Hungarian small districts according to the urban/rural index. Those small districts are rural areas with the given territory being less than 50% and with the population of more than 120 people/km^2. Kovács et al. (2015) specify eight complex types of rural districts (in the Rural Development Program 3.0 assessment). Németh and the colleagues (Németh, 2011; Németh et

1 http://ec.europa.eu/eurostat/documents/35209/35256/Urban_rural_poster_3levels_A1_Aug2013.pdf

al., 2018a) tried to simplify the notions. In their environmental and socially focused approach, they argue that rural areas are places where people can be in harmony with the nature. Settlements have to take their special peculiarities in their development concepts in order to fulfil the three E criteria of sustainability into consideration.

To summarize, the term of the rural region, based on the examples from the literature, cannot be defined by population density and the number of dwellers; however, it can be categorized with the help of these quantifiable factors.

2.2 Introduction to the research area – overview of the administrative, environmental and historical background of the cross-border region

The research area consists of three NUTS 3 level territorial units at two sides of the non-official Hungarian-Croatian cross-border region. Two are located in Hungary (Baranya, Somogy counties) and one in Croatia (Osijek-Baranja). All units occupy less than 10% of the countries' total area (EUROSTAT 2018).

Historical changes, hand in hand with environmental factors, have played an important role in the recent socio-economic situation. In this section, we highlighted the milestones about the territory's history. In the Roman times, Danube River was a military objective (parts of the limes-system had been built alongside the river) with settlements with military function. Later on, the Hungarian conquest led to prosperous agriculture and increasing population. The first significant depopulation started due to outer causes – after the Ottoman Empire, these settlements were destroyed and their infrastructure was demolished. In these times, the area was a border region between two large empires. Later, in the 17th century, immigration had started so a huge number of Swabian people arrived in South Transdanubia and Slavonia, which contributed to the multi-ethnic characteristics of the area. In the middle of the 19th century, the rail network took over the role of the rivers as it had become the primary and most effective way of transportation, which also affects the settlement system. After 1920, there was a large change of the development of the area - the Austro-Hungarian Monarchy collapsed and the recent territories of Osijek-Baranja had become the part of the Serbian-Croatian-Slovenian Kingdom (after 1929, it is known as Yugoslavia). After the Second World War, both sides of the border were part of communist systems but with differences.

Figure 2.1. The area (km²) and location of the counties
Source: Own contribution.

In its internal relations, structures similar to other socialist states were dominant in many respects, but the birth of Yugoslav self-managing socialism endowed the country with unique features. Unlike most other socialist countries, Yugoslavia continuously remained open to the West in several respects. The conditions of organised emigration and mass employment abroad were gradually created (Hajdú, 2013: 494).

The country developed its relations to the European Economic Community (EEC) from the mid-1960s on. In economic relations, the EEC became the most important trade partner for Yugoslavia, and in the framework of these relations the country was given development resources as well (Hajdú, 2013:494).

The transforming European Union, redefining itself in many respects, played a significant role from 1992 on in supporting Croatia and Slovenia and in establishing their international relations. In the transformation processes of the other ex-Yugoslav states, especially in Bosnia and Herzegovina, the EU failed to help these processes. It was the UNO, the NATO and the USA that became the major actors in solving the problems there. The EU contributed to stabilisation in the fields of finance and development (Hajdú, 2013: 495).

Hungary in 1990 and Croatia in 1991 declared their independence but in the case of Croatia, the transition was more forceful because the war of independence was started. After that, in 1993, the recent administrative units and counties were born. Nearly two decades of the 21st century, both sides of the border have become the part of the European Union with better communication possibilities, interregional projects and without strict border control.

The studied cross-border area is a belt stretching along both sides of the lower part of Mura, Drava Rivers and the Danube above the Drava firth. Partly due to the following reasons, this area is ecologically the most unified, organic and continuous river-system with green-belt. Recently, this area has also been called the "Amazon of Europe". Based on this, from the 1990's there was an increasing "meta-governing" need for a common nature protection area/Nature Park that joins the natural values of Croatia, Hungary and Serbia (Varjú, 2016:85).

As we focus on the environmental factors, one of the most important characteristics of the research area is the basin effect. The territory lies in the Pannonian Basin, which influences a wide range of other conditions as well, such as climate or hydrology. In the area, the dominant landscape is plain, primarily in the middle and South parts, where the Hungarian Great Plain lies. Somogy county is mainly covered by shifting sand (Martonné, 2006); however, the largest parts in the research area are alluvium plains; on the Croatian side, Drava (and its valley) is one of the most important tributaries of the Danube River. The counties' climate is temperate continental (according to Köppen climate classification) with Sub-Mediterranean influence in the south. Looking at the climate graphs, we cannot find significant differences between the three counties because of the small size and relatively small horizontal (latitude) and vertical (altitude) changes. In general, the highest amount of precipitation falls in summer months and there is a second peak in late autumn because of the Mediterranean effect. The amount of the annual sunshine hours varies between 1,800 and 2,000. The annual average temperature is 10-11°C, which varies according to the elevation. Similarities continue; both counties' coldest month is January and the warmest July. The annual precipitation is between 600-700 mm but it has annual changes. North Baranya has the highest amount of the precipitation – 750-800 mm. Both parts have convective precipitation in late spring-early summer, which can lead to flash floods in the mountainous areas, especially in the Mecsek Mountains.

Location, climate and the basic effect determine the drainage system as well; the whole area belongs to the Danube's catchment area. In hillier places, like Mecsek or the southwest part of Osijek-Baranja, brown forest soils can be found. These humid places with lower temperature created medium quality soils. The most fertile ones are located in the bedrock of quaternary loess, mainly in the outer Somogy, are chernozemic soils, which are the most valuable types of the basin's soils (Martonné, 2006).

Taking into account the natural conditions from the point of view of environmental planning, being a border river, the Drava cuts the area into a Hungarian and a Croatian part. Along the Drava River, both sides of the border area are historically peripheral, characterized by poor economic performance. Between 1920 and the end of the 1980's the Drava-region was almost perfectly closed. During the Soviet era both countries were subject to socialist ideology, however, former Yugoslavia was not part of the Soviet ascendancy area. Because of the very strict border guarding only local citizens or a person with permission could approach the border area, including villages nearby the border. The whole area had a very unfavourable position in terms of investment due to the geopolitical risks on the Hungarian side and the Yugoslavian civil war in the 1990's. In the past 25 years the trajectory of the development of this cross-border area differed from other parts of "the mother-countries". On the Croatian part "while the coastal areas and the metropolitan region (Central Croatia) went through an expansion, Slavonia, the Eastern part of the country, is clearly a loser of the same transformations" (Rácz, 2016; Varjú et al., 2014, Varjú, 2016:86).

The concept of Drava, as energy resource, appeared during the 19th century already, during the era of Austria-Hungary Monarchy. Several, more than 20, hydroelectric power plants were built on the upper part of the river. There were several concepts to build a hydroelectric station in the border region of Hungary and Yugoslavia (Croatian part), however an intergovernmental negotiation was achieved only at the end of the socialist era, in 1988, when Hungary and former Yugoslavia signed an agreement to build a power plant on the Drava near Djurdevac. After the (Hungarian) systemic change, (and in parallel with the big debate on the planned Gabčíkovo–Nagymaros dams on the Danube) Hungary turned towards an environmental related direction. Due to this turn, Croatia decided to build a power plant in Novo Virje, instead of Djurdevac. The negotiation and debate between the two countries (hydroelectric power station vs. nature protection and environmental interests) took until the middle of 2000's, once Croatia turned towards the EU. Negotiations for the accession started in 2005 and due this process, environmental issues and environmental sustainability came to the forefront in Croatia as well (Reményik, 2008; Cvritla, 2000; Bali, 2012). Croatia turned to an environmental-related direction, however, plans relating to hydroelectric power stations appeared from time to time, recently as well. Due to the above historical reasons natural assets remained in a good state, especially on the Hungarian side. From the 1990s high attention has been drawn to natural protection in this area. On the Croatian side Kopački rit was designated on the List of Ramsar areas in 1993. On the Hungarian side Danube-Drava National Park (and Directorate) was established in 1996 in order to pay high attention on the natural heritage. This nature conservation area is the largest protected area of national importance in the region. Wetlands are ex-lege protected, waters are continuously monitored under the umbrella of the European Water Framework Directive (EC 2000/60). Not only is the Drava under national natural protection for-and-aft on the Hungarian side. Almost 20% of the study area is NATURA 2000 area, 6.6% is under high national protection and 1.1% is under strict national protection totally closed from the public (Varjú et al., 2014, Varjú 2016:86-87).

2.3 Vulnerable places in a changing world – socio-economic indicators of the research area

Recent, interconnected like globalization, the post-industrial society or the dominance of the tertiary sector have significant spatial effects which led to an intensified concentration of metropolitan areas. These trends can be observed in the whole parts of the world but in the Eastern Europe, there is another crucial factor – the general decline of the population at the national level (Ubarevičienė, Van Ham, 2017), which affects regional development and almost all hierarchy of the settlement system (Makkai et al. 2017). As a result, these rural areas lost their competitiveness and declining which can be measured by quantitative (population drop, age structure, education level) and less quantifiable factors like its image or liveability. Based on these statements, rural places are highly vulnerable to changes and recent, large-scale problems like climate change or loss of the biodiversity. Therefore, these areas easily turn into "no-places", which refer to the attitude of habitats, companies or developers who say no and turn away from rural areas with the tool of outmigration or relocation. In the case of the research area, rural places are located far from metropolitan areas especially the largest ones, Budapest or Zagreb, with disadvantageous transport situation, which help these negative trends to emerge. In this part, we use indicators from Hungarian and Croatian censuses to highlight these processes with the help of different indicators.

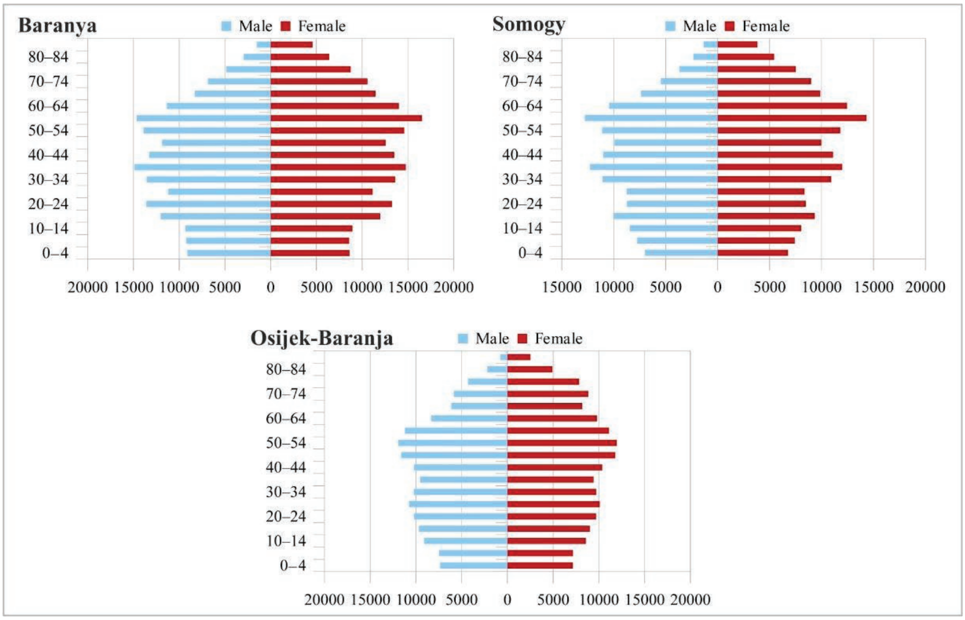

Figure 2.2. Population pyramids of each county
Source: Own contribution based on the data of the Hungarian and Croatian Statistical Offices (KSH, Državni zavod za statistiku - 2011)

Firstly, we examine the counties' population pyramids, which present the structure of the population by age and sex and the changes and past tendencies of the territory's society as well. As the charts show, the birth rates are low caused by low fertility rates as presented in figure 2.2. On the top of the pyramid, there is a high proportion of persons above 65 years and they are characterized by a rectangular shape. To conclude, these counties are in the fourth and fifth stage of the Demographic Transition Model as well as Hungary and Croatia. Historical changes in Hungarian counties, also depicted from the charts, have larger peaks, which refer to periods when the birth rates were higher mostly by the influence of family policy. In the Croatian pyramid, there are only two; smaller waves and columns, which refer to the lower number of population. The natural change in itself is not sufficient for the whole picture; migration also influences the area population. In the case of the RURES territory, there is a small scale of outmigration (e.g. in 2016, 646 people from Baranya migrated out from the county according to the census). As widely-known, primarily the young and well-educated males make the groups who take part in domestic or international migration, therefore the local society lost people who are in the labour market, which has a negative multiplier effect for the local economic situation.

2.3.1 Long-term effects of population decline on RES

The structure of the population has numerous future consequences like the increasing dependency ratio on active population (age between 15-65). In the case of the RURES project, population decline will cause possible long-term effects due to the socio-economic background of implementing and using new kind of technologies. Table 2.1 summarizes the possible environmental, social and economic challenges of the research area. According to that, there are several both negative and positive effects. The environmental pressure will decrease so the preservation of the resources can continue more successfully alongside with the regulation. In contrast, the loss of younger, well-educated people means that learning and maintaining new technologies can be more challenging; the studies found that younger people are more likely to accept new technologies, which connected to renewable resources (Devine-Wright, 2007). At the same time, the environmental pressure will decrease and scarcity means a new type of tourism advantages against the crowded and polluted metropolitan areas. The technological change can allow people to commute less and work and contact with those areas from villages as well.

Table 2.1. Long-term effects of population decline

<table>
<tr><th></th><th>Environmental</th><th>Social</th><th>Economic</th></tr>
<tr><td rowspan="3">Positive Effects</td><td>Fewer people will ease the pressure on the environment (e.g. pollution)</td><td rowspan="3">RES systems will help elderly people who are not in the labor market</td><td>New type of services appears</td></tr>
<tr><td>Carrying capacity will be better</td><td rowspan="2">Better circumstances for rural tourism</td></tr>
<tr><td>Elderly people consume and travel less, so they have a smaller ecological footprint</td></tr>
<tr><td rowspan="3">Negative Effects</td><td rowspan="3">Changing land use patterns</td><td>Elderly people are less likely to adopt new, unfamiliar technologies it so it will be hard to find suitable staff for RES technologies</td><td rowspan="3">Fewer active workers pay less local taxes, labour insufficiency, maintaining infrastructure will be costlier</td></tr>
<tr><td>Public support for elderly people means less expense for maintaining RES systems</td></tr>
<tr><td>Growing number of pensions will increase the pressure on active workers of the territory</td></tr>
</table>

Source: Own contribution

2.3.2 Spatial patterns – settlement system and internal patterns

After general trends, we narrow our focus and examine the research territory internal patterns. As figure 2.3 illustrates, there is a significant difference between the territorial units comparing Croatia and Hungary, which make the comparison more difficult. Metropolitan areas are rarely found in these counties and the largest concentrations are Pécs (144,000 inhabitants) and Osijek (108,000 inhabitants). In Hungarian counties, especially in Baranya county, there is a lack of middle-sized towns except for Komló. As the second maps illustrates, the settlements are under 1,000 inhabitants, except the surroundings of Pécs because of the suburbanization process and urban sprawl. In Somogy, the settlement system is more balanced as the number of small towns and the proportion of larger villages is higher. Despite this, this county has the lowest population density in Hungary (52 person/km^2).

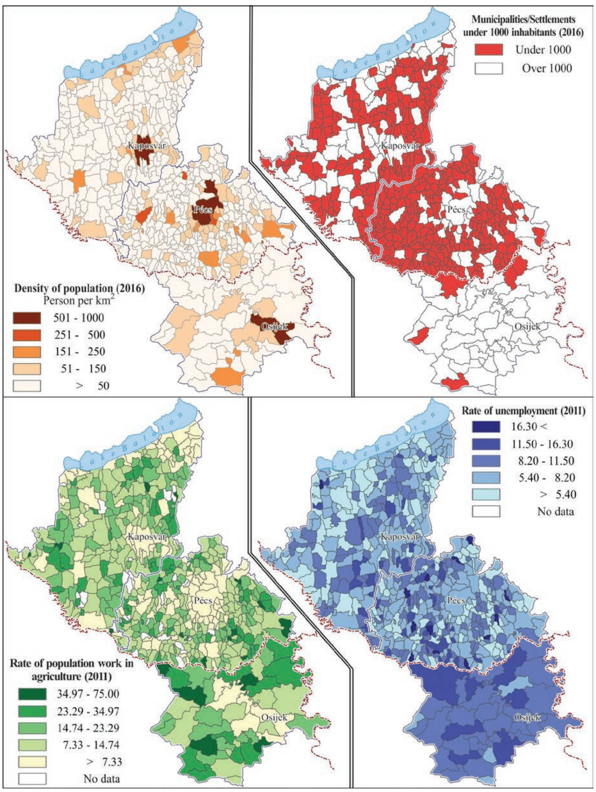

Figure 2.3. Spatial patterns of the research territory's population, settlements and socio-economic indicators
Source: Own contribution based on the data of the Hungarian and Croatian Statistical Offices (KSH, Državni zavod za statistiku – 2011, 2016)

Based on the data of population by age, the late stages of the demographic transition model, the low rate of young people (under 14 years old), which is between 5-10%, is evident. Ormánság in Baranya is one of the part of the territory where this number is the highest. In the Croatian part, the youngest municipalities are in the south parts. In contrast, the proportion of the old population who are inactive workers and are not in the labor market can be found mainly in Somogy, near Lake Balaton, which is a conurbation, and in the north part of Osijek-Baranja. The age structure of Pécs refers to the outmigration; it cannot hold its young population despite the university city status. According to the statistical data, Pécs has the most significant highly-skilled inhabitants in the research territory. If we examine this indicator in the county level, Osijek-Baranja has the highest ratio. Other cities like Kaposvár or the towns, encircling Lake Balaton, also have higher numbers. Rural areas, as a result of the migration and the decline of the primary sector's economic role, have disadvantageous values; the worst ratio taking place in Ormánság. As the next indicator on the map shows, the unemployment rate is highly connected to the settlement size (we use the data from 2011 census). The most economically vulnerable places are inner peripheries, encircling Pécs in Baranya, and in Osijek-Baranja located near to the border.

Comparing the two sides of the situation of the two countries, in Croatia, the agriculture plays a more important role than in Hungary with respect to the employment rate (Croatia: 14.57%, Hungary: 4.89%), which has mainly historical reasons. The ratio of people who are working in the secondary sector is nearly the same in every county, but in the case of service sector differences, it also occurs between the two countries. In the county level, these trends can be observed in a smaller scale; Baranya county has the lowest rate of active people working in agriculture (6%) and this number is nearly 10% in Osijek-Baranja county. As the left map points, the proportion of inhabitants working in the primary sector is the highest in the border region. The tertiary sector is one of the important indicators of economic growth; in the research area, Baranya has the highest proportion of the service sector (68%) because of the university status. Despite the importance of this sector, the city is highly dependent on their education institutions due to the lack of transnational companies.

3 ENVIRONMENTAL ATTITUDE IN RURAL AREAS OF THE BORDER REGION

Ákos Bodor, Alexander Titov, Viktor Varjú[2]

This chapter aims to provide an overview on "social conditions" of the Hungarian-Croatian cross-border area, focusing on Osijek-Baranja county (on the Croatian side) and Baranya and Somogy counties (on the Hungarian). The goal of this part of the RuRES research was to examine the attitude and the "available" environmental behaviour towards renewable energy and energy efficiency in the rural areas in this border region. The empirical research was two-fold - in the first part, a representative survey was conducted in two Baranya counties and in the second part, a representative survey at micro regional level was conducted in Somogy county in Koppány-Valley.

3.1 Measurement of the environmental attitude and behaviour

With the degradation of our natural endowment, and parallel to the appreciation of environmental protection and environmental policy, the study of the environmental attitude and "environmental behaviour" is more and more in the focus. In the view of Eagly and Chaiken (1993), the attitude is a "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour" (Eagly & Chaiken, 1993), and it is of vital importance in the forecasting of actual behaviour (Casaló & Escario, 2017), including the attitude concerning the environment (environmental protection) and behaviour as well.

A significant part of the environmental problems can be traced back to human behaviour, so most of research are targeted at the discovery of motivations and background of environmental actions. Several research have explored a tight correlation between an environmental attitude and environmental action (or non-action) (Bamberg & Möser, 2006; Kaiser et al., 2007; Levine & Strube, 2012). Németh et al. (Németh et al., 2018a; Németh et al., 2018b) focused, among other things, on the motivations of actions concerning environmental problems, "counter-measures", the issue of originally set objectives and the exploration of the actual achievements.

The factors influencing behaviour (also environmental behaviour) include other things besides the attitude. Most of the works on the environmental attitude (e.g. Gaterslaben et al., 2014, Steg & Vlek, 2009; Ertz et al., 2016) refer to the behaviour

[2] Awarded by Bolyai János Research Scholarship, 2016-2019

theory by Ajzen (1991) as a basic work, which refers, in addition to the attitude (also seen as a key factor), to a subjective norm (which refers to the pressure by the environment potentially influencing one's behaviour to implement or not implement some action), or to "experienced behaviour control" (referring to the past experiences and visible obstacles like money, schooling, knowledge available time) as a factor that also influences behaviour.

In the research of the environmental attitude, the role of several other factors, like the value system, identity, moral convictions, the already experienced advantages and disadvantages, context and habits, is also emphasized by some researchers, (Gatersleben et al., 2014, Steg & Vlek, 2009).

Less attention is in literature paid to the examination of differences regarding the environmental attitude by territorial types. Freudenburg and McGinn (1989) found that previous research had quite a mixed opinion with respect to differences according to territorial character (urban vs. rural, industrial vs. agriculture-dominated areas) and environmental attitude. Some research did not find any difference between environmental conviction and the character of the respondents' territory, and there were some that found a positive correlation between the urbanization level and the environmental conviction. For the "measurement" of the environmental attitude and environmental behaviour, both interviews (e.g. Vicente Molina et al., 2018) and questionnaires are used (e.g. Buta et al., 2014). A sampling ranged from a multi-step or systematic random sampling (e.g. Buta et al., 2014) to quota sampling (e.g. Vicente Molina et al., 2018). Most research, however, do not use representative samples, irrespective of the size of the researched territory, so they are not suitable for drawing general conclusions for certain territorial units (even though attempts are made). The representative sampling procedure of our research, however, allows some generalizations concerning the inhabitants living in the rural areas of the Croatian and Hungarian Baranya counties. The analysis of representative samples related to the environmental attitude and behaviour is usually allowed by international questionings (e.g. Eurobarometer), but these are typically only representative of large territorial units like a country or large NUTS2 territorial level. This research was focused on the rural spaces of the Hungarian and Croatian Baranya counties and tried to answer the question of how the non-big city population related to the use of renewable energy sources, issues of environmental protection, how important they consider environmental issues and the issue of renewable energy. The respondents surveying was done in the rural areas of Baranya county in Hungary and Croatia (Osijek-Baranja county), where a quota sampling was carried out, representative of 4 settlement types, gender and generation. On both the Hungarian and Croatian side of the border, 400 persons (a total of 800) were questioned in the framework of an approximately 30 minute interview. The questions included the respondents' environmental attitude in addition to social problems they have come across. Furthermore, we asked questions concerning certain environmental and energy efficiency actions. The questionnaire also included questions concerning the subjective material wellbeing of the respondents, their influence on the neighbourhood and demography issues. The settlement categories were defined as described in table 3.1 so that each settlement type should have the same weight in the sample.

Table 3.1: The number of and distribution of settlement types in the sample of the survey-Source: Calculate by the authors

	small village (below 500 dwellers)	small settlement (501-2000 dwellers)	medium-sized settlement (2001-5000 dwellers)	small town (5,001-10,000 dwellers)
HU	20 settlements; 112 persons	8 settlements; 150 persons	2 settlements; 88 persons	1 settlement; 50 persons
HR	12 settlements; 63 persons	12 settlements; 177 persons	2 settlements; 50 persons	1 settlement; 110 persons

To sum it up: a total of 31 settlements were included in the questioning session on the Hungarian side and 27 settlements in Croatia.

3.2 Environmental attitude and behavior – main findings of the representative questionnaire

When analysing the survey results, all questions were individually analysed and we also made complex variables from the respective questions so that the correlations of the environmental attitude should be more confidently analysed and the environmental attitude should not be represented by one single question. Accordingly, when composing the questions, we made efforts to address each attitude and behaviour pattern and all further characteristics with several questions using different wording but the same essence. The first block of the questioning was designed to discover the position of environmental problems among different societal issues and in the set of problems defined by the respondents. It was a general finding that the respondents on the Croatian side were more satisfied than their Hungarian counterparts and this difference was rather striking in certain issues (e.g. situation of the economy, issue of international terrorism, health issues). The issue of environmental pollution and the impacts of the climate change as social problems were considered as issues of a medium significance in both regions in our examination. An interesting contradiction can be found when comparing attitudes to the actions actually made or behaviours. On the whole, we can say that the survey revealed a higher environmental attitude of the Hungarian respondents than the Croatian ones, i.e. the Hungarian respondents attributed a greater significance to the issue of environmental pollution as a problem. On the other hand, if we look at environmental behaviours on the basis of the questionnaire responses, we can see that the Croatian respondents acted more environment consciously, e.g. when they buy a light bulb, the energy consumption of the products matters more to them than its price (although this is also true for the Hungarians; the breakdown of the percentages shows considerable differences (table 3.2).

Table 3.2. Breakdown in the percentage of the responses to question 7 on the Hungarian and Croatian side

Hungary			
	Frequency	Percent	Cumulative percent
KT/NA	5	0.6	0.6
Quality	154	19.2	19.9
Energy consumption of the product	301	37.6	57.4
Environment protecting effect of the product	63	7.9	65.3
Price of the product	210	26.2	91.5
Origin of the product	51	6.4	97.9
The brand	19	2	99.9
Other	1	0.1	100
Total	801	100	
Croatia			
	Frequency	Percent	Cumulative percent
KT/NA	1	0.3	0.3
Quality	64	16	16.3
Energy consumption of the product	199	49.8	66
Environment protecting effect of the product	37	9.3	75.3
Price of the product	89	22.3	97.5
Origin of the product	3	0.8	98.3
The brand	6	1.5	99.8
Other	1	0.3	100
Total	400	100	

A similar but opposite disparity can be seen when purchasing a new refrigerator. 20.4% of the Croatian respondents took energy efficiency into account when buying a refrigerator, while the same proportion for the Hungarian respondents was 47%. In addition, the Hungarian respondents felt in a significantly higher proportion (σ=0.001 at 95% confidence interval) that the quality of their personal lives was influenced by economic factors (averages: HU=4.2; HR=3.79).

Further interesting analyses were allowed by the search of correlations among the respective responses and the socio-demographic features of respondents. We integrated the questions concerning environmental attitude here (besides communality that can be taken as good, the percentage value of variance explained can only be defined as very low), creating a complex variable from them. Another complex index was made concerning the judgement of the economic effects of energy efficiency, and also for the intention and real action. At these complex indices, both the co-movement of the responses given to the different questions and the percentage value of variance explained were much higher. The next step was to make regression analyses, i.e. correlations were sought among social demography indices (gender, age, education, income, subjective financial situation) and the responses given to the respective questions. The result of the regression model calculation showed that only schooling had a significant forecasting effect for a positive environmental attitude (the explanation value of the model is significant but not very strong; we were only able to explain 0.7% of the variations of the attitudes). The findings reveal that those with the lowest education level had the lowest attitude value and the highest attitude value can be seen at those who had higher education qualification, but the rising trend between the two extremes cannot be justified. Besides the environmental attitude, we find it very important to stress how the respondents acted, i.e. what they had actually done in the last year for the protection of the environment or for energy efficiency. The examination of the regression model revealed that, interestingly enough, incomes or the subjective financial situation had no significant impact on environment-oriented actions and in this respect, no difference can be seen between the older and younger generation. On the other hand, the education level and attitude predicted possible environmental protection or energy efficiency actions, i.e. the higher the respondents' education level and the more environmentally conscious they consider themselves, the greater the chance for some actual steps to be made.

A key issue of the project is energy efficiency, with its expected economic impact, and the issue of state intervention in energy efficiency. The results of the regression model examinations showed that those respondents attributed a greater significance to the economic role of energy efficiency and supported state interventions in this issue (who has stronger future intentions for making environmentally conscious actions, who is more environmentally conscious and who already acted in an environmentally conscious way, who is older and who has a lower education level).

3.3 The results of the local population survey in Koppány Valley

A local population questionnaire survey was carried out in May, 2018 in 10 settlements of the Koppany Valley micro-region (n = 310, population quota based). A single and multiple choice, Likert scale and open answer questions were used in the survey questionnaire. A descriptive statistics method was carried out to analyse the results. The questionnaire consisted of several blocks, namely background (personal) information on the respondents, awareness about RES in general and specifically biomass-based energy sources awareness and acceptance.

3.3.1 Characteristics of the sample (background information)

The majority of the respondents were female 56% (172 people from the surveyed inhabitants) and 44% of the respondents were male (135 people). The gender ratio of the respondents was quite balanced.

From the age distribution point of view, the majority of the respondents belonged to the 46-60 age group. Figure 3.1 indicates that the majority of the respondents were older than 30 (88% of the total). Considering the education level of the respondents (figure 3.2), most of the people had a vocational or high school as the highest education degrees. Only 16% obtained a university degree.

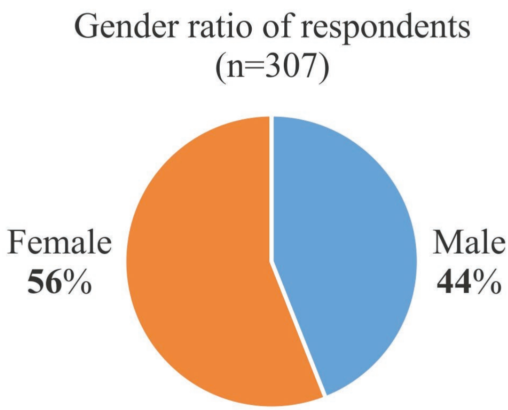

Figure 3.1 Respondents' gender.
Source: Own contribution

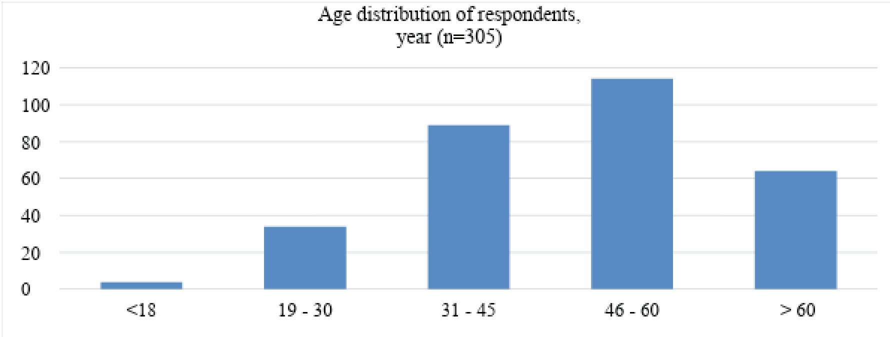

Figure 3.2 Respondents' age.
Source: Own contribution

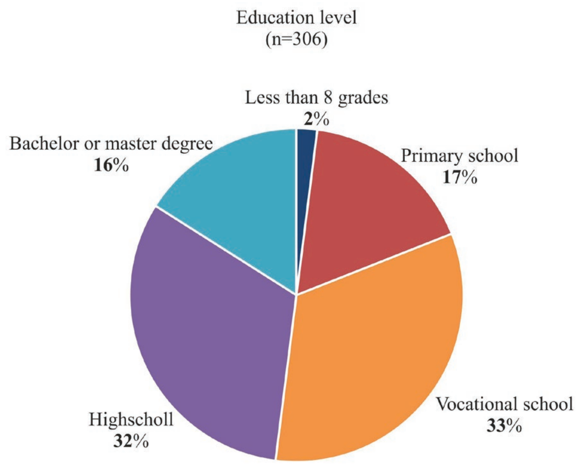

Figure 3.3 Respondents' education level.
Source: Own contribution

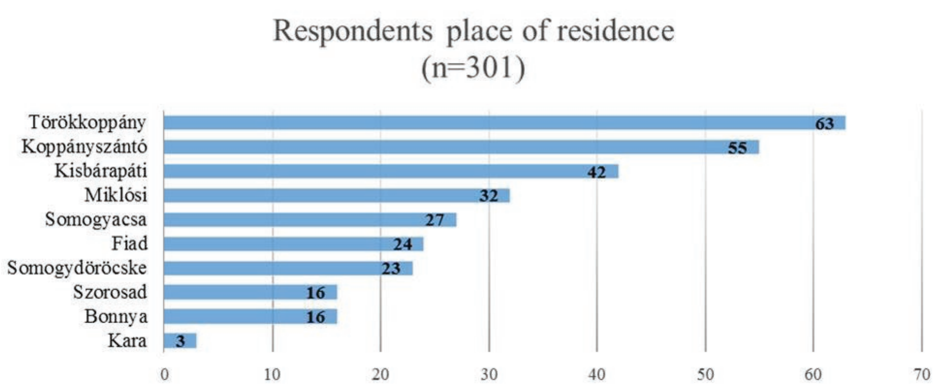

Figure 3.4 Respondents' place of residence.
Source: Own contribution

Based on the data presented in, we may conclude that the settlements with the highest number of the respondents are Törökkoppány, Koppányszántó and Kisbárapáti. In comparison, Szorosad, Bonnya and Kara are the villages with the lowest number of the respondents.

3.3.2 Awareness about RES

Among 300 surveyed inhabitants, 41 persons (13.7 %) have never heard about renewable energy sources (RES), while 259 persons (86.3 %) have heard about RES (Figure 3.5). It shows a high level of awareness about RES among stakeholders of Koppany Valley. Solar, wind and hydro energy are listed by the respondents as the most well-known sources as shown in Figure 3.6.

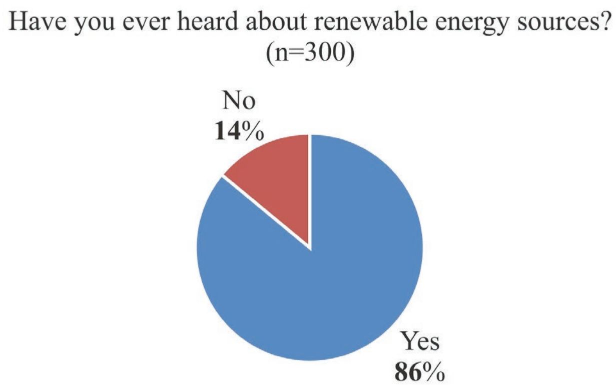

Figure 3.5 RES knowledge.
Source: Own contribution

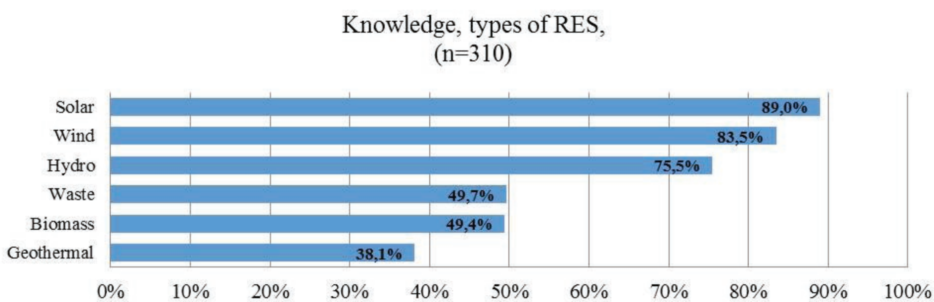

Figure 3.6 Knowledge about and types of RES.
Source: Own contribution

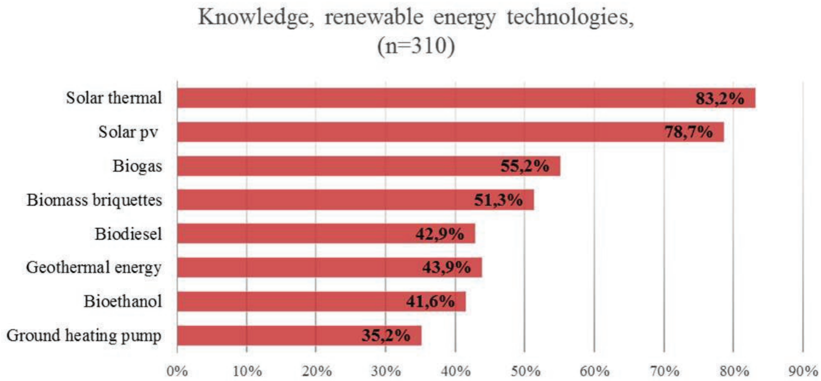

Figure 3.7 RES technologies knowledge.
Source: Own contribution

Figure 3.7 confirms the results presented in figure 3.6 by reflecting solar-based renewable energy technologies (solar thermal and solar PV) as the most recognized and well-known among the local population, 83.2 % and 78.7 % respectively.

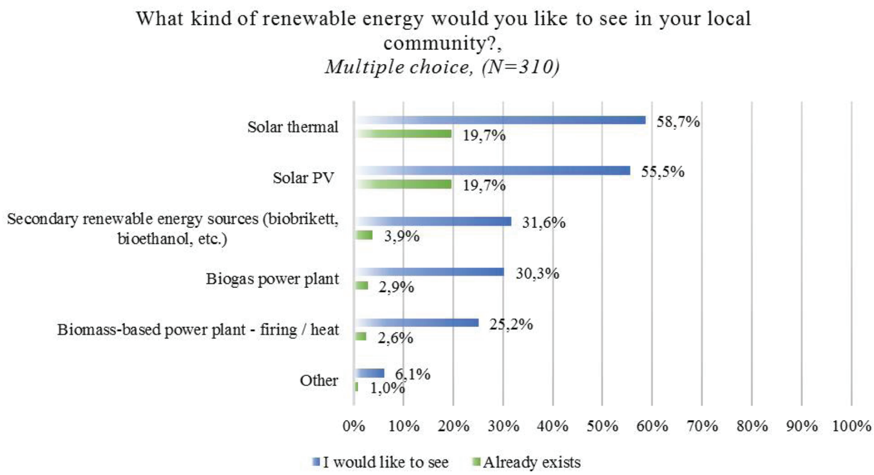

Figure 3.8 Acceptance of different RES.
Source: Own contribution

In accordance with the data illustrated in figures 3.6 and 3.7, we can see that the residents of Koppany Valley are willing to accept solar-based RES in their local community the most as shown in figure 3.8. Only 30.3 % of the respondents would like to have a biogas power plant.

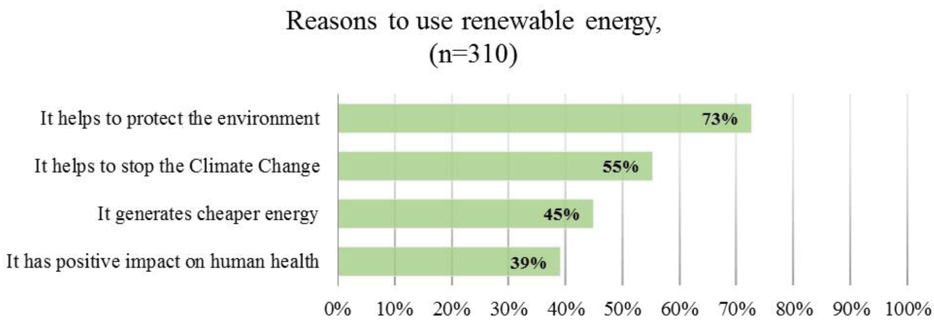

Figure 3.9 Reasons to use renewable energy.
Source: Own contribution

310 inhabitants were asked about the reasons of using RES using multiple choice questions as presented in figure 3.9. Among them, 73 % (the highest) selected the option which says "it helps to protect the environment". 55 % stated that "it helps to stop the climate change". 45 % of the respondents chose "it generates cheaper energy". Lastly, 39 % chose the "it has positive impact on human health" option.

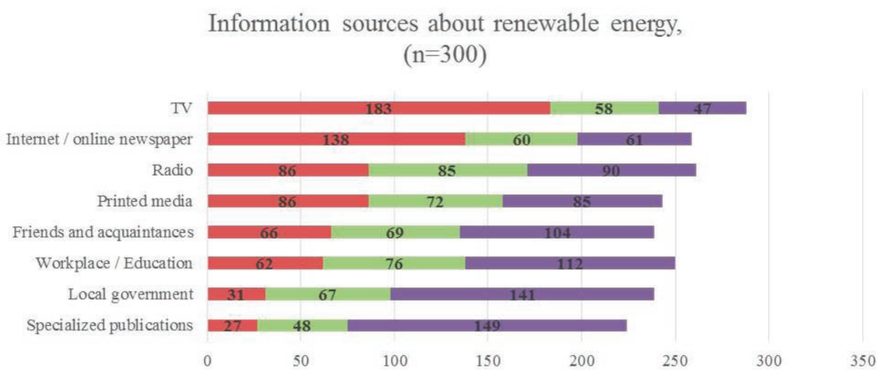

Figure 3.10 Information sources about RES.
Source: Own contribution

There are different sources to collect information about renewable energy. The graph examines, which sources are the most common or less important to provide the inhabitants with the information in the given area. TV was mentioned as the most common source to get information about renewable energy and the second is the Internet. The least important information sources, with respect to renewable energy, in the research area are local government and specialized publications as presented in figure 3.10.

3.3.3 Biomass-based energy sources knowledge and acceptance

61 % of the respondents claimed that they knowledge on biomass as shown in Figure 3.11. Among the biomass energy sources, biofuel, biogas and bio briquettes were mentioned as the most known types with more than 72 % of the awareness rate. 54 % of the population have knowledge about energy forest, energy grass and bio pellets as illustrated in Figure 3.12. Thus, general knowledge about biomass definition and bio-based energy sources among the inhabitants of Koppany Valley has basically a moderate level.

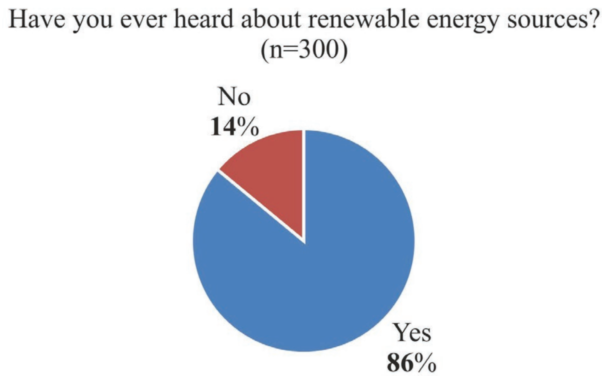

Figure 3.11 Basic biomass knowledge.
Source: Own contribution

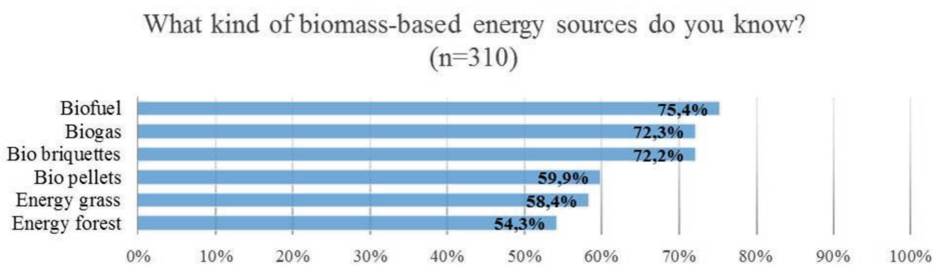

Figure 3.12 Bio-based energy sources knowledge.
Source: Own contribution

Then, we switched to the public acceptance questions part. We asked stakeholders if they would support the installation of a biogas power plant in their local community. 35% of the respondents answered “yes”, 20 % said “no” and the rest 45 % declared “maybe” (Figure 3.13). It means that the most of the respondents were not quite sure about biogas plant installation. In spite of this, 73 % of the respondents were ready to collect plant residues from their garden in order to get raw materials for the proposed biogas plant (Figure 3.14).

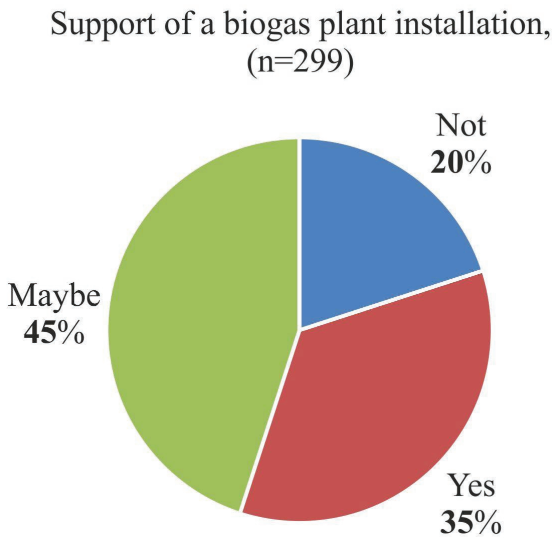

Figure 3.13 Support of biogas power plant installation.
Source: Own contribution

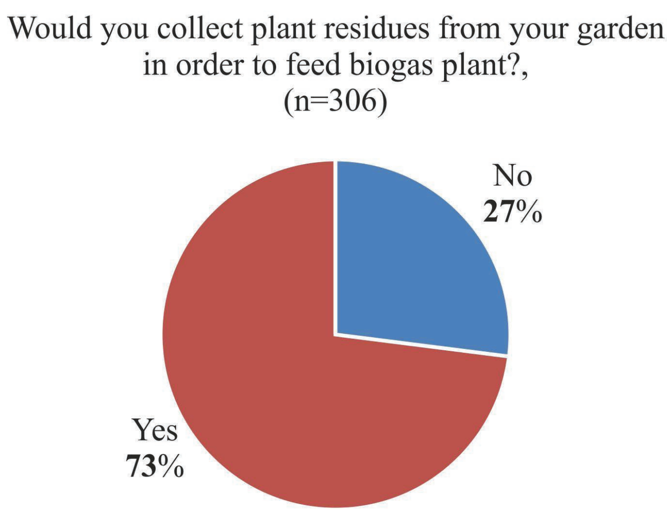

Figure 3.14 Collective activities.
Source: Own contribution

We asked the respondents to express their opinion about the statements using an estimation scale from 1 to 5, where 1 meant "completely disagree" and 5 meant "completely agree". The analysis of the different acceptance aspects as willingness to collect organic waste (this question was a Likert scale form as well), make financial contributions for the green energy utilization and readiness to participate in community activities related to biogas production is presented in figure 3.15. We can see that the respondents were much more likely to collect organic waste (so it confirmed our results presented in figure 3.14) than to work together or especially to provide financial aids.

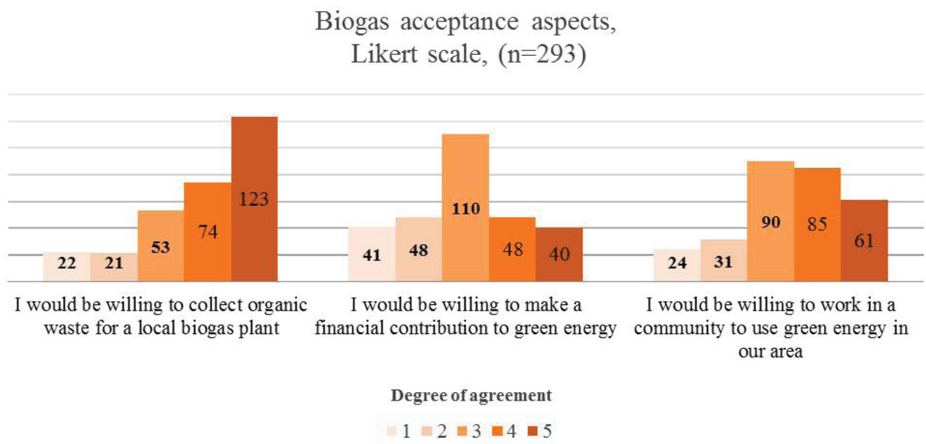

Figure 3.15 Different aspects of biogas plant acceptance.

Accumulation of raw materials is a crucial issue for the operational maintenance of a biogas plant. Therefore, the fact that the local population is willing to collect plant residues, organic waste and other bio sources for achieving a biogas plant purpose indicates a significant progress in the social potential of the area.

4 SOCIO-ECONOMIC BACKGROUND CRITERIA – STRENGTHENING THE SYNERGIES BETWEEN THE USE OF RENEWABLE ENERGY AND RURAL DEVELOPMENT

Péter Póla, Sándor Zsolt Kovács, Réka Horeczki

By the early 21st century, solutions favouring the aspects of sustainability are given more and more attention in the local economic development. These are typically built on innovative technologies that give smaller settlements (often in a handicapped situation) a chance for development. Developments related to renewable energy sources are like the ones suggested by Póla (2018).

According to the endogenous growth theory, the successful development of a region depends to a significant extent on the optimum utilization and adequate use of local resources, so local development should be based on local endowments and local resources (Mezei.& Póla 2016; Peyrache-Gadeau & Pecqueur, 2004). Our knowledge about these local resources is, however, limited. What quantity and quality are they available in? The largest part of the region, examined by the RuRES project is disadvantaged, because the foundation of a successful strategy is to have a correct list of their own resources as well as the discovery and development of these. An advantage of renewable energy sources is that they can be relatively easily registered on such a list of resources. Their disadvantage, on the other hand, is that their successful application requires complex and conscious planning in the development process. Additionally, the necessary background of human resources is already a task that requires a lot of time and resources.

Capital is a product created by the economy for production in the future, and this is also valid for human capital. Different ecosystem services (energy carriers, minerals, raw materials, etc.) all belong to the category of natural resources (Mezei & Póla, 2016). These kinds of resources, above all renewable energy sources, will allow the integration of territories into the system of economic development that struggle with a basic lack of resources, so new land use patterns can appear in these areas (Lukács 2009). It is very important, though, that the economic impacts will only be felt if a significant part of the tools and services related to the production (transportation, distribution, consumption) of renewable energy is local and regional products. This is also an important and not easy to meet criterion. It is clear that one of the most crucial elements of capital is human capital the development of which is indispensable for the adequate valorisation of renewable energy sources.

4.1 Renewable energy sources in multi-functional rural economy

It is logical that rural spaces are excellent for the production and utilization of renewable energy sources. The economic resource potential of rural areas is definitely above that of urban territories. An animal farm can be heated with biomass; huge building roof structures are excellent for the instalment of photovoltaic panels that generate electricity. In Western Europe, these buildings have been designed for years in a way that allows them to use renewable energies. In this respect, a perspective change is required both in Hungary and Croatia.

When building out systems of renewable energy, it is not only the availability of the energy source that privileges rural areas. It is less densely populated areas and smaller settlements where the construction and operation of systems at small scale is a real possibility. While the character of rural areas, with their lower number of population (fewer consumers) is rather a disadvantage for the economic efficiency, a smaller scale can now be an advantage. A similarly important aspect is the employment effect. While in towns and cities, the traditional industry, service and ICT sector have a significant number of employees, and job creation investments tend to target (big) cities in the first place, everything that promises an increase of an activity rate must be seized in villages (Póla, 2018). Developments related to renewable energies do have employment effects although dependent upon the type and technology. Where there is a little chance for alternative income generation (that returns faster and with a higher profit), the possibilities of turning towards renewable energies will increase. It is interesting that although Dalmatia is the region with the largest and Slavonia with the weakest solar energy utilization potential, it is Slavonia where by far the most investments related to photovoltaic energy are realized, and such investments have avoided the Adriatic region so far. The only reasonable explanation is that tourism in the latter region offers alternative investment possibilities paying well in the short run.

A serious challenge for rural regions is to find answers to the issue of unemployment that has risen after the modernization of agriculture that used to be a dominant employment sector. The ability to keep the population is a strategic objective everywhere and the primary tool for this is to create the economy diversification. Taking the employment and local economic development into account, the starting point must be to find local employment possibilities for rural inhabitants thusly allowing providing for their living. This should possibly be done in a way to create economic and/or social values, maintain the environment and cherish traditions.

Of the functions of rural areas (economic, ecological, socio-cultural), two are closely related to the production of renewable energy and energy utilization (Kovács et al., 2018).

The essence of economic function is competitive and profitable production (of typically foods and raw materials for the industry). The elements of the economic function include support for the establishment of alternative economic activities, including the developments concerning renewable energy, improvement of the possibilities of biomass-based energy production that fits well into the objectives of increasing the economy diversification and also matches the efforts for the adequate utilization of agricultural areas with less favourable endowments (Buday-Sántha, 2011). Strengthening of the economic function necessitates, a sort of rural re-industrialization, is one pillar that may lead to the introduction of smaller-scale manufacturing forms related to renewable energy, but above all, the production of renewable energy itself. In addition, the cost-efficient operation of rural businesses (farms and processing industry facilities) and public and private services can also be supported with cheap energy produced by local energy systems (Póla, 2018).

The most important factor concerning the ecological function is that rural areas are capable of providing recreation for urban population and the regeneration and protection of natural elements. The use of clean energy sources can also aid the protection of natural elements.

4.2 Conditions for the development of systems utilizing renewable energy sources and the limitations of their application

The design processes, implementation and numerous applications of tools and systems utilizing renewable energy and leading to energy saving have accelerated in recent years (Németh et al., 2015). Developments related to the innovative technology and operation following the investments raise several societal issues. One of the most important preconditions for the efficient valorisation of renewable energy sources is the presence of good quality human capital. The rural territories of the regions involved in the RuRES project are disadvantaged in this respect. Despite the presence of the universities of Osijek and Pécs and thereby the availability of technical skills, this human capacity does not reach the backward rural territories. Rural areas of the regions concerned are characterized by unfavourable demographic processes and low activity rate (Bálint, 2018). The schooling level cannot yet support the proliferation of major innovations and state-of-the-art technologies, and the base of vocational training and adult training is also in need of these regions' development. These problems decrease the capital absorption capacity of the area as well as the socio-economic environment is not favourable for either large businesses or the connected supplying small enterprises. This challenge concerns the cooperation system of local economic actors, the stakeholders of a local foreign direct investment policy and above all, the institutional system suitable for the generation of skilled labour force (Póla, 2018).

Because of the considerable demand of investments for financial resources and the relatively slow payback time, local self-governments with financial difficulties are only able to carry out significant investments in a supporting regulatory and financing environment although it is evident that these developments can lead to considerable savings at the settlements' institutions. The case is similar for inhabitants and businesses – despite the growing interest, investments often fail due to the lack of endogenous and exogenous resources.

The conditions for the integrated utilization of renewable energy sources must be improved. The community use of the resources available in the regions must be promoted. If municipal developments can decrease the energy demand of the infrastructure facilities considered as economic promotion tools (e.g. industrial parks), this may be attract businesses' attention.

So there is an economic development model. The first step of successful adaptation is attitude shaping and conscious economic development activity which, in some places, is the reinforcement of the economic organizational function of municipal self-governments, activation of local businesses and inhabitants, their preparation and involvement in developments.

To sum it up, we can say that a necessary condition for the strengthening of synergies between the development of renewable energies and rural development is the exploration and conscious development of socio-economic background conditions.

4.3 Conditions for the utilization biomass and the number one renewable energy of the rural areas

Although the natural endowments for the utilization of geothermal and solar energy are very good in the region involved in the RuRES project, the synergy mentioned above can be expected from energy production built on biomass in the first place. There are two basic reasons for this. One is that the quantity of biomass generated and generable in rural areas allows significant developments; the other is that biomass-based energy production has a much larger employment effect than the other two examined energies. Endowments for the generation of primary biomass are also good but the conscious collection and the use of by-products is very important too. A condition for the successful utilization of biomass for energy production is the quality of cooperation and coordination among the actors. These actors can, among others, be the following:

- agriculture and sylviculture producers;
- merchants and carriers;
- local and national authorities;
- educational actors in the region, etc.

In addition to the problems of cooperation and coordination, the use of biomass is limited by the uncertainties and fragility of ownerships. The users' interests are decreased by the characteristic feature of energy structure which, especially in the Hungarian counties of the examined region, is a serious restricting force coming from the development level of the distribution infrastructure of natural gas and the related state supports as they both set back the profitability of the renewable energies' uses. This is exacerbated by the general lack of capital typical of the rural areas. The considerable employment effect of the biomass use for energy generation is due to the fact that it is difficult to replace labour force (by mechanization) at several points of the process; starting from the preparation of soil through plant protection to harvesting and the collection of by-products or the operation of a micro-regional power station.

According to Németh et al. (2011), decentralized energy production systems, built on wood chops in the settlements with good endowments, are suitable in the Hungarian circumstances for the replacement of fossil energy sources and energy production at a competitive price. Furthermore, they also have a positive impact on the development of their direct environment. By the use of different kinds of biomass generated locally, a part of the money spent on energy carriers remains within the area and generates further development there and contributes to the decrease of imported energy dependence. A paradox situation is that the obstacles to the development and developability of renewable energies, including green energy (biomass), seem to be insurmountable just in those areas where this development direction is the greatest chance (or maybe the only chance). An adequate land use plan, clustering and cooperation (of producers and processors) are the foundation of the effective use of green energy.

4.4 Renewable energy sources in rural development strategies

The adequate exploration and then utilization of local resources require training, infrastructure development, local services, cooperation, etc. Although without external economic assistance, there is no chance of development in the most backward peripheral regions, i.e. it is not indifferent how these exogenous resources and supports are used. Conscious planning is the foundation of the effective use of resources.

Regional development based on renewable energy can be really successful if implemented on the basis of a complex strategy adapted to smaller areas. We can experience, however, that cooperation, that is a precondition for effective operation, is still weak. A well-established, bottom-up development strategy starting from a micro-regional level and harmonized at the national level is necessary accompanied by an adequate economic regulation (Lukács, 2009).

Presently, real bottom-up planning in the rural areas has been in progress at the level of local communities (LEADER), but the amount of resources available in this program does not allow larger-scale developments. The resources that would be enough for developments with real impacts and that can also assist the development of renewable energy sources are connected to a less organic strategy making process (see county level development concepts and integrated programs, financed from KEHOP, GINOP and TOP[3]).

The county development programs mention the conditions for the increased use of natural resources, but the necessary connections (e.g. training programs) are not clear (Póla, 2018). Accordingly, we cannot really talk about complex strategies definitely aiming at renewable energies. A positive fact, on the other hand, is the generation of projects implemented in regional cooperation, inspired just by LEADER, a result of which are successfully operating biomass fuelled power stations' instalments.

The rural areas, thus, need a consequent, long-term, legally and economically based renewable energy program whose financing conditions are provided. An integral element in such program is the assessment of the local (regional) energy production and energy utilization possibilities. If municipal developments can decrease the energy demand of the infrastructure facilities, that can be considered as economic stimulation tools (e.g. industrial parks), this may be attractive for businesses.

[3] KEHOP: Környezeti és Energiahatékonysági Operatív Program, Environment and Energy Efficiency Operational Programme; GINOP: Gazdaságfejlesztési és Innovációs Operatív Program, Economic Development and Innovation Operational Programme; TOP: Terület- és Településfejlesztési Operatív Program, Territorial and Settlement Development Operational Programme

5 RENEWABLE ENERGY POTENTIAL AND DECISION SUPPORT IN THE CROSS-BORDER REGION OF CROATIA AND HUNGARY – POTENTIALS FOR A MODEL APPLICATION

Matej Žnidarec, Mario Primorac, Cecília Mezei,
Sándor Zsolt Kovács

The cross-border Croatia-Hungary region has a significant solar, biomass and geothermal energy potential while hydro and wind energy potential is very low. That being said, this chapter will focus solely on solar, biomass and geothermal energy potentials in three cross-border counties. Osijek-Baranja County is situated in Croatia while Baranya and Somogy counties are situated in Hungary.

5.1 Demand for decision-making support by municipalities in rural areas

Municipal self-governments have a special role in the organisation, initiation and promotion of local developments. They are the local actors that are authorised to represent the interests of the local commodity and harmonise the development concepts of the individual local actors with each other. If all goes well, these concepts are channelled during a participative planning process (Gébert et al. 2016) into the frameworks of the local development plan, programme or maybe a single project where all stakeholders can have their voices heard and during which all potential added values (individual activity, own resources) are present.

The responsibility, however, which municipal self-governments carry for local development, is great. Furthermore, if we concentrate on the special features of the rural areas (ageing population, out-migration, concentrated disadvantages, worsening accessibility etc.) and the fact that they typically have (especially in Hungary) smaller municipalities (with less functions, deficient institutions and services, more limited budget, modest development power), the constraints of the development track are even stronger (table 5.1). In villages most things happen when the municipal self-government is able to acquire auxiliary development resources by some successful tendering activity. On the other hand, this tendering behaviour distorts local developments as well, as they usually reflect not to the most urgent problems but adapt to the priorities set by the central development policy: it is just the adaptation to the local needs that is neglected, while these projects absorb all the scarce financial resources that are at the disposal of the municipalities.

Table 5.1: Administrative and planning spatial categories of the two examined countries, 2018

Aspects	**Hungary**	**Croatia**
Type of state	centralised, unitary	centralised, unitary
Number of municipalities (LAU2)	3,155	556
Of which: number of urban municipalities	346	127
Average number of population per municipality	3,150[1)]	7,707[1)]
Number of settlements	3,155	6,756
Number of LAU1 levels without self-governance	districts (197)	-
Territorial self-governments (NUTS3)	counties and the capital city (20 altogether)	Županija (21)
Number of NUTS2 planning and statistical regions	8	2

Note: 1) calculating with census data (2011)
Source: Eurostat 2018, Rácz 2016, KSH 2018.

These municipal self-governments follow *forced tracks* also when some investors contact the respective municipality with an investment idea that seems to be good at a first glance. Then and there the body of representatives must decide whether they make a respective local resource (a construction site, a building of the municipality or the local remote heating system etc.) available for the investor. On such occasion it is very rare that deliberations are made whether the investment to be made is compatible with the local development strategy or plan, and it is also not typical to carefully consider and analyse alternatives of the investment (a remote heating of another type, the use of the public building or site for another function).

It is a huge challenge for small rural municipalities to *collect and systemise all information* necessary for the decision-making *and analyse and evaluate it at an adequate level*, when most of the local plans and development concepts are made using central statistical data, following tables and all the steps of the guidelines of single templates. Most of the times *expertise and competency for the coordination of local developments are also missing in situ*, and it cannot be an expectation, as the administrative staff of the mayor's offices consists of public servants who reflect on the narrowed range of functions of rural municipalities.

Thus, for the preparation of local development plans made in a participative way just those *driving forces, persons, experts* are missing in the first place who could be able to initiate the whole local process. This would be a prerequisite for the municipal self-government to take responsibility for alternative, i.e. non-obligatory tasks like the promotion, coordination and implementation of local developments. We have to admit that in many cases it is a matter of money. A smaller municipality generates (by local taxation) or accumulates – through state transfers – less *development resources*, they are also able to absorb less money by tenders. Size is thus a dominant factor. On the other hand, the inclusion, activation and understanding of local actors and the stimulation of their cooperation are not a matter of finances. It is more about an attitude, a *practice of inclusion* that is typically missing yet from the community planning practice of the East-Central European region – despite the fact that this would be a solution for the integration of local knowledge, local demands and the resources and efforts of the partners.

The next factor that is missing for successful adaptive local developments is just the *range and adequate evaluation of systemised information about local characteristics and local resources*. A lot of information can be collected from central statistical and information systems, but the finding, systematically collection and adequate handling of these pieces of information (analysis, evaluation, relation etc.) usually require special skills. The other source of the problems is that a part of local information does not even appear, or cannot be collected from central databases, as they are the property of local actors, and they should be asked personally, or, in many cases, information is accumulated as piles of papers or a collection of electronic documents at the local municipalities (and is often handled not as information but as administrative files).

We can thus sense a huge demand for information by those rural municipalities that lack the necessary professionalism, capacities and competencies for data collection, data management and also development planning. There may be and actually there are initiatives for the provision of data tables, following a complex structure, for respective settlements. From the Information Database of the Hungarian Central Statistical Office[4], from its territorial statistical module[5] e.g. it is relatively easy to collect data at settlement level. Another good example from the Hungarian institutional system is the National Regional Development and Spatial Planning Information System, TeIR[6] (Országos Területfejlesztési és Területrendezési Információs Rendszer) managed by Lechner Knowledge Centre[7], also suitable for the provision of data at settlement/territorial level, in some cases even for comparative analyses. Looking outside the research area of the project, the Dutch government, recognising the essence

4 http://www.ksh.hu/?lang=en
5 http://statinfo.ksh.hu/Statinfo/themeSelector.jsp?page=1&theme=T
6 https://www.teir.hu/
7 http://lechnerkozpont.hu/

of the problem, operates a website with an independent set of indicators[8] with the collaboration of the association of the Dutch municipalities (VNG), in which all municipalities are members, although membership is not obligatory. The system called Vensters (Windows)[9] managed by the VNG, the association of the Dutch municipalities is a platform that also has a telephone application suitable for the comparison of the performance and operation of the individual public service providers and governmental actors, basically at any dimension and scale and in connection of several categories of data and functions.

A *decision-making support system* can offer more than a complex table of data (i.e. the structured dissemination of collected data) inasmuch as it is suitable for the featuring of the *demand of alternative decisions* made with the consideration of certain (optional) conditions *for tools and resources, and/or the impacts and consequences of the decisions*. The use of the decision-making support application (if complemented by a user friendly platform) is also good for the handling of the problem that users of the model may not necessarily be experts of data collection and analysis, still they are able, and must be able to comprehend alternatives for a responsible investment and development decision

5.2 A decision-making support application focusing on renewable energies

The field of renewable energy developments, a special focus of the project, is an even more special area. Its speciality comes from the fact that a wide range of renewable energy sources and the dominant share of biomass are present in rural spaces as "raw material" for potential use. The potential is there, it should only be utilised. It is not an accident that we find priority J.68 called "Sustainable energy and renewables" in both the Hungarian and the Croatian national S3, intelligent specialisation strategies, generated by the European Union just for the promotion of bottom-up local, regional and national development strategies built on partnership[10]. The EU directive concerning the sector[11], the renewable energy indicators featured in the EU2020 strategy and to be channelled into the National Reform Programmes, and the renewable energy related development tenders have been a motivation for a long time to orientate developments from both private and public resources into the field of renewable energy (of course it does matter at what pace this happens). In the counties of the area in question too several investments have been made in the field of renewable energy both as community-funded projects and as private investments.

8 https://www.waarstaatjegemeente.nl/
9 https://www.venstersvoorbedrijfsvoering.nl/english/#!/
10 http://s3platform.jrc.ec.europa.eu/map
11 2009/28/EK irányelv

These investments started in the field of renewable energies can be used as examples, on the one hand, and can create a fashion for other investments, on the other hand and can also have measurable local economic development impact (Mezei 2008, 2013). The problem is just that possibilities lying in renewable energies (job creation, cost efficiency etc.) can generate realistic economic development project in rural spaces, but their appearance both in planning (strategies, concepts) and in implementation is untypical, apart from a few good examples (Kovács et al. 2018).

In the rural areas of the three counties selected in the project there is an obvious potential on which community or private investments could be made in the sector of renewable energy. In this local decision-making, the municipal self-governments have a huge responsibility: in the creation of local regulations and incentives, the promotion of local cooperations and in the shaping of the energy consumption of their own buildings. It is not easy, however, to make a good decision when the energy sector, the technological and technical background of potential investments and the range of tendering constructions require such specialised skills that may not necessarily be present at the local public administration. The analysis of the investment alternatives and the assessment of the potential impacts of interventions require considerable circumspection and knowledge. Parallel to the ever growing external pressure and attraction in the field of renewable energy (tendering constraint, fashion trends), it is just the small rural municipalities that lack the expertise necessary for making well-grounded decisions. These municipalities usually also lack the resources by which they could involve external resources (assignment of external experts) into the support of decision-making.

Baranya and Somogy counties on the Hungarian side, in addition, are two of the counties with the tiniest villages. The average number of population per settlement is only around 1,300 persons, and there are very many villages with less than 500 inhabitants (table 5.2). On the other hand, Osijek-Baranja County operating in the Croatian structure with much more integrated municipal system features an average number of population per settlement that is just below the national average (table 5.1).

Table 5.2: Main features of the counties in the area examined, 2018

aspects	Baranya (HU)	Somogy (HU)	Osijek-Baranja (HR)
Number of municipalities (LAU2)	301	246	42
Of which: number of urban municipalities	14	16	7
Average number of population per municipality	1,284[1)]	1,285[1)]	7,263[1)]

Note: 1) calculating with census data (2011)
Source: Rácz 2016, KSH 2018.

For making municipal decisions concerning the sector of renewable energy, no matter if it is local regulation, investment permits or self-financed investments, local decision-makers must possess exact information about those potentials that lie in renewable energy sources at local/regional level. A good decision-making support system also enumerates limitations that set back the utilisation of these potentials (see e.g. special construction rules for the installation of power plants, already operating biomass plants in the area etc.). Considerate decision-making is alleviated by the possibility of the users of the application to make comparative analyses (potentials in other settlements and regions, in other investments or technological solutions etc.), and the possession of preliminary information about the investment (which can evidently only be average investment/payback calculation planned for average capacity).

5.3 A potential version of the municipal decision-making support application, model

The paragraphs above demonstrate that there is a strong demand by the municipal sector for a kind of *application for the estimation of resources*. Thus, in the framework of this research we elaborated a version of a potential analysing model concentrating on natural, renewable energy sources. The model worked out, with respect to the fragmented Hungarian municipal system, is designed to demonstrate for as small a territorial unit as possible the realistically exploitable potentials of the sources of renewable energy (solar, geothermal and biomass).

Like in the case of all applications that operate with data and databases, furthermore, all this with an international territorial focus, the first problem to be solved is the collection of comparable (categories of) data. We also encountered this problem when elaborating this model, and we did not come up with a solution satisfactory from all respects, but the aim of this chapter is the demonstration of the theoretical and calculation frameworks, as opposed to the dissemination of detailed findings for all settlements.

The primary focus of the RuRES project is the energetics investment alternatives realisable in rural areas. For the verification and exact calibration of the model results we analysed several investments that had been implemented in the areas, and we justified their relevance with the results of the model.

We are aware of the fact, however, that the investment decisions grounded by the model results themselves are significantly weakened in small settlements by the lack of resources of the municipal self-governments, the deficiencies of the tendering system and the inadequate level of local knowledge, i.e. factors that are not quantifiable and so cannot be integrated into the model. Like in the case of all estimating models, it is true also here that the results can be utilised if supplemented by the current local knowledge.

5.4 Sun energy

Solar radiation is one of the atmospheric resources, a source of energy, a condition for life (photosynthesis) and a dominant factor in agricultural production.

The electromagnetic radiation coming from the Sun provides the energy necessary for the processes taking place in the atmosphere. It has two important characteristics: its *intensity* (strength) and *duration*. The value of radiation measured on the surface of the earth shows much radiation comes down to the bottom of the atmosphere. The *duration* of radiation is the actual duration of sunshine measured on the surface of the earth. The measurement unit of radiation is MJ/m^2. Instead of this, however, it is often the sunny periods (e.g. number of the hours of sunshine) that is measured (Varga-Haszonits, Varga, 1999).

The *intensity* of radiation depends on

- the incidence angle of the sun rays (geographical latitude),
- the composition of the atmosphere,
- pollutants that can be found in the atmosphere,
- the humidity of the air and
- cloud coverage.

Moving upwards, with the change of the altitude the intensity of radiation increases – as the air contains less and less steam and pollutants –, also, its composition changes (larger proportion of direct radiation, larger volume of ultraviolet radiation). The intensity of radiation is the stream of energy received by a surface per unit area; its measurement unit can be W/m^2 or $J/m^2/s$, calculated in total amount of energy: $MJ/m^2/s$ (Anda et al. 2010).

Due to its geographical location and developed agriculture, the cross-border Croatia-Hungary region is a source of different renewable energy sources. Because of its favourable location (geographical latitude 48° north), the cross-border region has a large solar energy potential (figure 4.1). The average annual solar irradiation on a horizontal plane in the cross-border region is around 1300 kWh/m^2. The annual optimal inclination angle of photovoltaic modules and solar thermal collectors is 34° for Osijek-Baranja County in Croatia and 35° for Baranya and Somogy counties in Hungary (PV GIS, 2018). According to the Hungarian Investment and Trade Agency (2014), the theoretical thermal energy potential produced from solar energy for Hungary is 28,472 MWh/year. Global, direct and diffuse monthly and annual solar irradiation for Osijek-Baranja, Baranya and Somogy counties is provided in table 4.1.

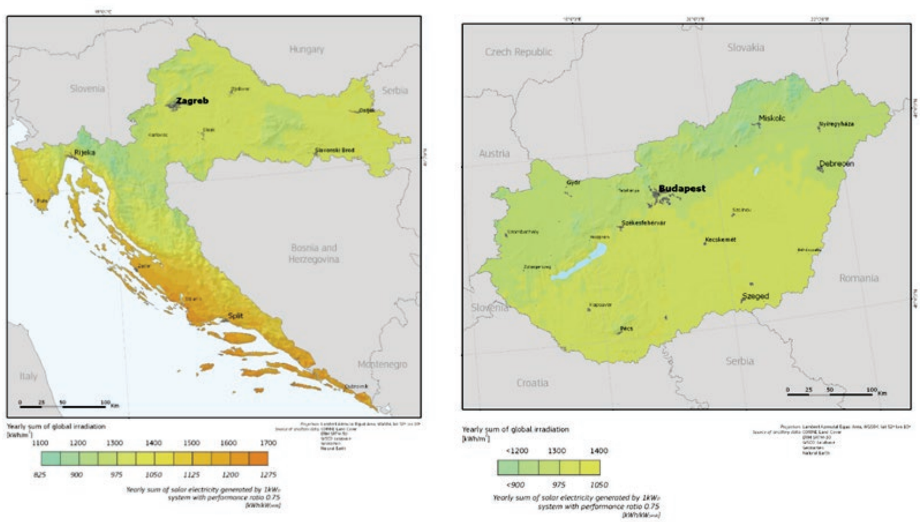

Figure 5.1. Annual solar irradiation in Croatia and Hungary
Source: PV GIS, 2018.

Table 5.3. Global, direct and diffuse monthly and annual solar irradiation for Osijek-Baranja, Baranya and Somogy counties

County	Osijek-Baranja (Osijek)			Somogy (Kaposvar)			Baranya (Pecs)		
Month	Global	Direct	Diffuse	Global	Direct	Diffuse	Global	Direct	Diffuse
	kWh/m²/day			kWh/m²/day			kWh/m²/day		
Jan	1.1	0.74	0.36	1.12	0.73	0.39	1.12	0.73	0.39
Feb	1.85	1.09	0.76	1.95	1.13	0.82	1.89	1.1	0.79
Mar	3.48	1.81	1.67	3.33	1.76	1.57	3.38	1.79	1.59
Apr	4.84	2.13	2.71	4.79	2.16	2.63	4.79	2.16	2.63
May	5.74	2.41	3.33	5.8	2.44	3.36	5.7	2.45	3.25
Jun	6.27	2.51	3.76	6.21	2.55	3.66	6.2	2.6	3.6
Jul	6.44	2.32	4.12	6.34	2.35	3.99	6.28	2.45	3.83
Aug	5.65	1.86	3.79	5.51	1.93	3.58	5.45	1.96	3.49
Sep	3.9	1.72	2.18	3.82	1.72	2.1	3.8	1.75	2.05
Oct	2.7	1.32	1.38	2.63	1.32	1.32	2.64	1.32	1.32
Nov	1.42	0.82	0.6	1.3	0.78	0.52	1.35	0.81	0.54
Dec	0.87	0.61	0.26	0.88	0.61	0.27	0.87	0.59	0.28
Year	1,350.02	589.08	760.94	1,332.02	592.51	739.51	1,325.79	600.33	725.46

Source: PVGIS 2018

The model calculates the maximum annual performance from the irradiation values of the respective settlements. During our previous researches we classified the solar energy potential of the settlements, using two reference values (1,480 and 1,530 kWh/m^2) into three basic categories: below average, average and excellent (Mezei ed. 2015). In the region examined in this research we can see excellent and good irradiation values on the whole, and so we can have no reservations on the input side before the implementation of developments for the utilisation of solar energy, and so we abandoned this categorisation, i.e. there is no area not recommended for investment in the study areas.

For the installation of solar power plants, public areas, industrial sites and purchased former private lands can all be used, so this does not require special differentiation among the settlements, but it is important to remark that we can see prohibitions by local decrees and regulations in some areas, and so we integrated this aspect into our application by formulating a closed-ended question (*Do you know any local regulation which prohibits the installation of new solar power plant?*).

In the case of solar energy we examined a solar energy park implemented in late 2012 in Sellye, in the Ormánság area – one of the most backward areas of Baranya county and Hungary. One the basis of the results of our model, the irradiation value of the settlement is 1,526 kWh/m^2, which is slightly above the project average (1,522.53 kWh/m^2) and significantly exceeds the national average (1,481.1 kWh/m^2), which was an important location factor in the implementation of solar energy based investments in the area. The solar power plant, constructed as a private investment, has a capacity of 0.49 MW, due to restrictions by the law, and since its foundation until 2015 it was the biggest power plant of its kind in Hungary. The double-axis tracker system that was realised with an investment of approximately 1.65 million € on an area of 2.5 hectares has a total of 50 PV panels, 70 m^2 each and is suitable for the generation of electricity equal to the annual consumption of 250 families (Nyári 2014).

***

Another possibility of using solar energy is the application of solar thermal collectors to produce hot water that is used in the water supply and heating system of the respective building. An example for this is the secondary school of Valpovo in Osijek-Baranja where the former natural gas based heating and hot water production system was partly replaced by the installation of solar thermal collectors. In winter months the system operates as an auxiliary system that produces 1.2–10 percent of the actual monthly hot water demand, while in summer months 160–280 per cent of the actual demand can be produced. On the whole, 30 percent of the annual demand can be generated by solar thermal collectors. This of course leads to a decrease in the energy budget and the reduction of the emission of hazardous materials (Hornung et al. 2010, Stojkov et al. 2015).

5.5 Biomass

The use of biomass in energy production is usually classified by the states of matter of the biomass generated as a source of energy: we can distinguish solid, liquid and gas biomass. Incinerable biomasses typically have relatively low content of humidity and consequently high calorific value. An important requirement when using incinerable biomasses is that the non-combustible ashes should have chemical compositions that to not damage the furnace and are not melted onto the heating surface, also, do not cause a significant pollution of the air.

According to the "Potential of renewable energy sources in Osijek-Baranja County", 2013 ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013), biomass can be divided with respect to the origin of its creation as biomass from

- agriculture;
- forestry;
- solid waste.

5.5.1 Agriculture biomass

Agriculture biomass is formed by a regular agriculture activity during the year. It can be divided into biomass from *farming* – remains after harvest and vegetable farming, *cattle breeding* – liquid and solid manure and biomass that origins from *perennial crops* – wood and other remains created by regular maintenance of perennial crops ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013).

Agriculture biomass, depending on the applied technology, can be used for production of heat, electricity, mechanical energy (liquid fuels) as well as derivatives which can be used for production of usable energy (Ivanović & Glavaš, 2013). The most common derivatives produced from agriculture biomass are briquettes, pellets, biogas and biofuels ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013). Table 5.4 shows a lower heating value of different agriculture remains.

Table 5.4. Lower heating values of different agriculture remains ().

Biomass type	Lower heating value [MJ/kg]
Wheat straw	14.0
Barley straw	14.2
Oat straw	14.5
Roast straw	14.0
Corn leaf	13.5

Corn cob	14.7
Sunflower stalks	14.5
Sunflower shell	17.6
Soy strain	15.7
Rapeseed straw	17.4
Tobacco stalks	13.9
Residues of resin	14.0-14.2

Source: Ivanović & Glavaš, 2013

According to Lechtenböhmer, Prantner, Schneider, Fülöp & Sáfián (2016), Hungary's theoretical energy potential of biogas, biofuels and energy production from waste (biomass) is 54 167 GWh/year while the authors in the Hungarian Investment and Trade Agency (2014) claim that the theoretical energy potential of all types of biomass is 83 333 GWh/year.

5.5.2 Biogas

Agriculture biomass can be used for production of high-energy fuel called biogas. Biogas is mostly produced by anaerobic digestion of biomass. Combustion of biogas can be used for production of electricity, heat or both at the same time with cogeneration. The average lower heating value of biogas is 21 MJ/kg. Biogas can be produced in mono-digestion or co-digestion with corn silage in 30% share. The energy potential of biogas production can be calculated as below. Table 5.5 shows the annual energy potential of biogas production in 2016 for Osijek-Baranja, Baranya and Somogy counties.

$$BP = m \cdot oST \cdot p \cdot k \; [kWh/god]$$

where

BP – energy potential of produced biogas [kWh/year]

m – mass of cattle, pig and poultry manure produced in the county [t/year]

oST – share of dry organic matter in fresh raw material

p – methane yield per mass of organic dry matter in fresh raw material [m^3/t oST]

k – methane energy value [kWh/Nm^3]

Table 5.5. Annual energy potential of biogas production in 2016 for Osijek-Baranja, Baranya and Somogy counties.

Baranya				
Type	Number *	Availability of manure per unit [t/year] **	Annual availability of manure [t/year]	Theoretical energy potential [MWh/year]
Cattle	34,000	10	340,000	187,000
Pigs	226,000	1.20	271,200	45,182
Poultry	1,915,000	0.008	15,320	15,167
Somogy				
Type	Number***	Availability of manure per unit [t/year] **	Annual availability of manure [t/year]	Theoretical energy potential [MWh/year]
Cattle	46,000	10	460,000	253,000
Pigs	145,000	1.20	174,000	290,550
Poultry	484,000	0.008	3,872	3,833
Osijek-Baranja				
Type	Number****	Availability of manure per unit [t/year]	Annual availability of manure [t/year]	Theoretical energy potential [MWh/year]
Cattle	85,828	10	858,280	472,054
Pigs	342,841	1.20	341,960	56,970
Poultry	544,938	0.008	4,360	4,317

Sources:
* *(Központi Statisztikai Hivatal, 2018)*
** *(Energy Efficiency and Renewables Supporting Policies in Local level for Energy, 2012)*
*** *(Központi Statisztikai Hivatal, 2016)*
**** *(Hrvatska poljoprivredna agencija, 2016)*
***** *(Hrvatska poljoprivredna agencija, 2017)*

Biologically gasifiable biomass typically consists of plant waste or animal waste with higher humidity content, and so in this field we assessed the size of livestock in the settlements, using the data provided by the statistical offices (KSH and DZS). Taking the number of livestock (cattle, pig and poultry) kept in the settlements into consideration we can estimate the volume of manure generated. The amount of manure produced by cattle is 10 t/year/animal (12% content of dry matter), by pigs it is 1.2 t/year/animal (8%), by poultry 0.008t/year/animal (30%) on the average.

The expected output of biogas produced by cattle is 375 m^3/t (of dry matter), by pigs 500 m^3/t, by poultry 400 m^3/t. Methane content is 62.5% on the average at all three types of manure in our calculations. Accordingly, 1 m^3 of biogas is suitable for the generation of 1.78 kWh by our model (Laczó 2012; Mezei ed. 2015). This means the following: the contribution to energy production by one cattle, pig or poultry is 500,625, 53.4 and 1,068 kWh, respectively, if their organic manure as is used biomass.

5.5.3 Liquid biofuels

Liquid biofuels bioethanol and biodiesel are produced by hydrolysis and esterification of vegetable oils with alcohol. In the cross-border region, corn and sugar beet can be used for production of bioethanol while rapeseed and soy can be used for biodiesel production. The theoretical annual energy potential of bioethanol production from corn and sugar beet and biodiesel production from rapeseed and soy is given in Table 5.6 for Osijek-Baranja County ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013) and in table 5.5 for Baranya and Somogy counties.

Table 5.6. Annual theoretical energy potential of liquid biofuels production in Osijek-Baranja county ().

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

Source: "Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013
** based on average yield of agriculture culture from Statistical anniversaries of the Republic of Croatia for the period from 2006 to 2008 and available agriculture land for cultivation of energy crops data;*
*** a.v. – average value between dry milling and wet milling process*

Table 5.7. Annual theoretical energy potential of liquid biofuels production in Baranya and Somogy counties.

Raw material type	Raw material mass [t/year] 2016		Biofuel quantity [t/year]		Lower heating value [GJ/t]	Theoretical energy potential [GWh/year]	
	Baranya *	**Somogy** **	**Baranya**	**Somogy**		Baranya	Somogy
	Bioethanol						
Corn	656,619	682,987	197,557	205,490	27	1,482	1,541
Sugar beet	74,490	126,055	5,774	9,772	27	43	73
	Biodiesel						
Rapeseed	60,585	86,466	24,836	35,445	37	255	364
Soy	58,903	8,071	11,156	1,529	37	115	16

Sources:
** (Központi Statisztikai Hivatal, 2018)*
** * (Energy Efficiency and Renewables Supporting Policies in Local level for Energy, 2012)*

5.5.4 Forestry biomass

Most commonly used wood biomass types for energy purposes are wood, wood chips, bark, sawdust, wood shaving, briquettes and pellets. According to the data from 2014, Osijek-Baranja County had 12,723.31 ha of forest area, i.e. 29.05% of the total county area. Forestry biomass can be used for the production of heat, electricity and liquid and gaseous fuels with different types of thermochemical and biochemical processes. Figure 5.2 illustrates a distribution of wood stock in Osijek-Baranja County. The theoretical energy potential of wood biomass for Osijek-Baranja County is provided in table 5.8 (Food and Agriculture Organization of the United Nations, 2009).

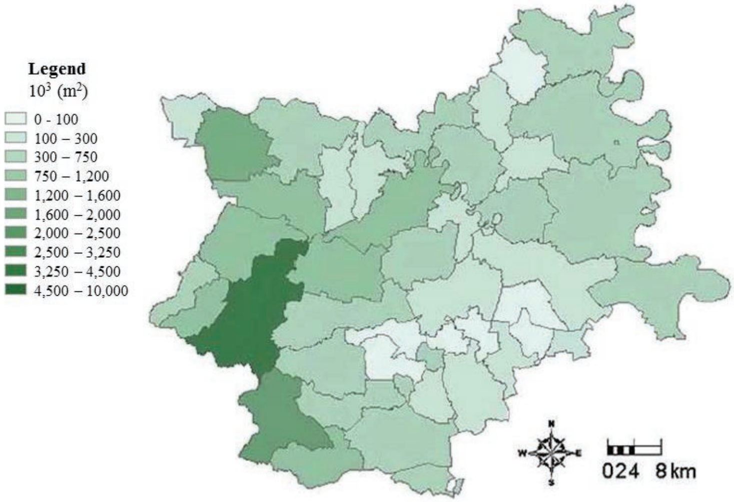

Figure 5.2. Distribution of wood stock in Osijek-Baranja County. Source: Food and Agriculture Organization of the United Nations, 2009.

Table 5.8. Theoretical annual energy potential of wood biomass for Osijek-Baranja County (Food and Agriculture Organization of the United Nations, 2009).

Total wood stock [m³]	Total annual increment [m³]	Annual energy potential of wood biomass (including conifers) [m³]		Theoretical annual energy potential of wood biomass (including conifers)			
				Planned cutting		Performed cutting	
22,291,528	758,143	Planned cutting	Performed cutting	GWh	TJ	GWh	TJ
		274,143	186,370	479	1,724	344	1,239

The volume of biomass in this group, as a potential is integrated into our model in two ways: on the one hand, using the Corine database we assessed the size of the local forested areas (of the settlements) – in hectares –, and based on this we estimate the expected calculable sustainable output (equivalent with dry wood) of extraction at 4t/year/ha, while its caloric value is approximately 17 MJ/kg in our calculations (Laczó 2012). On the other hand, we considered the size of lands not used by agriculture (ha) as potential areas for planting energy forests[12], the expected output of which is 15t/year/ha annually, the calorific value is 18 MJ/kg (Tamás, Blaskó 2008; Laczó 2012).

[12] The establishment of plantation bears several ecological risks caused by the disadvantages of soil preparation and monoculture production; we will raise the awareness of the users of the model about this in the descriptive part of the model!

An important limiting factor in our model is the existence of already operating power plants using biomass in the respective settlements and their direct environment, as an already operating plant may absorb the significant part of the potentials and thereby the economies of scale of a new plant may not be reached.

As a good example for the use of biomass in the region, we can mention the Arany-Mező Inc. in Bicsérd. The business is an agricultural company active both in animal husbandry (pig farm and cattle farm) and plant cultivation, cultivating more than 2,000 hectares of plough land, from which 1,100–1,200 hectares are used to produce the fodder base of animal husbandry. An important part of developments realised in the animal husbandry sector was the adequate treatment of organic manure and slurry generated, and for this purpose a biogas plant was built in Bicsérd. The capacity utilisation of the investment inaugurated in 2011 is 95%. The system absorbs an annual amount of approximately 40,000 tons of organic waste, 90–95% of which is slurry and solid manure generated in animal husbandry. This production capacity allows the annual production of 4.3 million kWh electricity (the annual demand of 950 households on the average) and 5.1 million kWh of heat (the annual demand of 450 households on the average). A very important fact from agronomic aspect is that fermentation liquid generated as a by-product of biogas production is used in agriculture as a fertiliser. As this means savings of other fertilisers, it also improves the profitability of biogas production (Kovács et al. 2018).

A similar biogas plant using organic manure of animals and other agricultural wastes can be found in Vajszló (Rideg 2009), producing 4.5 GWh of green energy and 4.8 GWh of thermal energy, also, on the other side of the border, in the settlements Vuka and Goranji in Osijek-Baranja, biogas power plants of 1000 kW output operate (Fabek, Grabar 2013).

5.5.5 Solid waste biomass

Solid waste biomass is considered as a biodegradable part of municipal waste, food industry and other related industries. Furthermore, solid waste biomass can origin from wood industry. The theoretical annual energy potential of solid waste biomass for Osijek-Baranja County is given in table 4.7 ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013).

Table 5.9. Theoretical annual energy potential of solid waste biomass for Osijek-Baranja County ("Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013).

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

Sources:
**National waste register for the period from 2008 to 2010 (Croatian Environment Agency)*
*** produced using biogas production technology*

5.6 Waste

Waste, if collected and treated adequately, is also a resource, it can be converted into recycled raw material or fuel used for electricity production. It is an important aspect how redundant materials mixed into the system of wastes are disposed: separately or together with the mixed waste, as in the former case it is clean and recyclable raw material, while in the latter case it is contaminated and so usable things, after sorting out, can only be converted into RDF (refuse derived fuel) or SRF (solid recovered fuel).

We integrated waste and its energetics potential into our system in two ways of calculation. On the one hand, we collected data of the settlements from the databases of HCSO concerning the amount of waste transported annually from the settlements (tons/year), and also the proportion of waste collected selectively (%). On the basis of our researches and our discussions in the topic the calculation is as follows: the baseline is the amount of communal waste and 10 percent of it as the volume collected selectively (t). Of the volume of mixed waste calculated this way, 45 per cent can be used as potential biogas source; the amount of energy that can be generated from this is 6 MJ/kg, which of course can also be converted into kWh (Mezei et al. 2018).

The other way for the utilisation of wastes is the construction of power plants incinerating the plastic content of formerly established waste deposits out of use now. This plastic cannot be used as biogas but has a potential for energy production. The baseline in this case is the communal waste of the settlements again. Calculating with an average 20 years of lifespan for waste deposits, we multiply the amount of the last available annual amount of communal waste of the settlements by twenty, and then 15 percent of this is taken as potential (plastic content), from which 14 MJ/kg energy can be generated on the average (Vér et al. 2017, Mezei et al. 2018).

As regards the potential of energy production based on the biogas from the deposits, it is also based on the volume transported to the deposits in twenty years (t), where 750 kg of waste is equivalent to 1 m^3, from which 17 MJ/m^3 energy can be produced (SMKP 2009, Mezei et al. 2018.).

The use of waste for energy production can also be limited by a power plant already working nearby as a potential buyer of "raw materials", and so their locations by settlements were also integrated into the model.

According to our analysis of ten small rural settlements using waste as a potential raw material for energy production, in the Koppány River valley there is a strong potential of waste for energy generation (table 5.10). There are several alternative uses for the disposal of biologically degradable wastes, but even closed old waste deposits have energy potentials. Being an average rural area, the centralised waste management system results in a longer transport route in the Koppány River valley, also, the range of waste management services is narrower than in most urban settlements (possibility of selective collection at households, frequency of transport etc.).

A specific problem in the Koppány River valley is the low capacity of the composting plant of the neighbourhood. The recently introduced biological waste collection using "selective bins" resulted in 12 tons of compostable waste in the region, which lags significantly behind the real potential. A further change in the behaviour of society (selective waste collection) and a new investment could considerably improve composting capacities also in this region (Mezei et al. 2018).

Table 5.10: Waste-based energetics potential in the Koppány River valley, 2017

Settlement / specification of potential	Energy potential of the annual communal waste (MJ/year)	Energy potential of waste deposits, MJ	Potential of biogas production located in the waste deposits, MJ
Bonnya	113,499	2,122,711	22,912
Fiad	63,587	1,105,942	11,937
Kára	36,480	669,441	7,226
Kisbárapáti	189,088	3,295,369	35,569
Koppányszántó	151,885	2,719,833	29,357
Miklósi	112,684	1,966,100	21,221
Somogyacsa	86,588	1,678,012	18,112
Somogydöröcske	68,597	1,256,397	13,561
Szorosad	55,126	980,972	10,588
Törökkoppány	199,830	3,452,301	37,263

Source: Mezei et al. 2018

5.7 Geothermal energy

Geothermal energy is the internal energy stored by the high temperature masses of the earth's crust, mantle and core. This internal energy flows from the hot zones in the depths towards the surface, and this phenomenon is called geothermal heat flow. The temperature of the earth's mantle rises with the increase of the depth, in accordance with the law of heat conduction, and so the energy content per unit of material increases with the depth. This increase of temperature per unit of depth is called the geothermal gradient. Thus, the closer the high temperature medium carrying the internal energy to the surface in the given area, the more advisable the production of geothermal energy. The geothermal heat flow and the value of the geothermal gradient are not dispersed homogeneously; they show specific territorial distribution depending on the process of the development of the crust (MEKH 2016).

For the survey of geothermal energy, we registered the number of thermal wells in the administrative territories of the settlements (MEKH 2016; Maljković, Guðmundsson 2017), which is considered by the model partly as a limiting factor, but also as a factor that decreases risk. The former restriction is of quantitative character: several productive wells in the vicinity of each other may lead to the temporary decrease of the current capacities, while former successful investments, increasing the relevance of the new ones, decrease the risks lying in the quality of the available resource (drilling a thermal well always bears some risk: what water we find in what depth, of what temperature, with hat characteristics (e.g. mineral content) and whether it is suitable for the location of the planned technology (e.g. steam generation)).

The geothermal endowments of the examined area, as regards the values of the geothermal gradient, are excellent in Osijek-Baranja and Somogy counties (40-50°C/km) and are even better in Baranya county (over 50°C/km). With the application of different Hungarian and Croatian geological maps, we registered the potentials lying in the depth of the ground in the settlements in two categories (a minimum of 50°C at 1000 metres / a minimum of 90°C at 2000 metres) as a possibility. This actually gives the three basic categories of the geothermal potential of the settlement; where none is present, no geothermal investment is recommended; where the lower temperature can be obtained with large certainty, only a medium potential can be detected, while a base with 90°C temperature is a strong potential for the settlements.

The cross-border region is situated in the former Pannonian sea area; therefore it has a higher thermal flux density than the rest of the South-eastern Europe. It can reach a value of 100 mW/m^2 as illustrated in Figure 5.3.

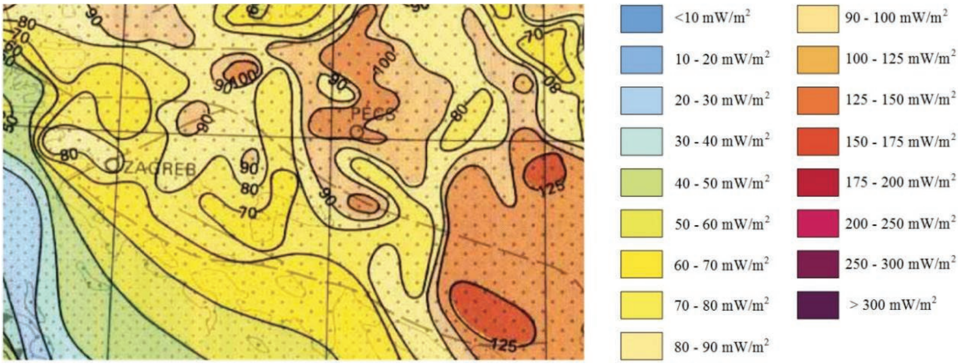

Figure 5.3. Thermal flux density in the former Pannonia sea area
Source: Oktatási Hivatal, 2018; Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji, 2013.

According to "Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," 2013, the temperature gradient for Osijek-Baranja County is between 4°C and 5°C per every 100 m of depth (figure 5.4). The best example of geothermal energy exploitation in Osijek-Baranja County is Bizovac where thermal water is used for heating and spa.

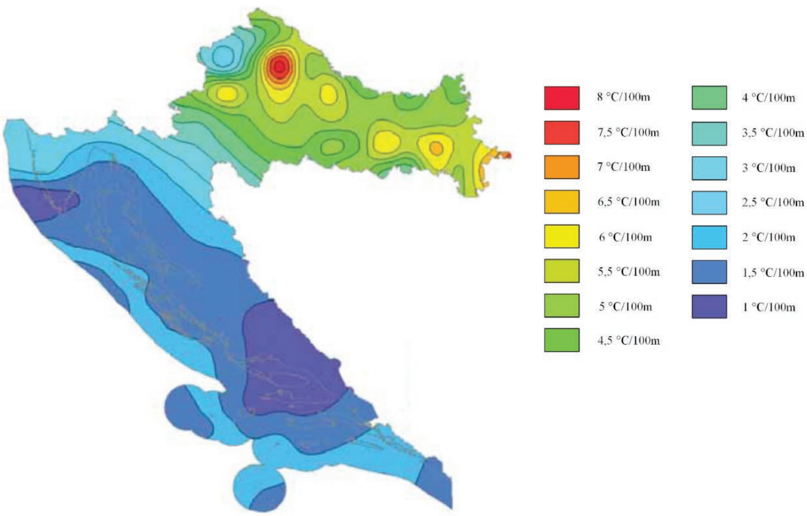

Figure 5.4. Temperature gradient of soil in Croatia
Source: Jelić, Kevrić & Krasić, 1995.

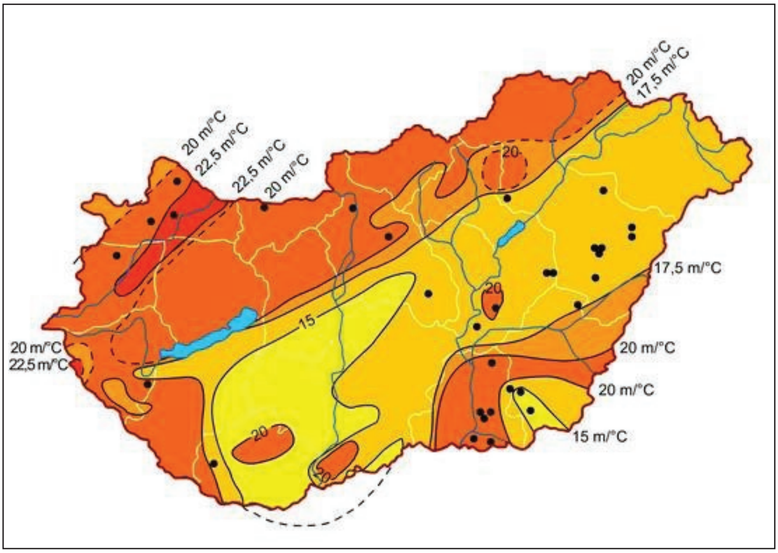

Figure 5.5. Temperature gradient of soil in Hungary
Source: Oktatási Hivatal, 2018.

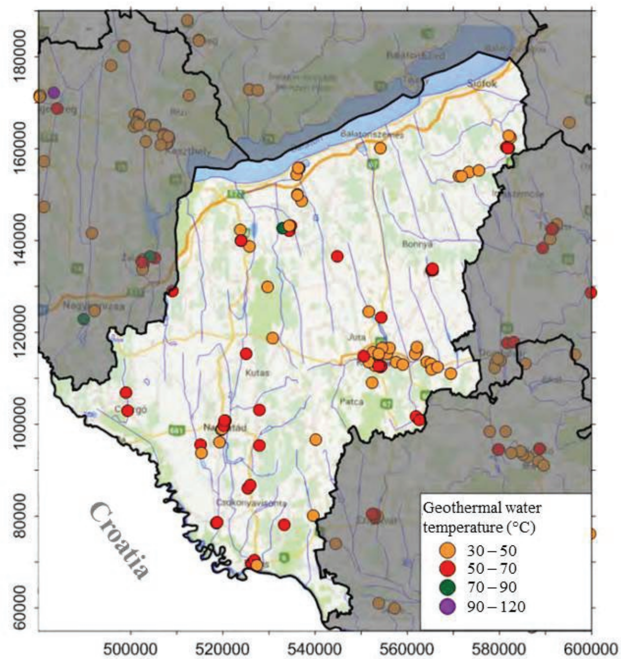

Figure 5.6. Geothermal water sources in Somogy county in Hungary
Source: MEKH, 2016.

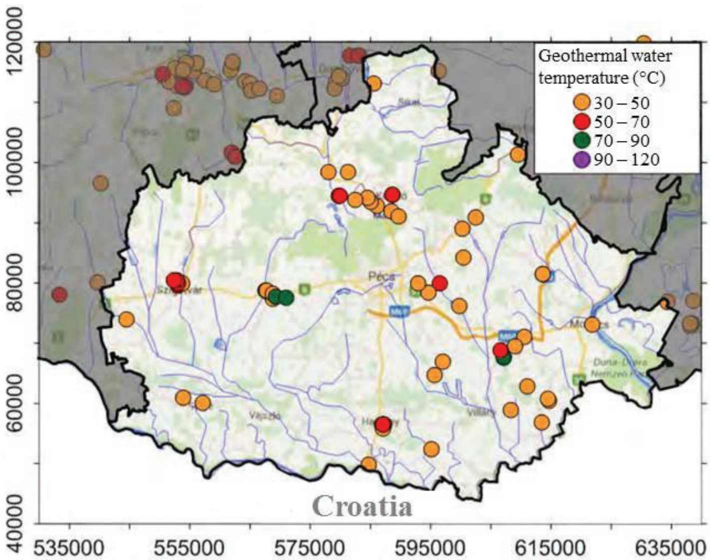

Figure 5.7. Geothermal water sources in Somogy county in Hungary
Source: MEKH, 2016.

According to the Hungarian Investment and Trade Agency, 2014, the geothermal energy potential of Hungary is 17,639 MWh/year. The temperature gradient for Somogy and Baranya counties in Hungary, according to Oktatási Hivatal (2018), is between 5°C and 7°C for every 100 m of depth (figure 4.5). In Hungary, thermal water sources are better recorded than in Croatia. The thermal water sources for Somogy and Baranya counties are provided in figure 5.6 and figure 5.7, respectively (MEKH, 2016).

The most up-to-date remote heating system in Baranya County operates in Szentlőrinc where 3,000 homes and public institutions are provided with geothermal energy by a large capacity and high temperature system. In Szentlőrinc the reinjection of used and cooled thermal water back into the reservoir also works well. The other well functioning geothermal heating system of Baranya county, getting more public attention, can be found in the town of Bóly where the network integrating public institutions, by now the industrial park and the apprentice workshop was built in three phases between 2003 and 2010, from approximately 1.9 million € (from tenderable and own resources) (MEKH 2016, Kovács et al. 2018).

The thermal wells operating in Somogy County are usually used for balneology purposes, and consequently stimulate local economy through health tourism, just think of the medical and thermal spas of Barcs, Buzsák, Csokonyavisonta, Igal, Kaposvár, Marcali and Nagyatád.

In the only geothermal quarry operating in Osijek-Baranja (Bizovac), touristic use – spa – prevails, but, besides the well drilled in the mid-20th century during the search for crude oil and natural gas, several test drillings have given positive results in the county (Ernestinovo, Babina Greda) (Maljković 2008), as a result of which it is possible in the future to establish a few geothermal energy based remote heating systems in Osijek-Baranja County (Maljković, Guðmundsson 2017).

5.8 Limitations and development potential of the model

Like every model that operates with data and databases, this decision-making support platform has a limited usability. The main reason for this is the international character of the model, which makes it impossible to have all data series with total compatibility for each settlement in both Hungary and Croatia. Considerable sets of data of settlements collected in Hungary are not collected and/or published by the Croatian statistical organs, and so the model in its present form can only provide data at settlement level in Hungary, in Croatia it is regional level (Osijek-Baranja County, only) for which it is able to demonstrate the potentials. The availability of data in Croatia for each settlement could make this module complete.

Following a substantial number of case studies the model could also integrate data of energetics investments (costs, capacities, prices, economic indices etc.), with the use of which and on the ground of the methodology by Pelin et al. (2015) and Kovács and Suvák (2014) payback time, unit cost (LCOE) and net present value could also be calculated, knowing settlement potentials and desired located capacity. These calculations, however, require a considerable amount of market and economic data that were unknown during our research and so can only be integrated into a later version of the model.

6 TECHNOLOGIES FOR UTILIZATION OF RENEWABLE ENERGY SOURCES

Goran Knežević, Krešimir Fekete

This chapter explains the various commercially proven energy production technologies that use biomass, solar energy and geothermal energy. The description for wind farms is omitted because, according to "Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji," (2013), the exploitation of the wind energy potential in the cross-border area of Croatia and Hungary is not economically profitable.

6.1 Biomass power plants

The use of biomass for the production of electricity instead of fossil fuels gives advantages in terms of reducing greenhouse gas emissions, a possible reduction in production costs, and can also be an initiator of the development of the local economy in the rural area.

In order to analyse the use of biomass for electricity generation, it is important to consider three key components (International Renewable Energy Agency, 2012):

a, biomass feedstock – comes in different forms and has different properties that affect its use for electricity generation;

b, biomass conversion – a process in which biomass is converted into a fuel for the production of electricity;

c, power generation technology – a wide range of technologies that use biomass as a fuel for power generation.

The continuous and sustainable source of biomass and its quality are of crucial importance for the cost-effectiveness of biomass power plants. The essential characteristics of the feedstock are the energy value, content of ash and humidity and its homogeneity. These characteristics affect the price, transport costs, pre-processing costs and storage costs of the feedstock. In addition, according to the type of the feedstock, suitable technologies for electricity generation are selected.

Biomass sources can be divided into those from rural areas (forest residues, wood residues, agricultural residues, energy crops, livestock feces) and those from urban areas (urban wood waste, biogas from wastewater and sewage, landfill gas, municipal solid waste). Biomass can be converted into energy using heat-chemical processes (i.e. combustion, gasification and pyrolysis) or biochemical processes such as anaerobic digestion.

6.1.1 Processes of biomass conversion into energy

6.1.1.1 Combustion

In this method of using biomass, a conventional thermodynamic Rankine cycle, where biomass is burned in a high-pressure steam generator, is used. Steam goes to a steam turbine connected to the generator producing electricity. The overall process efficiency is around 25% (International Renewable Energy Agency, 2012).

In small-scale power plants, bubbling fluidized bed boilers (BFB) are used with fuels having a low-calorific value and high moisture content. The circulating fluidized bed boilers (CFB) are commonly used in large power plants with a basic concept similar to BFB. CFB has increased flexibility compared to BFBs in terms of firing various fuels with high moisture content and it has significantly higher efficiency, up to 95% (Pascual Peña, 2011).

Co-firing is a process in which biomass is added to coal in a classical thermoelectric power plant. Direct co-firing of biomass with coal is possible with a biomass fraction of 5-10%. For a larger biomass share, extensive biomass processing (e.g. torrefaction) or changes in the design of the thermal power plant (e.g. separate combustion of biomass and coal in different boilers, different burners, dryers) is required.

6.1.1.2 Gasification and pyrolysis

The end product of wood biomass gasification is gas with a high share of methane used to drive a gas engine connected to a generator that produces electricity. The basic process of gasification consists of drying, thermal decomposition of organic matter or pyrolysis, partial combustion of gases, steam and coal from biomass and gasification of residues. The pyrolysis takes place at high temperature with the added heat without the presence of oxygen and water. For gasification, it is necessary to dissolve the medium (steam, air or oxygen) for the chemical change of the feedstock molecular structure from the complex molecules of the primary fuel to the less complex molecules of gas (Šljivac et al., 2012).

The process of gasification of biomass begins by heating, drying and pyrolysis followed by a chemical reaction between biomass pyrolysis and processing medium and the desired gas (generator gas) is obtained. Integrated gasification plants other than the gasification reactor contain a biomass processing system, a biomass reactor system, a gas purification system, ash and a solid residue removal system. Types of gasification technologies can be seen in Figure 6.1 (Šljivac et al., 2012).

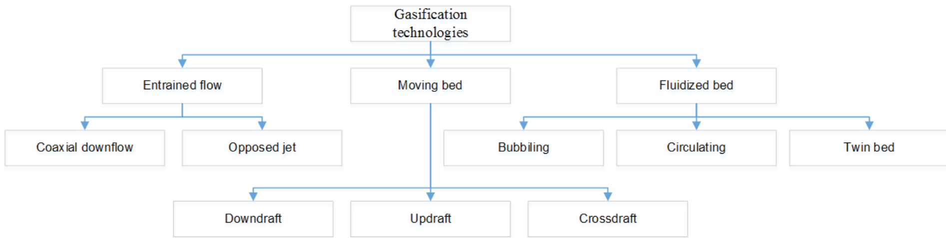

Figure 6.1. Gasification technologies
Source: Šljivac et al., (2012)

6.1.1.3 Anaerobic digestion

Anaerobic digestion is fermentation of organic material without the presence of oxygen. Anaerobic digestion produces biogas consisting of methane mixture (40-75%), carbon dioxide (25-60%) and other gases such as hydrogen, hydrogen sulphide and carbon monoxide. Its calorific value is about 21 MJ/m^3. The types of digesters are shown in Figure 6.2.

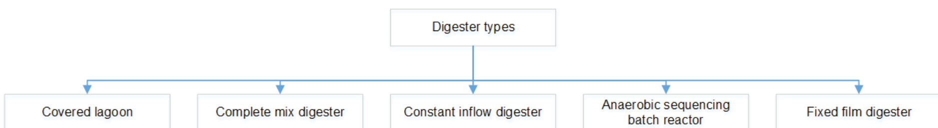

Figure 6.2. Digester types.
Source: Šljivac et al. (2012)

For liquid waste, covered lagoons, constant inflow digester and fixed film digester are used. Complete mix digesters are used for sludge waste. The waste is deposited in the digester where it is stirred and heated and releases the biogas which is subtracted from the upper part of the digester. An anaerobic sequential batch reactor (ASBR) is a high speed fermentation system that is adapted to treat diluted dung. The process consists of four phases of operation allowing a high flow of the material while retaining the microorganism in the reactor.

Digesters can also be divided into batch and continuous digesters. The batch digester works on the principle of batch filling; the digester is filled with fresh feedstock and cleaned upon digestion. They can be vertical, horizontal or with multiple tanks, and differ in the manner of mixing the substrate (with full mixing or pulsed digestion). Digesters with a complete mix of substrates are round, vertical, suitable for liquid manure and the retention time is 30-90 days. Pulsed digesters have a horizontal reservoir suitable for solid manure and the retention time is 15-30 days (Al Seadi et al., 2009).

Figure 6.3 shows the maturity of a particular technology and expected production costs if the technology is applied for commercial purposes. With the commercially available technologies listed above, the image shows the technologies that are still in the research phase.

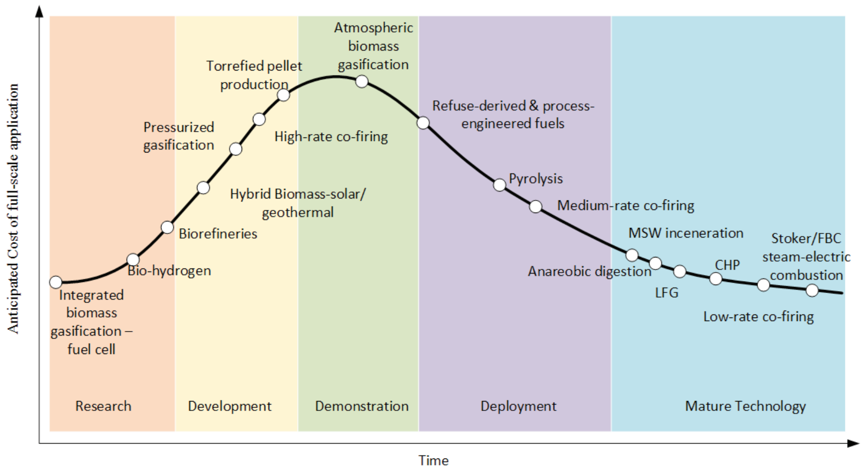

Figure 6.3. Biomass power generation technology maturity status and anticipated costs of full-scale application.
Source: Al Seadi et al., 2009

6.1.2 Costs

6.1.2.1 Biomass feedstock costs

Feedstock prices have a significant impact on total electricity production costs in biomass power plants. Table 6.1 shows the prices of feedstock for six European Union countries (although for some items fixed prices are listed, these are the indicative prices obtained on the basis of the analysis of existing plants and regulations in the observed countries according to (Kühner, 2013)). Negative prices mean that an entity that takes feedstock receives an additional premium charged from those who produced that feedstock (e.g., a municipal waste disposal fee).

Table 6.1. Feedstock cost assessment.

	Austria	Finland	Germany	Greece	The Netherlands	Poland
	€/t					
Straw (minimal costs)	35	34	32	38	34	36
Straw (price)	80 to 180	n.a.	160	144	144	n.a.
Forestry residues (price)	30 to 80	25 to 80	30 to 80	30 to 80	30 to 80	30 to 80
Organic municipal waste (gate fee)	-15 to -60					
Surplus manure (price)	-	-	-10	-	-15 do -25	-
Waste wood (gate fee)	-25 to -60					
Landscape & road side management (price)	66-81					
Food processing residues	0 to 180					
Energy crops	80	80	80 to 160	80 to 150	80 to 150	80

**n.a. –not available*
Source: Kühner, 2013

6.1.2.2 Investment costs

The technology type determines the cost and effectiveness of biomass power generation equipment although the equipment cost of certain technologies can vary significantly. Investment costs include the costs of planning, designing, equipment costs and power plant construction. Additional costs that may be significant are the costs of connecting the plant to the electricity grid. The indicative values of the total investment costs of a particular technology for the production of electricity from biomass in the OECD countries can be seen in Figure 6.4.

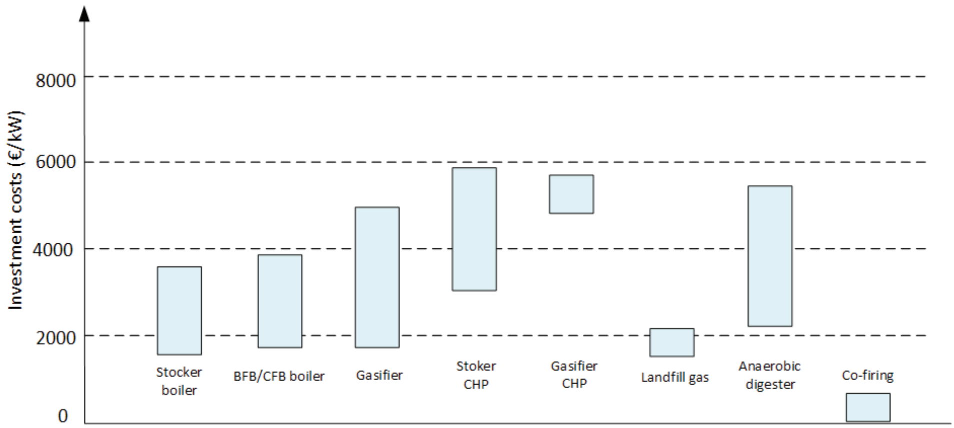

Figure 6.4. Investment costs of biomass electricity production technology in OECD countries
Source: International Renewable Energy Agency, 2015

6.1.2.3 Operating and maintenance costs

Fixed operating and maintenance (O&M) costs of biomass power plants typically range from 2 to 6% of total investment costs per year, while variable operating and maintenance costs are relatively low, around 0.004 €/kWh. Fixed operating and maintenance costs include salaries, planned maintenance, insurance premiums, etc. Variable operating and maintenance costs are defined according to the amount of electricity produced and include, for example, ash disposal, unplanned maintenance and replacement of certain power plant components.

Table 6.2. Operating and maintenance costs of biomass power plants

Technology	Fixed O&M (% of CAPEX/YEAR)	Variable O&M (USD/MWh)
Stoker/BFB/CFB boilers	3.2-4.2 3-6	3.5-4.3
Gasifier	3 6	3.1
Anaerobic digester	2.1-3.2 2.3-7	3.6
Landfill gas	11-20	

Source: International Renewable Energy Agency, 2012

6.1.2.4 Connection costs

Connection costs depend on the distance between the location of the power plant and the electricity grid. Connection costs are calculated in the study of the optimal technical solution for connection of the power plant. In comparison to the total investment costs of the power plant, the costs of connection to the grid are usually low, with a share in total investment of less than 5% (Samadi & Sascha, 2017) (Swider et al., 2008). Off-grid systems are economically bad solutions because the energy produced cannot be sold to the grid; therefore, there is no possibility of an incentive price. An off-grid system can be economically justified in cases where the plant location is so far away from the power grid that connection costs are too high.

6.1.2.5 Levelized cost of energy (LCOE)

The levelized cost of electricity (LCOE) is the net present value of the total costs of electricity over the lifetime divided by the total energy output of the asset over that lifetime.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

I_t = investment expenditures in the year t;

M_t = operating and maintenance expenditures in the year t;

F_t = fuel expenditures in the year t;

E_t = electricity produced in the year t;

r = discount rate;

n = lifetime of the power plant.

A wide range of investment costs of a particular technology accompanied by a wide range of feedstock prices result in a wide range of LCOEs as shown in Figure 6.5. In the scenario when the investment costs and the price of the feedstock are low, the price of electricity production in biomass power plants with around 50 €/MWh can be competitive on the electricity market. With the increase in investment costs and feedstock prices, the production price of electricity without subsidy is not competitive on the market.

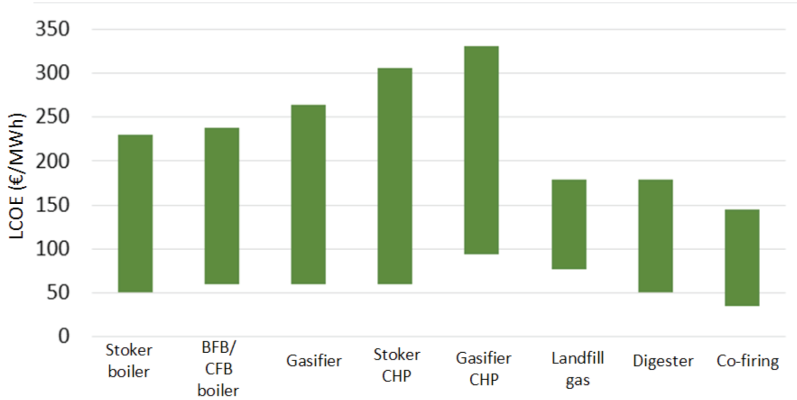

Figure 6.5. LCOE for different biomass technologies
Source: International Renewable Energy Agency, 2012

6.2 Photovoltaic power plants

The solar radiation energy continues to reach the Earth that rotates around its axis and the Sun (Šljivac & Topić, 2018). There are two main types of energy utilization from solar radiation – for the production of electricity and thermal energy. Today's technological solutions enable the transformation of solar energy into electricity in two ways:

a, solar thermal power plants – solar energy is first transformed into heat which is then transformed into mechanical energy through a turbine (or some other heat machine), which drives an electric generator. According to Šljivac and Topić (2018), there are three common solutions: parabolic through a solar thermal power plant, central tower power plant (or heliostat power plant or power tower) and parabolic plate technology. In the cross-border region of Croatia and Hungary, there are no examples of such power plants and for this reason, they are not described in detail;

b, photovoltaic power (PV) plants – solar energy is directly transformed into electricity using a photoelectric effect. The above-mentioned technology is widely applied in the cross-border region of Croatia and Hungary and will be described in detail.

Figure 6.6 shows the installed power and annually produced energy of the PV systems in the Republic of Croatia for the years 2010-2015. According to the data from publication *Energy in Croatia* (Vuk et al., 2010, 2011, 2012, 2013, 2015), a significant increase in the installed power of the PV power plants can be noticed.

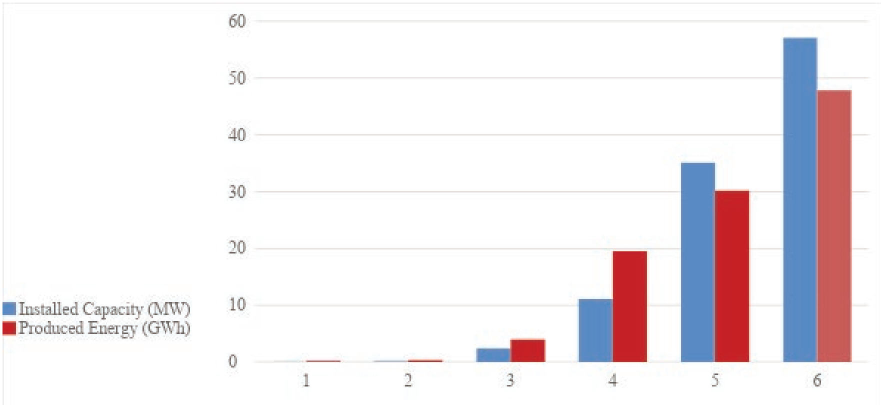

Figure 6.6. Installed capacity and annually produced energy of PVs in Croatia. Source: Vuk et al., 2010, 2011, 2012, 2013, 2015

6.2.1 The technology of photovoltaic power plants

The photovoltaic cell is a semiconductor diode consisting of semiconductor types *p* and *n* most commonly made of silicon (monocrystalline, polycrystalline or amorphous silicon), and less of other materials (e.g. cadmium and tellurium). One of the available technology solutions is the production of photovoltaic cells by a thin film technology, which yields thinner modules (cheaper) but with less efficiency. Table 6.3 shows five photovoltaic cells made by different technologies together with their basic data.

The usual voltage of one cell is about 0.5 V, which is insufficient for practical applications and therefore more individual cells are connected to each other in order to compose a photovoltaic module (usually 36 cells with 12 V output voltage). More photovoltaic modules are then connected into a series or parallel to form a so-called string (Figure 6.7). MPP stands for a maximum power point.

Table 6.3. Different photovoltaic technologies and their basic characteristics.

	Bisol BMO 250	Bisol BMU 250	Solar Frontier SF 150	Masdar MPV100-S	First Solar FS 277
Technologies	monocrystal-line Si	polycrystalline Si	thin film	amorphous Si	thin film Cd-Te
Maximum power (W)	250	250	150	100	77.5
Short circuit current (A)	8.8	8.75	2.2	1.57	1.22

Open circuit voltage (V)	37.9	38.4	108	100	90.5
MPP current (A)	8.2	8.25	1.85	1.33	1.11
MPP voltage (V)	30.5	30.3	81.5	76	69.9
Module efficiency (%)	15.3	15.3	12.2	6.99	10.8
Length (mm)	1649	1649	1257	1300	1200
Width (mm)	991	991	977	1100	600
Thickness (mm)	40	40	35	32	6.8

Source: Šljivac & Topić, 2018a

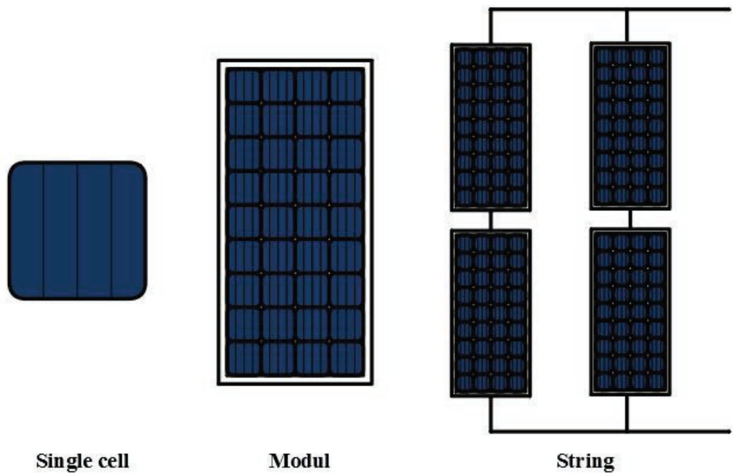

Figure 6.7. From single photovoltaic cell to a module and string
Source: Šljivac & Topić, 2018a

Photovoltaic strings, together with other devices and equipment (inverters, connecting cables, switches, circuit breakers, etc.) make a photovoltaic system or photovoltaic (PV) power plant. Regarding the connection of a PV power plant with the utility network, there are two main approaches:

a, connected to the utility grid (on-grid) - figure 6.8;

b, off-grid (island) system.

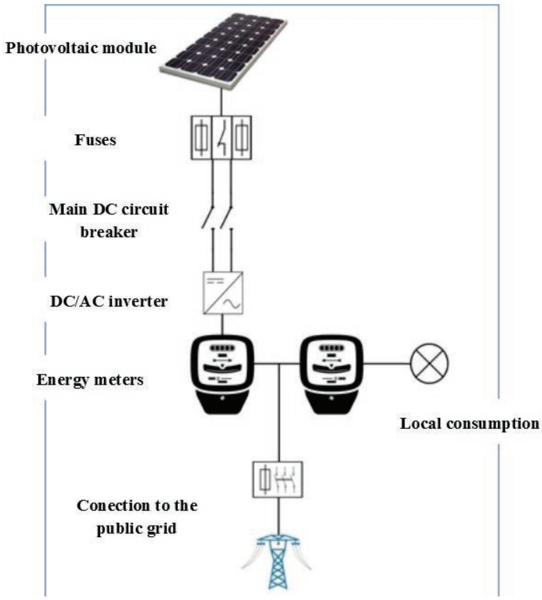

Figure 6.8. Example of an on-grid PV system.
Source: Own contribution

6.2.2 PV power plants' costs

6.2.2.1 Investment costs

The most significant costs of PV systems are the investment costs that are made up from:

- equipment costs (photovoltaic modules, inverter and other equipment necessary for connection and installation);
- installation costs;
- capital cost (interest etc.);
- other costs (insurance, license etc.).

Investment costs have recorded a significant decrease in the last few years as can be seen in Figure 6.9. The data presented in figure 6.9 were collected from the annual statistical reports PV Status Report issued by the EU Joint Research Center (Jager-Waldau, 2013; Jäger-Waldau, 2010, 2011, 2012, 2014a).

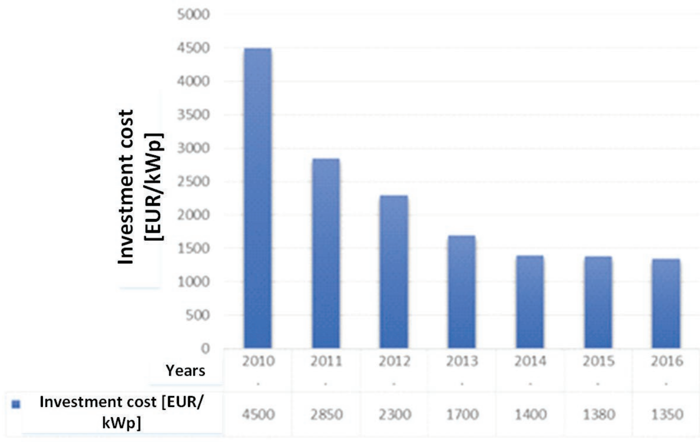

Figure 6.9. Investment costs for household PV systems in the period 2010-2015.

6.2.2.2 Operation and maintenance costs

PV plants do not consume fuel for their work; consequently, no fuel costs are present. Also, the operation of PV power plants is fully automated and requires no human staff, so there are no costs regarding salaries. The only costs that need to be taken into consideration are the maintenance costs, which are 1.5-2% of the investment costs annually according to the literature (Jäger-Waldau, 2014b). In addition to the annual maintenance costs, the literature (Jäger-Waldau, 2014b) suggests that inverter needs to be replaced after ten years of operation and it is important to take the cost of the inverter replacement into consideration.

6.2.2.3 Levelized cost of energy (LCOE)

The equation (5.1) is used in order to calculate LCOE with the assumption that fuel costs are equal to zero. LCOE for household PV systems for 2016, according to the literature (Jager-Waldau, 2016a), is shown in table 5.4. The results in table 5.4 are obtained with a different discount rate as well. Operation and maintenance costs are assumed to be 2% of the investment costs, the production of the PV plant is 1000 kWh/kWp per year and the lifespan of the plant is 20 years.

Table 6.4. LCOE for household PV plant according to different discount rates.

	Cost	LCOE	LCOE			LCOE	LCOE		
	[EUR/ kWp]		Capital			Operation and maintenance	Total		
Discount rate		0%	3%	5%	10%		3%	5%	10%
		[EURcent/kWh]							
Equipment	910	4.55	1.39	2.40	5.17	1.82	7.76	8.77	11.54
Installation of equipment	300	1.50	0.46	0.79	1.70	0.60	2.56	2.89	3.80
Other (insurance, license etc.)	140	0.70	0.21	0.37	0.79	0.28	1.19	1.35	1.77
Total	1350	6.75	2.06	3.56	7.66	2.70	11.51	13.02	17.12

Source: Jäger-Waldau, 2016

Figure 6.10 shows the share of individual cost components in the total costs of the PV plant. The data are provided pursuant to the literature (Jäger-Waldau, 2014b).

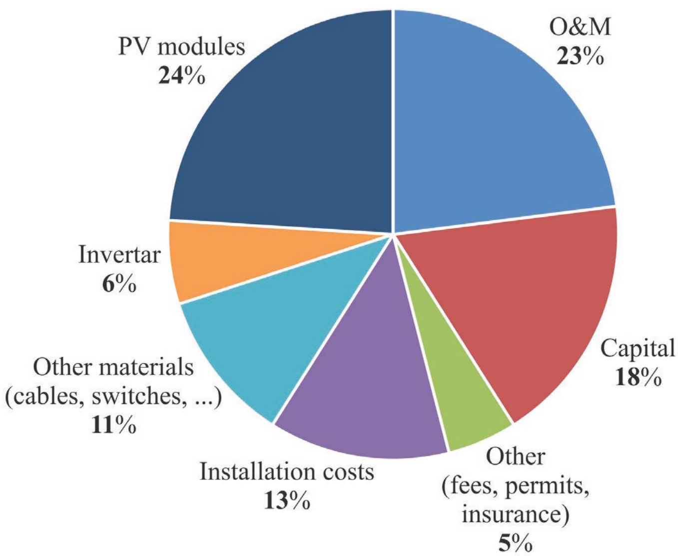

Figure 6.10. The share of individual cost components in the total costs of the PV plant for 2014.
Source: Jäger-Waldau, 2014b

LCOE calculation for the PV power plant that is installed at the location in Osijek, Croatia is shown in the literature (Marčetić, Fekete, Knežević, & Klaić, 2018). The following assumptions are made:

- calculations are made for the following years – 2012, 2013, 2014, 2015 i 2016;
- size of the PV power plant is 10 kWp;
- the lifespan of the power plant is 20 years;
- the discount rate is 5%;
- investment costs are according to the literature (JRC PV Status report 2010-2016). Fuel costs are negligible. Maintenance costs are assumed to be 1.5% of the investment costs. After 10 years of the operation, the replacement of the inverter is assumed. The rate of maintenance costs is changed from 1.5% to 1% and 2% in order to investigate how maintenance cost affect LCOE;
- annual production is according to (PV GIS) 11000 kWh/year.

The calculated LCOEs for every observed year and three different maintenance costs are shown in figure 6.11.

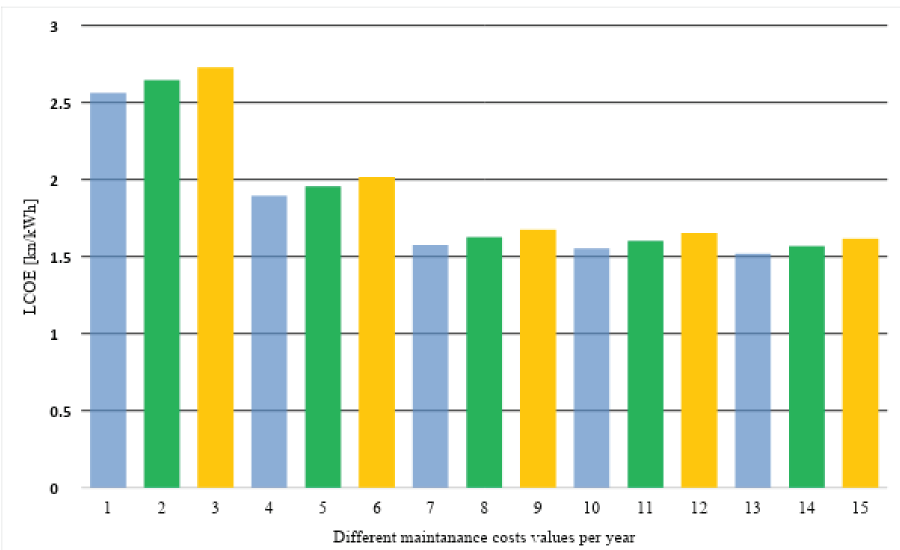

Figure 6.11. LCOE for three different maintenance costs and for the years 2012-2016
Source: Marčetić et al., 2018.

6.3 Solar thermal collectors

Heat generated from solar radiation can be used for heating objects, water or in refrigeration units. Systems in which solar radiation is exploited by an appropriate architecture of the building (arrangement of rooms and glazed surfaces, etc.) are called passive systems. If solar radiation is transformed into thermal energy, with the help or, for this purpose built-in appliances (the so-called solar collectors), systems are called active. Only active systems for exploiting the Sun's radiation are presented in detail.

6.3.1 The technology of solar thermal collectors

The main characteristic of solar collectors is the maximum temperature achieved by the medium fluid (the most commonly, water with the addition of glycol, etc.). Due to the maximum temperature of the medium fluid, solar collectors can be divided into two groups, namely, low-temperature and high-temperature.

6.3.1.1 Low-temperature solar thermal collectors

The simplest low-temperature solutions are used for heating pools or industrial facilities. They are made with tubes without a cover or with facades that have air passages. They are best for temperatures up to 10° C above ambient (Šljivac & Topić, 2018). When it is necessary to achieve a higher temperature (40-60° C), flat plate solar collectors made of a plate with a coating that enhances the absorption of solar radiation, tubes filled with working fluid and cover glass are used (Figure 6.12). The efficiency of flat plate solar thermal collectors is between 70% and 80%.

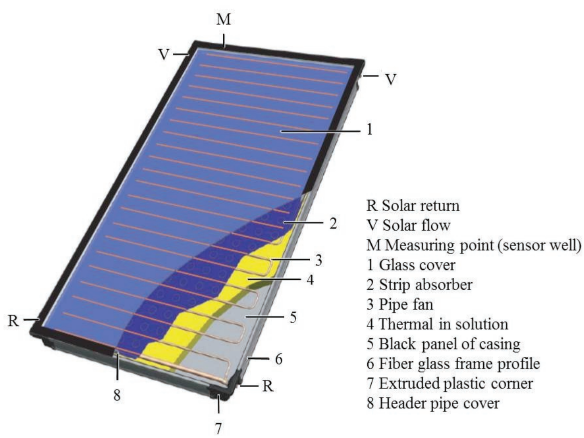

Figure 6.12. Example of a flat plate solar thermal collector
Source: Buderus, 2007.

6.3.1.2 High-temperature solar thermal collectors

They are the most complex design of solar collectors because they require vacuum tubes with or without reflective mirrors. They reach a higher temperature (up to 100° C) than flat plate solar collectors, but they are also less effective (50-60%). An example of a vacuum tube collector is shown in figure F.13 and an example of a vacuum tube in Figure 6.14.

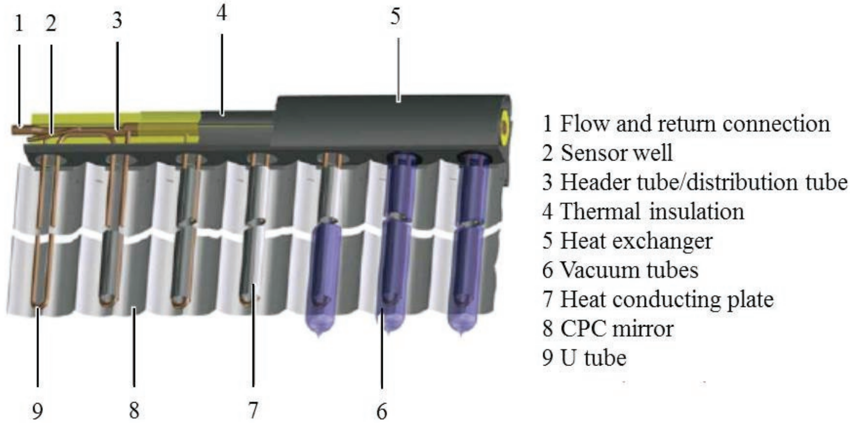

Figure 6.13. Example of a vacuum tube solar thermal collector
Source: Buderus, 2007.

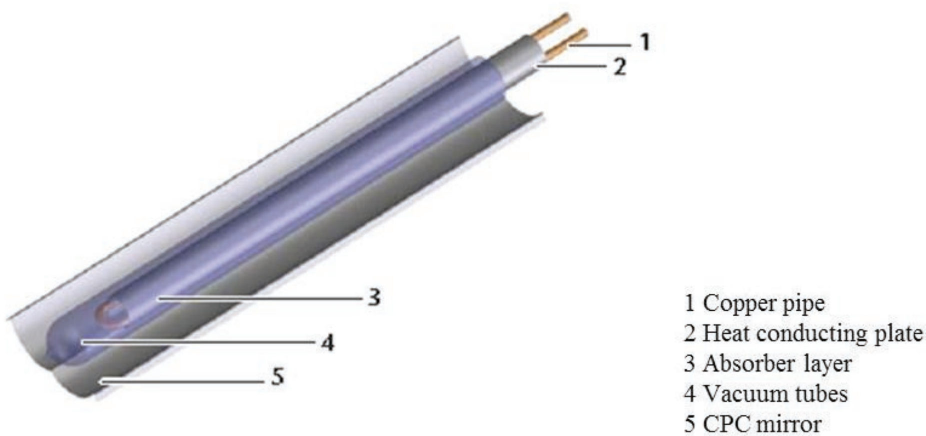

Figure 6.14. Example of a vacuum tube
Source: Buderus, 2007

6.3.2 Investment costs of solar thermal collectors

Solar collectors similar to the PV power plant have very high investment costs compared to the other cost components. Unlike the PV power plant, solar collectors did not record a significant decrease in the investment cost in the last few years. Figure 6.15 shows the trend of investment costs of flat plate solar thermal collectors from 1997 to 2013. The data apply to Austria and are taken from the literature (Stryi-Hipp, 2016).

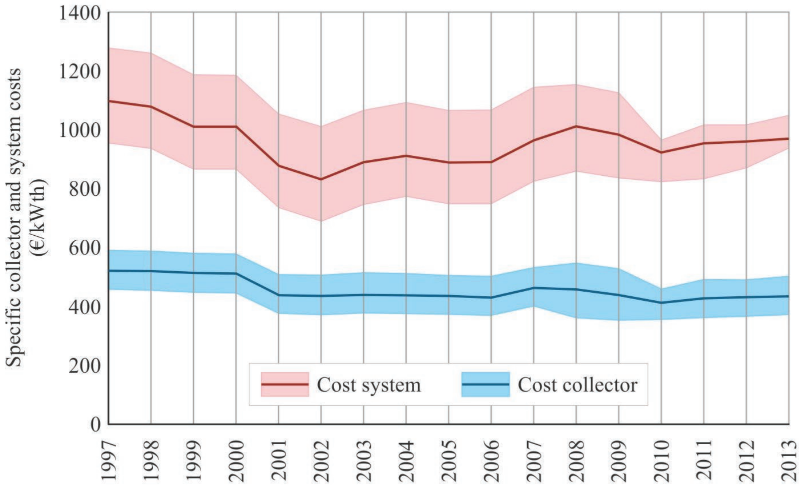

Figure 6.15. Example of investment costs for flat plate solar thermal collectors obtained for Austria in the period from 1997 to 2013
Source: Stryi-Hipp, 2016.

6.4 Heat pumps

Heat pumps are systems that mediate in heat transfer between high temperature thermal tanks and low temperature tanks. They are used for low temperature heating systems but can be used in a cooling mode. Figure 6.16 illustrates a scheme of the heat pumps in a heating mode.

The heat pump system consists of three circuits (Guzović & Soldo, n.d.):

- heat source circuit (shown in Figure 6.16 with A);
- circuit of the operating medium (shown in Figure 6.16 with B);
- heat sink circuit (shown in Figure 6.16 with C).

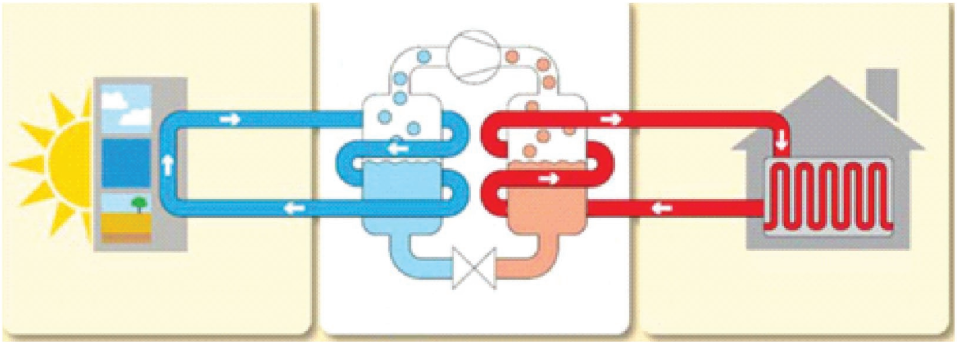

Figure 6.16. Schematic illustration of a heat pump in a heating mode.
Source: Guzović & Soldo, n.d

The medium in circuit A takes over heat from a heat source that can be ground, water or air. With open systems, underground water flows directly over the evaporator. In the heat exchanger system in the soil, a glycolic mixture flows in the heat source circuit connecting the heat exchanger in the ground and the evaporator (Guzović & Soldo, n.d.).

In circuit B, the vapour-phase operating medium from the evaporator comes to a compressor where the increase in pressure increases the operating medium temperature, which then transforms to a liquid state. In the heat exchanger, the operating medium supplies the heat to the heating medium in the heat sink circuit. By expanding through the expansion valve, the operating medium expands to a lower pressure and temperature and in the evaporator, under the influence of the heat source, again transforms into a gas state. The heating medium in the sink circuit gives heat to the space that has to be heated.

By installing a four-way valve, the same device can be adjusted to operate in the cooling mode. In this case, the sink of heat becomes ground, groundwater or environmental air, while the heat of the cooled space is drained on the evaporator by air or water/glycol mixture (Guzović & Soldo, n.d.).

6.4.1 Categorization of heat pumps

Figure 6.17 shows the categorization of heat pumps according to the heat source.

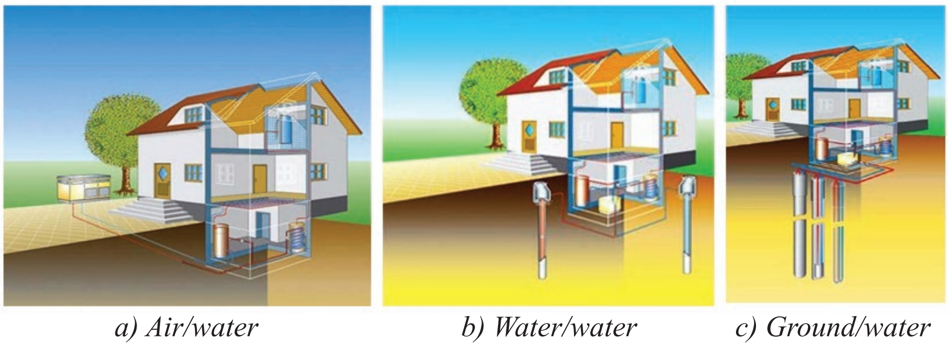

Figure 6.17. Categorization of heat pumps according to the heat source
Source: "EKO-PULS d.o.o, Toplinske pumpe," n.d.

The air/water heat pump takes energy from the air to heat the water in the heating system. Water/water heat pump systems utilize surface and underground water sources to obtain heat energy, while ground/water systems use heat from the ground surface layer and give it to water in the heating system. Ground/water heaters are called geothermal heat pumps that can be divided into closed circuit systems (vertical or horizontal) and open circuit systems (two wells - production well and discharge well or drain). The vertical system is shown in Figure 6.17c), while the different types of horizontal systems are shown in Figure 6.18.

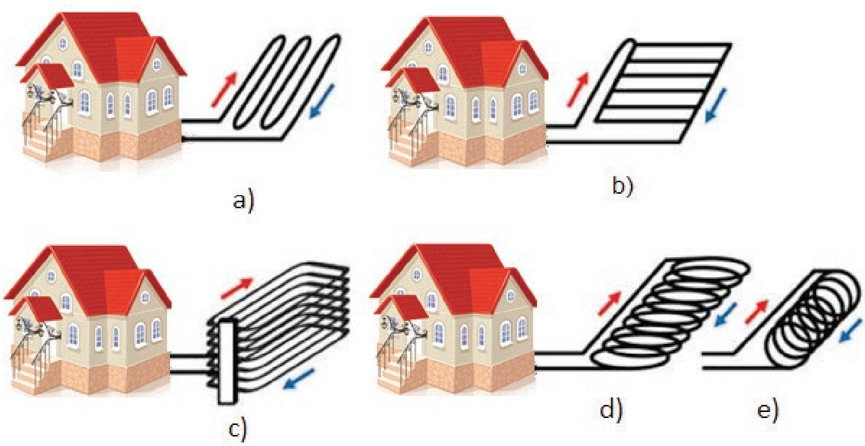

Figure 6.18. Horizontal systems of ground/water heat pumps -
a) horizontal field with serial-connected pipes, b) horizontal field with parallel pipes,
c) channel collector, d) spiral collector "Slinky", e) spiral collector "Svec".
Source: "EKO-PULS d.o.o, Toplinske pumpe," n.d

6.4.2 Investment costs

Investment costs for heat pumps can be divided into heat pump unit costs, costs of heat exchanger (ground/water heat pumps), drilling costs and water distribution costs to heat pump (water/water heat pumps) and costs of a heat transfer system in the building itself. Table 6.5 shows a relative increase in investment costs in heat pumps compared to a conventional gas heating system.

Table 6.5. Relative increase in investment costs of heat pumps compared to the conventional heating systems.

	Ground/water	Water/water	Air/water
Heat generator	320-600%	320-600%	350%
Heat source	300-430%	200-300%	-
Heat transfer system	150-200%	150-200%	150-200%

Figure 6.19 provides the prices of heat pump units, while in Figures 6.20 and 6.21, the heat exchanger costs as well as water wells and water distribution costs depending on the heating effect are provided.

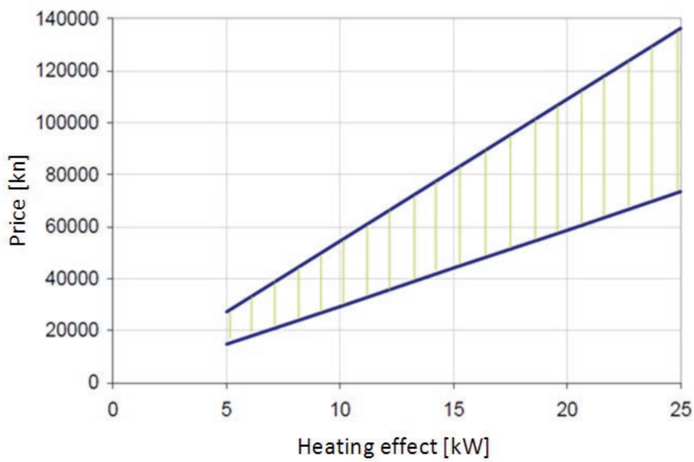

Figure 6.19. Price of heat pump units depending on the heating effect
Source: Grozdek, 2015.

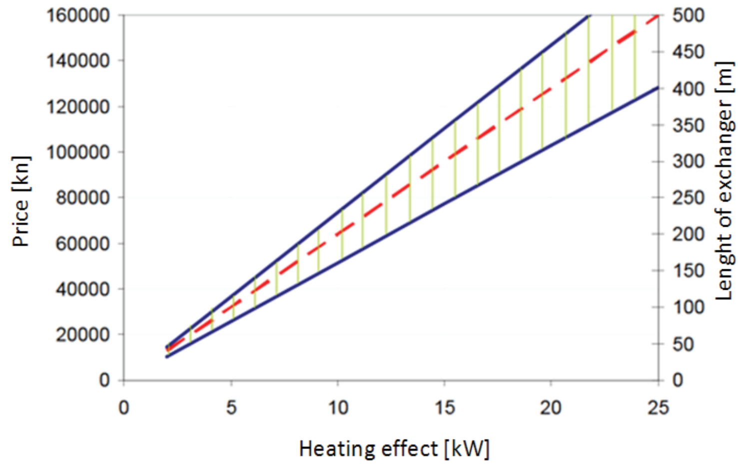

Figure 6.20. Price of a heat exchanger depending on the heating effect
Source: Grozdek, 2015.

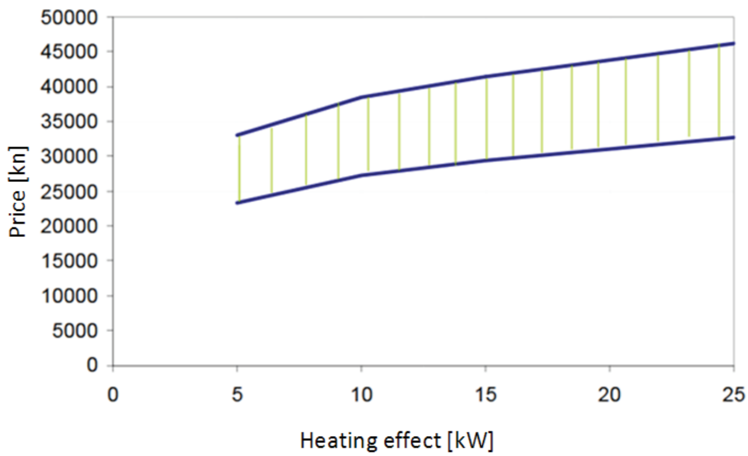

Figure 6.21. Price of water wells and water distribution depending on the heating effect
Source: Grozdek, 2015.

The price of the heat energy obtained by the heat pump having coefficient of performance equals 3.5 is, according to Grozdek (2015),

- 3.5 times lower than the heat energy obtained by electro-heating;
- 1.5 to 4.5 times lower than the energy obtained from oil;
- 1.3 to 2.6 times lower than the energy obtained from gas.

7 ENERGY EFFICIENCY RECOMMENDATIONS FOR THE RURAL AREAS OF THE CB REGION

Danijel Topić

Together with the usage of renewable energy sources, energy efficiency measures are one of the basic EU tools for achieving energy policies for 2020, 2030 and 2050 (European Commission, 2007; European Commission, 2016). With the aim of increasing energy efficiency and rational usage of energy, EU adopted several directives directly related to energy efficiency such as Directives 2004/8/EC, 2006/32/EC, 2009/125/EC, 2010/30/EU and 2012/27/EU. Since 2018, the newest directive 2018/844 EU, which brings changes to directive 2010/30/EU and 2012/27/EU, was adopted.

7.1 What is the energy efficiency?

Firstly, it is important to define energy efficiency. According to UNDP (2008), energy efficiency is defined as follows:

Energy efficiency is a sum of planned and conducted measures with the goal of using as less energy as possible but simultaneously keep the same production quantity or comfort level.

In this chapter, the set of recommendations of energy efficiency measures emphasizing the application in the rural areas of the cross-border Croatia and Hungary region will be shown. The increase of energy efficiency directly affects the environment protection because it decreases energy consumption. This leads to energy savings causing financial savings which can be used for other rural development purposes. The energy efficiency recommendations will be related to the usage of heat and electricity.

7.2 Heat

Heat is mostly used for technological generation processes, space heating and preparation of hot water. We will focus on space heating and preparation of hot water in the rural areas form the point energy savings view. According to UNDP (2008), the structure of energy consumption in the average household in Croatia is as follows -

62% of the total energy consumed in a household is used for space heating, 15% for lighting, electric appliances and air conditioning, 12% for cooking and 11% for hot water. Since the most energy is used for space heating, there is the highest potential for energy savings. In space heating, according to UNDP (2008), there are following energy losses:

- losses through windows - 51%;
- losses through external walls - 21%;
- losses of the heating system - 12%;
- losses through a roof - 10%;
- losses through floors - 6%.

In order to achieve minimum energy losses, the following is recommended:

- thermal protection (insulation) of an object;
- usage of the ventilation systems with the heat recuperation;
- usage of renewable energy sources.

To achieve an energy efficient building (low energy or passive building), according to Leko and Buzov (2010), the following rules should be abided by:

- thermal insulation on the roof should be minimum 20 - 40 cm (recommendation is to use rock wool);
- thermal insulation of the outside walls should be minimum 18 - 30 cm (recommendation is to use rock wool);
- thermal insulation of the ceiling of nonheated cellars should be minimum 14 - 20 cm;
- all outside openings should have energy efficient frames, three-layer glass with low-E coating, filled with gas and have a minimum coefficient of heat transfer of U<0.80 W/m2K;
- all outer shell should be air impermeable with the usage of mechanical ventilation with heat recuperation;
- use as much local renewable energy sources for heating, cooling and preparation of hot water as possible.

The influence of house thermal insulation on energy savings is presented in figure 7.1

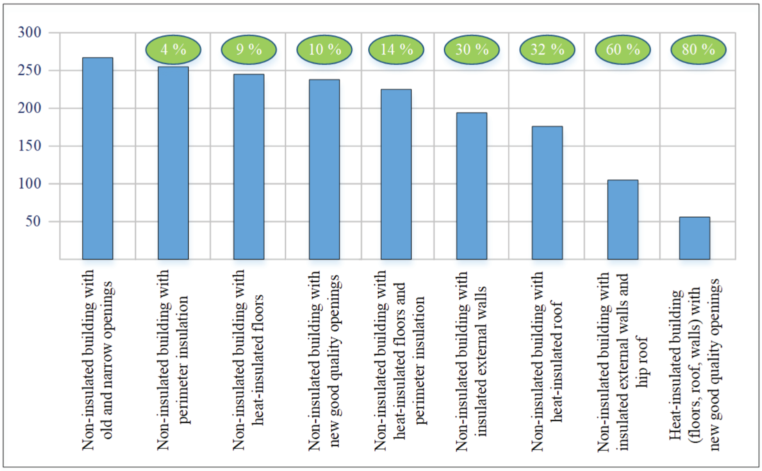

Figure 7.1. Influence of house thermal insulation on energy savings (kWh/m²)
Source: Buzov (2010)

With the aim of increasing energy efficiency in a heat usage, it is recommended to use renewable energy sources. For the rural areas of the cross-border Croatia and Hungary region, the following renewable energy sources technologies are recommended – solar thermal collectors, heat pumps and biomass based micro heating systems (pellet and wood chips furnaces). Solar thermal collectors and heat pumps are described in chapters 6.3 and 6.4.

Figure 7.2. Central heating system with a combination of solar thermal collectors and wood chips boiler (Urbersdorf).
Source: Photos by the author

According to Topić, Knežević, Šljivac et al. (2018), solar thermal collectors, in a combination with a wood chips boiler, can be used for thermal heating (or as a support to a heating system) during cold spring and autumn days. In figure 7.2, an example of a heating system with a combination of solar thermal collectors and wood chips boiler in Urbersdorf, Austria is shown. Biomass and biogas power plants are very convenient for the application in rural areas due to raw materials availability. The members of the RuRES research team visited this power plant.

Figure 7.3 illustrates solar thermal collectors of building "Šparne hiže" in Koprivnica. The purpose of solar thermal collectors is to increase energy efficiency. In figure 7.4, a part of the energy management system is presented.

Figure 7.3. Solar thermal collectors of building "Šparne hiže" in Koprivnica. Source: Photo by the author

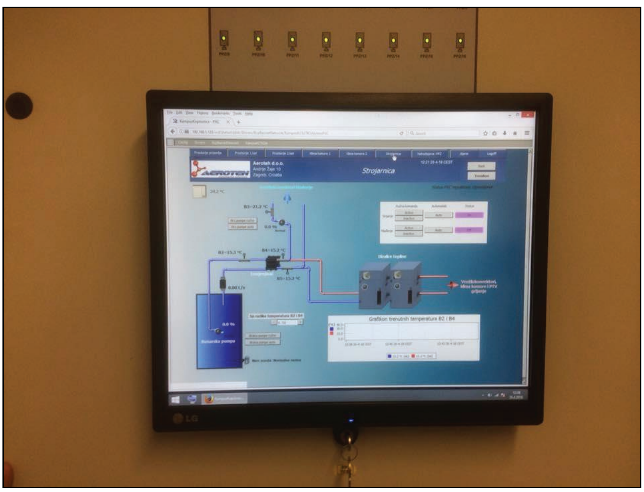

Figure 7.4. Part of the energy management system. Source: Photo by the author

The members of the RuRES research team visited this building. Based on the experience, a similar system can be applied in the industry in rural areas or in buildings of local governments.

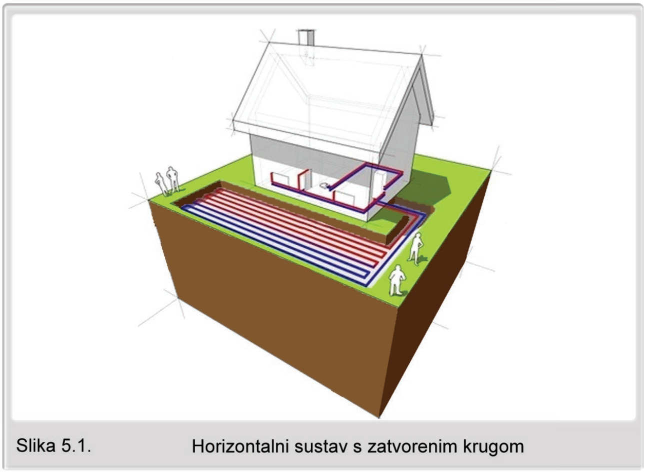

Figure 7.5. Horizontal heat pump system with a closed cycle.
Source: Perko et al., 2011

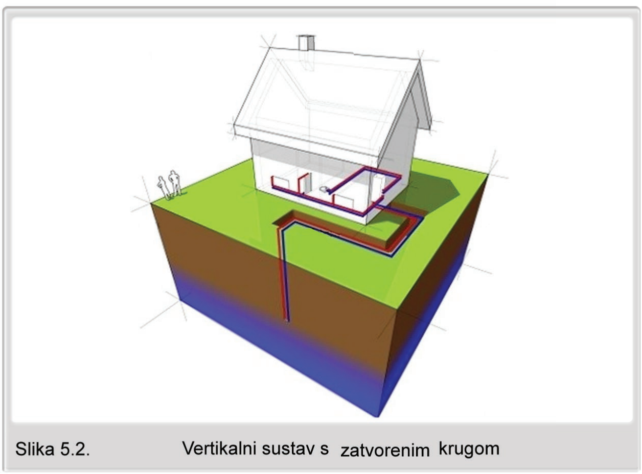

Figure 7.6. Vertical heat pump system with a closed cycle.
Source: Perko et al., 2011

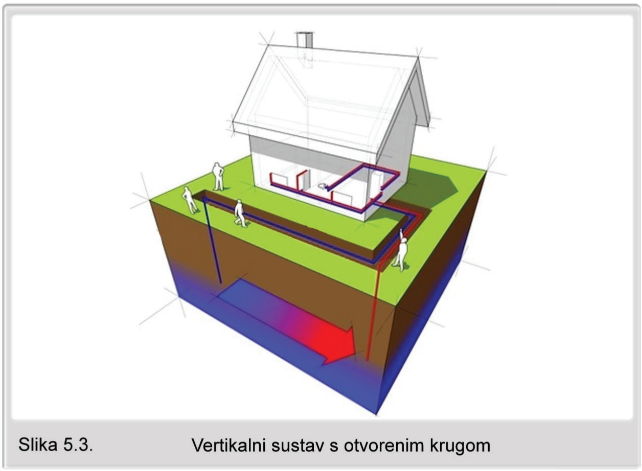

Figure 7.7. Vertical heat pump system with an open cycle.
Source: Perko et al., 2011

The examples of heat pump calculation and possible applications of heat pumps are described in Perko et al. (2011). According to Perko et al. (2011), for a house with the area of 186-223 m2, needed heat power is around 10.6 to 11.4 kW. Possible applications of heat pumps are presented in figures 7.5, 7.6 and 7.7.

7.3 Electricity

Electricity is a resource which is nowadays indispensable. Electricity consumers (households, industry and other service activities) can be supplied with electricity from a power grid or their own electricity generation. Regardless of the source, the goal is to use electricity efficiently due to following reasons:

- efficient electricity usage means less energy consumption for the same production or comfort level, which results in lower costs;
- environmental protection – less energy consumption for the same production or comfort level, which results in lower greenhouse gas emissions and lower negative impact on the environment.

Energy efficiency from the point of view of lower costs means that with the improvement of energy efficiency, financial savings will occur and these financial savings can be used for the improvement of the production quality, quality of life, quality of services etc.

According to the European Environment Agency (2018), for every generated kWh of electricity in 2014, CO_2 emissions were 136.7 gCO_2/kWh in Croatia and 206.6 gCO_2/kWh in Hungary, respectively. Energy efficiency can be achieved with the following measures:

- usage of energy efficient appliances with the highest class of efficiency (A+++);
- usage of lighting systems based on LED technologies;
- compensation of reactive power (especially in industry);
- usage of renewable energy sources.

LED lighting is the most efficient lighting body. Unlike incandescent light bulbs, which use only around 5% of energy for light (95% are losses in the form of heat), LED bulbs transform around 80% of used energy into light. In addition, a lifetime of modern LED bulbs is more than 25,000 working hours (to compare, compact fluo bulbs have a lifetime of around 8,000 working hours and incandescent bulbs around 1,200 working hours); their cost is relatively low and they are widely available. That being said, we always recommend the usage of LED bulbs for lighting systems.

For industry consumers (e.g. wood industry), it is important to make a compensation of reactive power. With compensation of reactive power, firstly we decrease consumer costs (financial savings can be invested elsewhere). Furthermore, we decrease energy losses in distribution and transmission lines, which results in a decrease of CO_2 emissions as previously described.

With the usage of renewable energy sources, close to the point of consumption, we influence on the increase of energy efficiency. A recommendation is to use renewable energy sources on the point of consumption for covering of one's own electricity needs. For family houses in the rural areas of the cross-border Croatia and Hungary region, the most convenient are photovoltaic (PV) systems. According to Topić, Knežević, Šljivac et al. (2018), photovoltaic systems can be on-grid or off-grid (standalone). Off-grid PV systems can be used in remote areas without an access to a power grid.

On-grid PV systems, if sized correctly, can contribute to the decrease of energy losses in a power grid, improvement of voltage profiles and postpone investments in distribution lines. On the other hand, off-grid PV systems can be used for power supply of objects which do not have an access to a power grid such as cottages, local community buildings, etc. Off-grid PV systems can be used for honey production (figure 7.8), irrigation system supply (Mohsin & Abdulbaqi, 2018; Pushpraj, Gupta, Gupta & Mulla, 2017; Topić, Šljivac, Stojkov, Perko & Gašparović, 2014) and many other applications.

Figure 7.8. Off-grid PV system for honey production.
Source: OPG – Nenad Grčić

For the wood industry or farms, biomass and biogas power plants are very convenient because they can be used for covering of one's own consumption (electricity and heat) but they can be used as a power supply of local consumers as well.

In the RuRES research, a simplified model of an off-grid PV system, which can be used in rural areas, is developed and the research results were published in a scientific paper (Topić, Knežević, Kosić, & Perko, 2018). In figure 7.9, a scheme of the off-grid PV system, which can be used in rural areas, is shown.

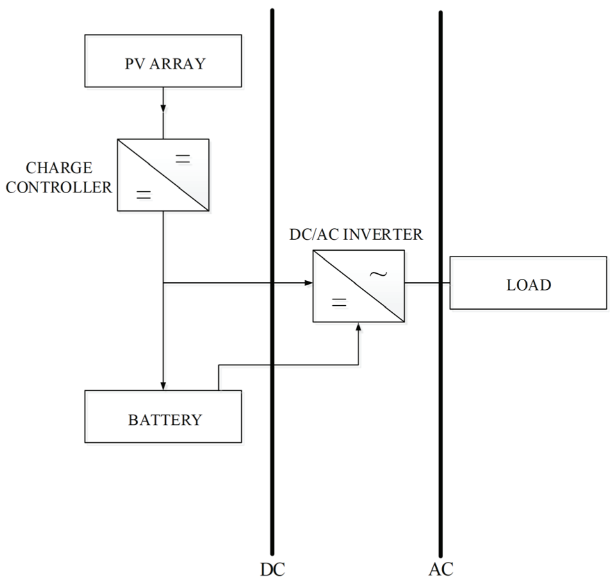

Figure 7.9. Scheme of the off-grid PV system
Source: Topić et al. 2018

8 APPLICATION OF RES IN THE RURAL AREAS

Damir Šljivac, Zvonimir Klaić

8.1 Energy concepts in the cross-border (CB) region of Croatia and Hungary based on renewable energy sources

Renewable energy sources (RES) are a very important part of energy balances in almost every country. They provide electric and thermal energy with reduced pollution and exclude the use of fossil fuels. Also, unlike conventional technologies, RES use many dispersed sources of energy and they are compatible with the "smart grid" implementation in an electric distribution grid.

The CB area of Croatia and Hungary, rural continental eastern part of Croatia and southern part of Hungary, possesses a very significant potential of renewable energy sources especially high in the usage of biomass from the forestry and rests from the agricultural production including the possible biogas production at the farms. Its estimated potential is over 1.3 TJ/km^2 but it is also one of the highest geothermal gradients in Europe with over 0.049 ^{o}C/m (Pannonian basin). Although solar potentials, compared to the south Mediterranean coastal part of Croatia, seem low, compared to Germany, having installed the most of European capacities in PV systems, the solar radiation on this part of the south-east Europe is over 20 % higher. Some parts of the region even possess medium wind energy potentials with a ten-year average wind-speed of 4-5 m/s.

Some projects on implementing RES in electricity production have mostly been performed in rural areas of the cross-border area, especially in the field of agriculture. Further, there were some research on the usage of biomass, biogas, solar energy in photovoltaic systems in Croatia and a direct geothermal energy usage in Hungary. However, this region generally seems to lag behind the rest of Croatia and Hungary not only by installing RES capacities, but particularly in transferring knowledge and technology to raise industrial competitiveness when the field of RES is at stake.

According to (Ren21, 2016), distributed renewable energy (DRE) systems used for power, cooking, heating and cooling systems are systems that generate and distribute services independently of any centralized system in either urban or rural areas of the developing world. The systems have already been providing energy services to millions of people and numbers have annually been increasing. DRE systems can serve as a complement to centralized energy generation systems or as a substitute. They offer an unprecedented opportunity to accelerate the transition to modern energy services in remote and rural areas, while simultaneously offering co-benefits such as improved health (through the displacement of indoor air pollution), contributions to climate change mitigation as well as positive effects on income growth, women's empowerment and distributive equity, affordable lighting, enhance communications and facilitate greater quality and availability of education. DRE systems as well as the hybridization of existing microgrids may also reduce the dependence on fossil fuel imports.

There are many possible renewable energy technologies that could be used in rural areas but their implementation strongly depends on the energy service that would be provided as presented in the table 8.1.

Table 8.1. Energy services and associated used renewable energy technologies

Energy service	Income-generating value	Renewable energy technologies
Irrigation	Better crop yields, higher-value crops, greater reliability of irrigation systems, enabling of crop growth during periods when market prices are higher	Wind, solar PV, biomass, micro-hydro
Illumination	Reading, extension of operating hours	Wind, solar PV, biomass, micro-hydro, geothermal
Grinding, milling, husking	Creation of value-added products from raw agricultural commodities	Wind, solar PV, biomass, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value-added products, preservation of products that enable sale in higher value markets	Biomass, solar heat, geothermal
Expelling	Production of refined oil from seeds	Biomass, solar heat
Transport	Reaching new markets	Biomass (biodiesel)
TV, radio, computer, Internet, telephone	Support of entertainment businesses, education, access to market news, co-ordination with suppliers and distributors	Wind, solar PV, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end-users (e.g. phone charging businesses)	Wind, solar PV, biomass, micro-hydro, geothermal
Refrigeration	Selling cooled products, increasing the durability of products	Wind, solar PV, biomass, micro-hydro

Source: (Ren21, 2016)

However, there are not only technology issues to be considered but also general conceptual differences on possible future development and usage of RES in rural areas of this cross-border region as follows:

1. Rural industry investment returns driven energy concept - aimed to ensure investment returns based on sold electricity feed-in tariff and/or value of produced or sold heat.
2. Community energy fosters integrated energy concept - aimed to demonstrate the economic and organizational feasibility of creating a community-driven RES energy village/rural area (Ren21, 2016).
3. Energy access concept(s) such as (Ren21, 2016):
   - a, remote community energy access to energy and fuel - obtaining access to energy and fuel for transportation on, for example a remote island, and reducing the costs of transporting and using imported fuel;
   - b, community-based electrification energy concept - aimed to provide a reliable electricity (power) supply through power generation and distribution critical for the sustainable development of rural communities;
   - c, renewable microgrids - basically off-line energy (power) systems with high flexibility in the application aimed to provide an energy (power) access for local population with no access to an energy (power) grid (or even to disconnect from the grid in order to reduce the cost and/or dependency on fossil fuels).

For the rural areas of the cross-border Hungary-Croatia region, a region consisting mainly of small family agricultural farms and largely lacking financial means for huge investments, certainly the most suitable energy concept would be the renewable microgrid energy concept.

According to (Schnitzer et al., 2014), (renewable) microgrids – distributed systems (DRE) of local energy generation, transmission, and use – are today technologically and operationally ready to provide communities with electricity services, particularly in rural and peri-urban areas of less developed countries. Over 1.2 billion people, which includes over 550 million people in Africa and 300 million people in India alone, do not have access to electricity. The traditional approach to serve these communities is to extend the central grid. This approach is inefficient due to a combination of capital scarcity, insufficient energy service, reduced grid reliability, extended building times and construction challenges to connect remote areas. Adequately financed and operated microgrids based on renewable and/or appropriate resources can overcome many of the challenges faced by traditional lighting or electrification strategies.

There are several types of renewable microgrids that are associated with the aforementioned energy concepts, namely NREL (2018):

- large grid-connected microgrids (e.g. military bases or campuses);
- small grid-connected microgrids (e.g. single gensets to backup unreliable central grids);
- large remote microgrids (e.g. island utilities);
- small rural remote microgrids (e.g. villages).

Rural microgrids tend to transmit power over low-voltage distribution networks from interconnected local RES generation such as photovoltaics, biomass CHP (co-generation of heat and power), micro-hydro and wind power plants, etc. to a relatively small number of customers. However, depending on the energy service provided, there could be a significant difference in an adequate microgrid design even when the same RES technology is used.

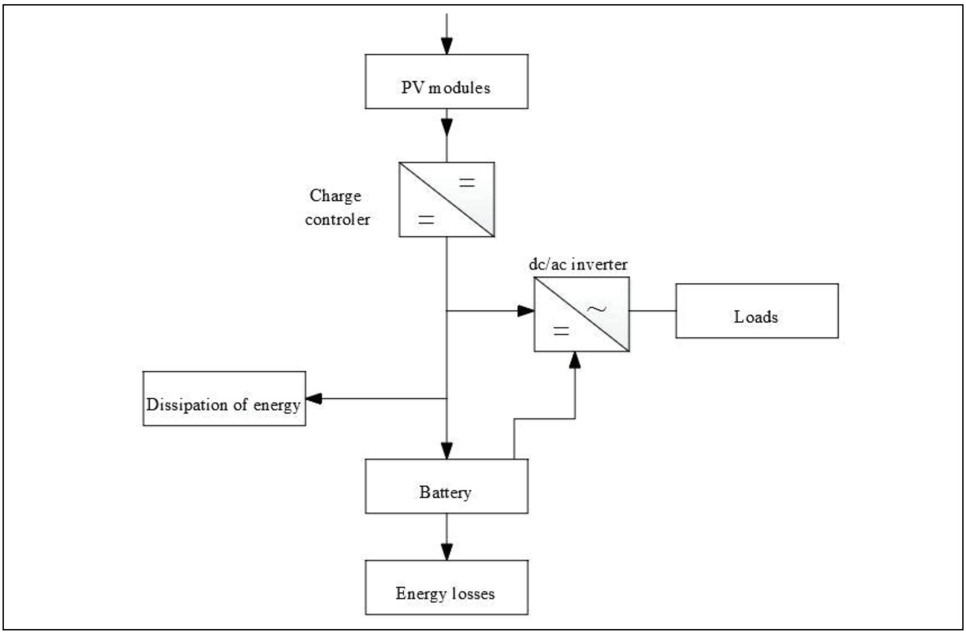

Figure 8.1. Microgrid off-line PV system for electrification
Source: Topić et al. 2013.

To exemplify, due to a strong decrease in investment costs and the significant solar potential in the region, photovoltaic systems are approaching the so-called grid parity, meaning that during their lifetime, they would pay-off the entire investment solely from electricity bill savings. This type of PV systems called on-grid systems (connected to the grid) are the most common. However, in case there is no or in case of our cross-border region rural areas, usually expensive access to the remote grid the payback period of a microgrid based on an off-line PV system would be particularly much lower. Even so, the design of such an off-line system strongly depends on the energy service provided.

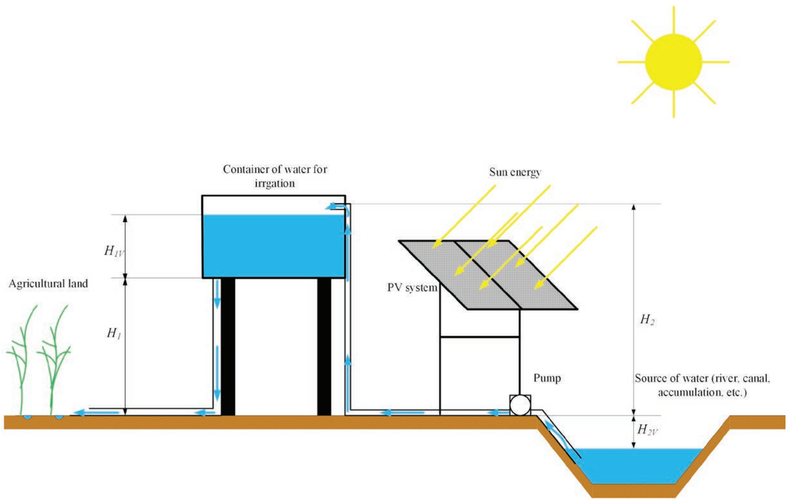

Figure 8.2. Microgrid off-line PV system for irrigation
Source: Topić et al. 2014

8.1.1 Good practical examples in Croatia

Out of many solar PV, biomass and biogas projects, only some good practical examples will be presented here, such as

- residential scale 10 kW_e PV research power plant on the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek building, Osijek, Osijek-Baranja county;
- commercial scale 325 kW_e PV system on the commercial building of Ricardo d.o.o. (Inc.) in Darda, Baranja, north of Osijek, Osijek-Baranja county;
- internal combustion engine 1700 kW_e biogas CHP plant Orlovnjak, Žito d.d. (Ltd.) Group on milk cow farm Orlovnjak, Slavonija, south of Osijek, Osijek-Baranja county;

- steam turbine 3300 kW_e + 15.000 kW_{th} biomass CHP plant Strizivojna Hrast, wood floor industry in Strizivojna, Slavonija, south of Đakovo, Osijek-Baranja county.

8.1.1.1 Residential scale 10 kW_e PV research power plant on the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek (FERIT) building, Osijek, Osijek-Baranja county

This residential scale PV research power plant was established in 2014 within IPA CBC Croatia-Hungary REGPHOSYS (Photovoltaic Systems as Actuators of Regional Development) project with the overall objectives of the development of optimal photovoltaic system configuration for climatic conditions of the cross-border region and investigating the impact of photovoltaic systems on the electrical power system, economics and environment. During the project implementation, a common knowledge database about the area characteristics significant for the application of photovoltaic systems was developed and the cross-border innovation network of research teams for the development of photovoltaic systems was established. Furthermore, the photovoltaic systems were optimized for climatic conditions of the project impact area in terms of selecting solar cells technology and inverter topology.

Figure 8.3. Laboratory for RES, FERIT Osijek
Source: Photos by the authors

As a result of this activity, an online database with the measurements of regional climate and weather conditions, electrical characteristics of 5 different PV technologies (mono and polycrystalline Si, amorphous Si, HTJ and CIS) together with electricity production from 10 kW research power plant consisting of two 5 kW arrays (mono and polycrystalline Si) has been established and available with more information on http://reslab.ferit.hr/ .

Figure 8.4. Online database http://reslab.ferit.hr/
Source: (RESLAB, 2018)

8.1.1.2 Commercial scale 325 kW_e PV system on the commercial building Ricardo d.o.o. (Inc.) in Darda, Baranja, north of Osijek, Osijek-Baranja county

Basic commercial scale PV power plant data (Šljivac, 2013):

- location: Darda;
- rated power: 325.00 kWp;
- gross / active PV area of power plant space: 2,116.25 / 2,130.37 m²;
- solar irradiation PV power plant (array of FN modules): 2,989,670 kWh;
- (alternating) electricity produced by the PV power plant: 368,285 kWh;
- part of electricity supplied to the grid: 368.285 kWh;
- overall PV power plant efficiency (including a series of FN modules and other losses): 12.3%;
- PV power plant efficiency (only other losses): 80.7%;
- specific yearly PV power plant yield (energy per kW): 1.133 kWh/kWp;
- avoided CO^2 emissions: 326,175 kg/yr.

The basic block scheme of the PV power plant RICARDO, according to the investor's submitted data (Šljivac, 2013), produced by KönigSolar in PVSYST is shown in Figure 8.5.

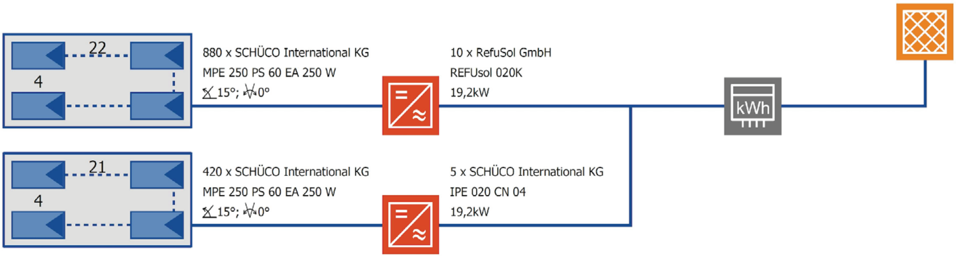

Figure 8.5. Basic block scheme of 325 kW PV power plant Ricardo
Source: (Šljivac, 2013)

A total of 1300 FN modules were used in two series (880 and 420 modules) of the SCHÜCO International KG MPE 250 PS 60 EA installed power of 250 W each, resulting in a total installed power of the PV power plant of 325 kW. The module spatial arrangement for the roof of the building is shown in figure 7.6.

Figure 8.6. 325 kW PV power plant Ricardo, Darda, Baranja
Source: Šljivac, 2013

This project is particularly interesting due to the fact that it is a part of high level RES integrated into the 10 kV distribution feeder Bilje–Beli Manastir in Baranja with 9 different RES (PV and biomass) power plants being installed on a single feeder (part) of a rather rural distribution grid, as presented with red colour in Figure 8.7., and with the expected high rise of voltage and possible current overloads in the future.

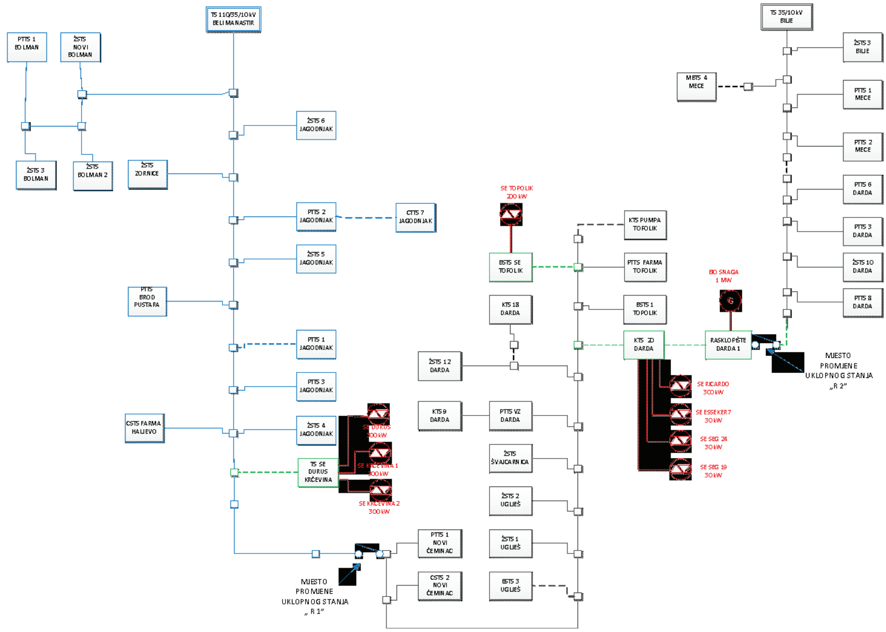

Figure 8.7. Integration of 9 different RES power plants (red color) on a single 10 kV feeder Bilje - Beli Manastir in the Croatian part of Baranja
Source: Šljivac, 2013

8.1.1.3 Internal combustion engine 1700 kW$_e$ biogas CHP plant Orlovnjak, Žito d.d. (Ltd.) Group on milk cow farm Orlovnjak, Slavonija, south of Osijek, Osijek-Baranja county

With this 1700 kW$_e$ CHP power plant, which started operating in May 2016, a private investor from Žito Group, a large agricultural company in Slavonija, started building several biogas CHP plants and increasing the share of renewable energy sources in electricity generation thus ensuring the stability of the local distribution electricity system and simultaneously contributing to the implementation of the common EU energy policy prescribed by the National Action Plan for RES in 2020.

The project basic data (Šljivac & Klaić, 2017):

- investor: FARMA MUZNIH KRAVA (Milk Cow Farm) ORLOVNJAK D.O.O. (Inc.);
- location: Osijek-Baranja county, Antunovac, home number 182/1 k.o. Orlovnjak;
- operational mode: in parallel with the distribution network;
- connection voltage: 10 (20) kV.

For biogas production, an anaerobic digestion system is used enabling anaerobic digestion of milk cows manure, agricultural biomass and food industry waste into a manure with higher nitrogen ratio but most importantly into so called biogas consisting mostly of methane CH_4 and carbon-dioxide CO^2 in a so called digester (or bioreactor or fermenter) presented generally in figure 8.8.

Figure 8.8. Anaerobic digester in CHP plant Orlovnjak for biogas production
Source: Šljivac & Klaić, 2017

Biogas is collected at the soft membrane on the top of the digester and then burned in CHP plant consisting of two gas aggregates, namely a gas engine (in this case Jenbacher JMS 412) connected (by shaft) to (in this case STAMFORD 1268 kVA) a synchronous generator with a stable operating condition connected to a 10 kV distribution grid usually at a connection transformer (in this case TS 35/10 kV Osijek Istok (East)).

Figure 8.9. Usual CHP aggregate biogas configuration (Jenbacher – in figure) internal combustion gas engine + synchronous generator
Source: Žito grupa, 2018

While electricity is being sold to the grid with a feed-in tariff (in this case 1.20 HRK/kWh), thermal energy from the engine gas combustion is being used for heating the farm and drying agricultural biomass for energy and other uses (e.g. heating greenhouses used for vegetable production on one farm in Ivankovo). The increased revenue from the production of electricity and heat from the plant resulted in return on the investment in approximately four years (Žito grupa, 2018).

8.1.1.4 Steam turbine 3300 kW$_e$ + 15000 kW$_{th}$ biomass CHP plant Strizivojna Hrast, wood floor industry in Strizivojna, Slavonija, south of Đakovo, Osijek-Baranja county

The wood floor (parket) company Strizivojna Hrast (Oak) d.o.o. (Inc.) put the first cogeneration plant in Croatia for the production of electricity and heat based on the combustion of biomass into operation. The investment is worth 117 million and Erste Bank, together with the Croatian Bank for Reconstruction and Development (HBOR), financed around 70% of the entire investment. The company Strizivojna Hrast have been engaged in the production of laminate flooring for domestic and foreign markets for many years. A classical steam turbine based CHP (co-generation) plant development project is launched with the aim of producing their own electricity and heat using resources from the existing wood floor (parket) production (forest and wood biomass) (Hrast Strizivojna, 2018).

Figure 8.10. Steam turbine CHP plant 3.3 MWe + 15 MWth Strizivojna Hrast
Source: Hrast Strizivojna, 2018

The CHP plant achieved savings in energy costs and increased its revenue from the sale of surplus electricity (out of 3.3 MW_e) to HROTE (Croatian Energy Market Operator) planning to expand its product lines and the use of waste heat to increase the current capacity for drying wood elements for further processing (with approx. 15 MW_{th} available). As a result of the increasing production capacity, they increased the number of employees by about 20%. The investment replaced the usage of diesel fuel which is, in addition to being environmentally unacceptable, also very expensive. In addition to cost savings, the increased revenue from the production of electricity and heat from the plant resulted in return on the investment in six to seven years.

8.2 Impact of distributed generation on power quality in the rural areas

The number of installed power plants with renewable energy sources (and other distributed sources) in the world has been steadily growing on a daily basis. Initially, various incentive measures were contributed to the European Union, while some of the technologies in the meantime had become so much cheaper resulting in being cost-effective without incentives. Although the benefits of renewable energy sources are well-known and unquestionable, each of these sources, with respect to the type and technology, by its production, affects the power quality in the power system where it is connected. The literature elaborates on the potential impact of certain types and technologies of power plants with renewable sources to the power quality – photovoltaic power plants, wind power plants, fuel cells, generators and turbines which use different propellant fuels (gas, diesel), (Baggini, 2008; Dugan, McGranaghan, Santoso, & Beaty, 2002). Although the influence of the power plant on the power grid can be predicted by simulations, the final status confirmation are carried out measurements upon the construction of the power plant.

Measurements are performed before and after the connection of the distributed source (the duration of measurement is 7 days), the results are analysed and compared to the applicable standards and regulations – HRN EN 50160 and Croatian Grid Code (HRN EN 50160:2012, 2012; Narodne novine, 2006).

8.2.1 Influence of REPP on the power quality of the distribution network

Although the power conversion technology has a certain role in the power quality (such as wind and sun which, due to power changes, may cause voltage fluctuations), the power quality mostly depends on the interface and connection of the distributed generation and the type of connection with the electric power system, (Dugan et al., 2002).

The main types of the interface and system connections are as follows:

- synchronous machines;
- asynchronous (induction) machines;
- electronic converters.

Since there are no power plants with asynchronous (induction) machines in the eastern Croatia, their influence on the power quality will not be discussed in this paper.

8.2.1.1 Synchronous machines

Although synchronous machines are a well-known technology in the power system, there are some challenges to be faced with when using them as distributed sources. Due to their inertia, they can well tolerate leaps in the system, which is good when they are used as a reserve energy source. In the case of their application as distributed sources, they would be able to easily handle the island operation but also supply short circuit, (Dugan et al., 2002).

Although small distributed sources do not have enough power to regulate the voltage in the system, there is a possibility that a synchronous machine is large in relation to the system's capacity and it is involved in regulating the voltage of the power system. Of course, this contributes to the better power quality in some weak systems. However, these cases should be carefully studied and then meticulously aligned with the protection and regulation of the network voltage.

In Croatia, synchronous generators are mostly used in biogas plants and biomass power plants. The main raw materials for propulsion are located near farms (predominantly cow farms) and near the woods, power plants are built in rural areas. Synchronous generators are commonly connected to a middle voltage power network through three-phase transformers that have delta-wye windings connection. For distribution networks in rural areas, it is characteristic that they are "weak", i.e. there is usually no significant consumption. Therefore, with carefully adjusted protection, problems with voltage regulation can be expected, so it is important to keep in mind that the voltage, with the connected power plant, is not too high. So far, this challenge has been mainly solved by the manual regulating voltage on the transformer. In the normal operation of such power plants, problems with other indicators of the power quality are not expected.

8.2.1.2 Electronic converters

All distributed source technology, which produces DC or AC power with other than network frequency, must be connected to the power grid via an electronic converter. Although electronic converters have an undeniable influence on the power quality, in the form of higher harmonics current, the newer pulse-width modulation technology brings significant improvements (Dugan et al., 2002).

In the photovoltaic power plant, the most important part, considering the power quality, is a converter which converts the direct current from photovoltaic modules into alternating current, (Baggini, 2008). The converter has several functions and the first one is to control the photovoltaic route. When the sun rises in the morning, the photovoltaic module is connected to the network. As insolation and temperature change during the day, the converter adjusts the current and voltage to maximize the power output from the photovoltaic modules. At the end of the day, the converter disconnects the system from the network.

8.2.2 Power quality measurements

For the purpose of the Study of the Impact of the Power Plant on the Power Grid, power quality measurements are performed before and after connecting the power plant to the power grid. Power quality measurements are performed using class A accuracy analyser, which is defined in IEC 61000-4-30. The measurement results are analysed according to HRN EN 50160: 2012, Voltage Characteristics in Public Distribution Systems (EN 50160: 2010) (HRN EN 50160:2012, 2012), where the limits for certain power quality indices are defined. Each measurement lasts for 7 days.

There is an obligation to analyse the results of power quality measurements according to EN 50160 and the Croatian Grid Code.

The European standard EN 50160 defines the main features of the supply voltage in the public distribution system at the consumer's supply place. The following indices are set by the standard:

- voltage dips and interruptions;
- voltage variations;
- harmonics and interharmonics;
- transient overvoltages;
- voltage imbalance;
- line frequency;
- the presence of DC voltage in AC voltage;
- the presence of signalling voltages.

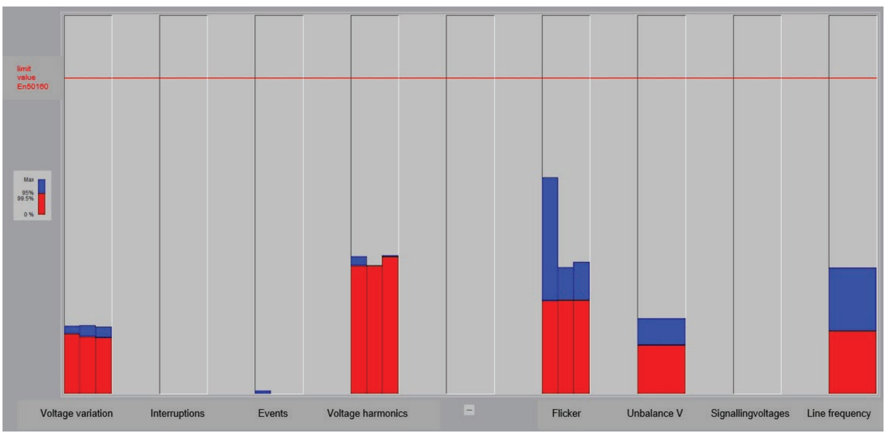

Figure 8.11. Summarized results of the power quality measurements on 300 kW Source: (BPP) Hrastin.

Therefore, the measurement and analysis of the power quality include all of the aforementioned indices and voltage characteristics, (Feracci, 2001).

Figure 8.11 shows the summarized results of the power quality measurements on 300 kW biogas power plant (BPP) Hrastin. Seven groups of columns represent seven power quality indices, namely frequency, events, voltage changes, total harmonic distortion (THD), long-term flicker, voltage imbalance and voltage harmonics. Some indices are displayed by three columns, such as voltage changes, as each column indicates one phase. Columns can be either red or blue; red columns indicate 95% of the week and the blue represent the maximum values. The red horizontal line represents the limit values for each of the power quality indices. In cases where the red colour column is higher than the red horizontal line, it means that the index values do not comply with the limits of EN 50160.

As already mentioned, an analysis of the power quality measurement according to the Grid Code is also required, (Novine, 2006). Similarly to HRN EN 50160: 2012, the Grid Code provides limitations for voltage fluctuations and frequency changes, but for some of the power quality indices, there are limits to the allowed contribution of the power plant to the distribution network. Such rules exist for the following:

- THD*U* (Total Harmonic Distortion of Voltage);
- flickers;
- voltage imbalance.

Due to these requirements, the results of the power quality measurements are analysed and compared before and after the connection of the power plant to the distribution network.

8.2.2.1 Analysis of the power quality measurement results

During the last 10 years (from 2008), the power quality measurements, during the integration of 9 biogas (BPP) and 7 photovoltaic power plants (PPP) in the distribution grid in Slavonija, were performed by the Laboratory of Electromagnetic Compatibility, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek (Klaić & Primorac, 2017; Klaić, Primorac, Topić & Knežević, 2018; Klaić, Šljivac, Primorac, Topić & Stojkov, 2018). The measurements lasting for 7 days were performed first before and then after the connection of each of the power plants. All measurement results showed that the power quality indices were in accordance with the European norm EN 50160 and Croatian Grid Code. To illustrate, Table 8.2 shows the summarized results of the measurement at 300 kW PPP Drenje.

Table 8.2. Results of the power quality measurement – biogas power plants.

Power Plant	Nominal Power [kW]	Voltage Fluctuation	Events	Harmonics	Flickers	Imbalance	Frequency
BIO1	1000	+	+	+	+		
BIO2	1000		-		-		
BIO3	300		+	-	-		
BIO4	1400	+	+		-		
BIO5	1700	-	+	+	+		
BIO6	1000	+	+	+	+		
BIO7	1000						
BIO8	1000	+		+	+	+	
BIO9	1000			+	-	-	

Source: Own contribution

Tables 8.2 and 8.3 show the summarized measurement results for every power plant, and for each power quality index, namely voltage variations, voltage events, harmonics, flickers, voltage imbalance and line frequency. In the tables, mark "+" means that the index has been improved after connecting the power plant and mark "-" means that the index deteriorated after connecting the power plant. A cell without a mark means that a certain power quality index was very similar before and after the connection of the power plant.

Table 8.3. Results of the power quality measurement – photovoltaic power plants.

Power Plant	Nominal Power [kW]	Voltage Fluctuation	Events	Harmonics	Flickers	Imbalance	Frequency
PV1	30				-		
PV 2	10	+	+	+	+		
PV 3	200				-		
PV 4	10		+		+		
PV 5	30	-					
PV 6	30				+		
PV 7	300				-		

Source: Own contribution

Table 8.2 shows that the particular worsening occurred in 5 power plants, namely voltage variations worsened in BIO5, voltage events in BIO2, harmonics in BIO3, imbalance in BIO9 and flickers in BIO2, BIO3, BIO4, and BIO9. Table 2 shows that the worsening occurred in 4 power plants, namely index voltage variations worsened in PV5 and flickers in PV1, PV3 and PV7.

Thus, from the power quality indices, the flickers stand out. A more detailed analysis of the measurements has shown that the biogas power plants mostly cause recorded flickers, but the contributions are not large and are within the limits of EN 50160 and the Croatian Grid Code. In comparison, the photovoltaic power plants cause only a smaller part of the recorded flickers. This can be seen in Figure 8.13 demonstrating the short-term flickers and maximum current values from 300 kW PPP Drenje. In the first half of the measurement week, the flickers were recorded during the night when the power plant was not in operation (green ellipses), and in the second half of the measurement week, there were two cases when the power plant production caused flickers (red ellipses).

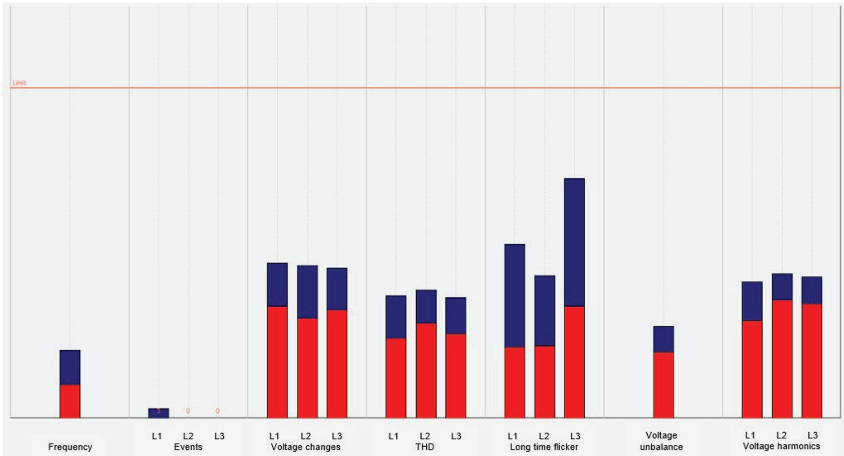

Figure 8.12. Summarized results of the power quality measurement at 300 kW photovoltaic power plant Drenje.
Source: Own contribution

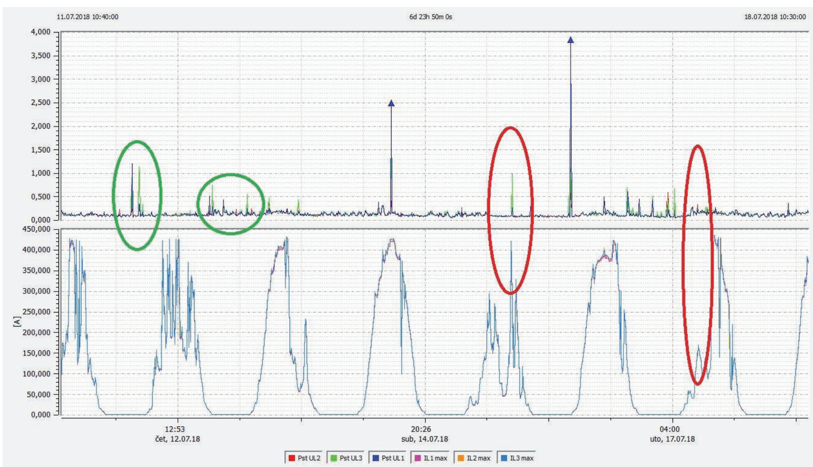

Figure 8.13. Short-term flickers and maximum current values – 300 kW PPP Drenje.
Source: Own contribution

The main conclusion is that all the power plants included in the measurements had allowed contributions according to EN 50160 and the Croatian Grid Code. Problems may possibly be expected during future connections if new power plants are connected to the same connection points as the already existing distributed sources.

9 EXAMPLES OF GOOD PRACTICE

Denis Pelin, Matej Žnidarec, Dario Došen

9.1 Laboratory for Renewable Energy Sources

The Laboratory for Renewable Energy Sources was established and equipped in 2014 within the Photovoltaic Systems as Actuators of Regional Development (REGPHO-SYS) project funded by IPA cross-border Croatia-Hungary program. The Laboratory consists of the indoor (Figure 9.1) and outdoor part (Figure 8.2), which is located right next to the indoor part. The indoor part of the Laboratory contains a part of the system used for measuring, processing and storing data acquired from the photovoltaic technologies and equipment used for teaching classes at the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek.

Figure 9.1. Indoor part of the Laboratory for Renewable Energy Sources.
Source: Photo by the authors

Figure 9.2. Outdoor part of the Laboratory for Renewable Energy Sources.
Source: Photo by the authors

9.1.1 Data acquisition system of 5 photovoltaic modules made of different technologies

The system for measuring, processing and storing data acquired from the photovoltaic technologies started operating in 2017. The system measures electrical parameters acquired from the photovoltaic technologies and meteorological parameters on the test site.

The system for measuring, processing and storing data consists of three individual subsystems as follows:

1. data acquisition system of 5 photovoltaic modules made of different technologies;
2. data acquisition system of 10 kWp photovoltaic system ETFOS1;
3. data acquisition of meteorological parameters on the test site.

9.1.1.1 Data acquisition system of 5 photovoltaic modules made of different technologies

The photovoltaic technologies and corresponding modules which the measurements are performed are on as follows:

1. Monocrystalline silicon (Bisol BMO 250);
2. Polycrystalline silicon (Bisol BMU 250);

3. Amorphous silicon (Masdar MPV100-S);
4. Copper-indium selenide – CIS (Solar Frontier SF150-S);
5. Heterojunction with intrinsic layer – HIT (Panasonic VBHN240SE10).

The photovoltaic modules are connected to the alternating current distribution network over single-phase grid-tie micro-inverters with an integrated maximum power point tracker (Figure 9.3) and represent micro photovoltaic systems. The measurement system is connected to the DC side of the inverter which measures output current, voltage and cell temperature of a photovoltaic module every second with various types of sensors. The sensors are connected to ATmega 328p microcontroller, which primarily processes and then send data to the main computer. Data is then stored on the main computer being ready for further processing. Figure 9.4 shows a block diagram of the data acquisition system of 5 photovoltaic modules made of different technologies.

Figure 9.3. Single-phase grid-tie inverter of photovoltaic modules.
Source: Photo by the authors

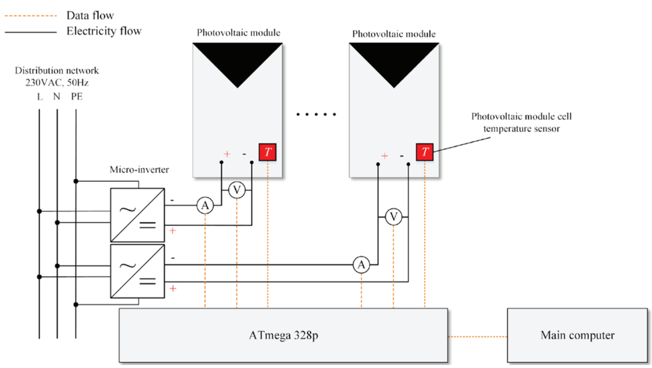

Figure 9.4. Block diagram of the data acquisition system of 5 photovoltaic modules made of different technologies.
Source: Own contribution

9.1.1.2 Data acquisition system of 10 kWp photovoltaic system ETFOS1

The photovoltaic system ETFOS1 with the installed capacity of 10 kWp consists of 2 photovoltaic strings. The first photovoltaic string consists of 20 series-connected photovoltaic modules made of monocrystalline silicon (Bisol BMO 250) while the second one consists of 20 series-connected photovoltaic modules made of polycrystalline silicon (Bisol BMU 250). The photovoltaic strings are connected to the three-phase grid-tie inverter over two inputs equipped with the maximum power point tracker. The inverter (Kaco Powador 12.0 TL3), illustrated in figure 8.5, is connected to the distribution network. The measurements of electrical parameters are performed by the inverter itself. The measured values are then sent to the main computer where they are processed and stored. The inverter measures DC output currents and voltages of the photovoltaic strings, AC output phase currents and phase voltages every 15 seconds.

Figure 9.5. Inverter KacoPowador 12.0 TL3.
Source: Photo by the authors

9.1.1.3 Data acquisition of meteorological parameters on the test site

The meteorological data is measured by the weather station and pyranometer (Figure 9.6) placed on the Faculty building roof where the photovoltaic technologies are located. The weather station measures ambient temperature, air humidity, wind speed, wind direction and air pressure every minute while the pyranometer (Kipp & Zonnen SMP3) measures solar irradiance every second. The measured data is sent to the main computer where they are processed and stored.

Figure 9.6. Weather station and pyranometer placed on the Faculty building roof.

The measured data is stored and processed on a local computer. Upon processing data, it is sent into a cloud storage and simultaneously displayed on the laboratory Faculty website. On the web platform, the data is additionally processed into diagrams. Figure 9.7 shows a schematic preview of the connected power plant and its energy production in real-time.

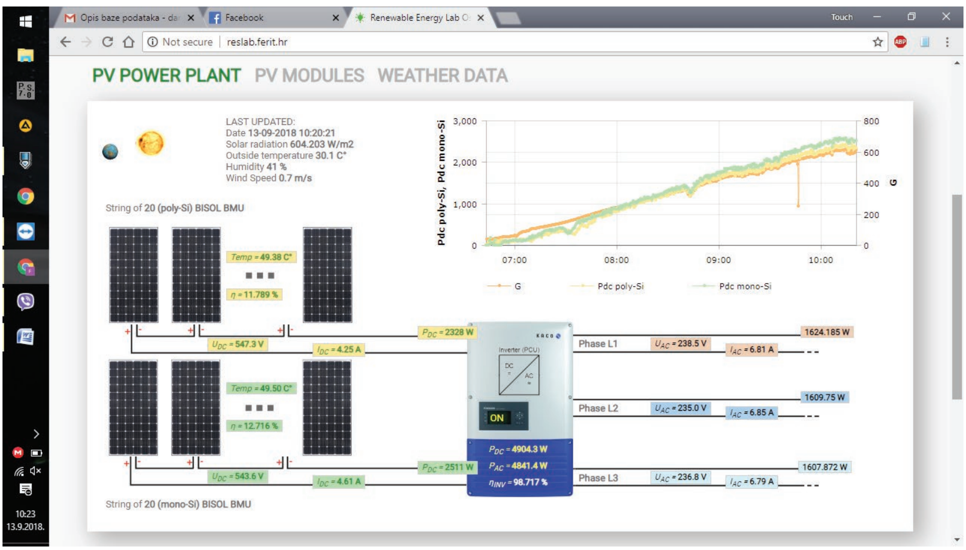

Figure 9.7. Schematic preview of the power plant (reslab.ferit.hr) with the real-time measurement. Source: own contribution

Data processing is a process of checking the acquired data from sensors in a predicted set of values. The predicted set of values eliminates false or deviated sensor data. Data processing also calculates current/average module efficiency values and current/summary produced electrical energy. Additionally, it calculates the efficiency of the photovoltaic power plant inverter ETFOS1. The integrated algorithm of ATmega 328p microcontroller processes the data in 30 intervals per second and outputs an average value every second. Measured values like solar radiation, weather data and a moment of measurement (night, day, season) are additionally processes on the local computer attached to the microprocessor.

Both the microcontroller and the computer algorithm constantly monitor the time and expected values of the measured data and in case of interruption or breakdown of data acquisition, a quiet alarm is triggered (messages are sent) to inform about this scenario. The alarm is needed for this kind of long-term measurements to free up time of the researchers.

The data processing includes further grouping of data, classifying time periods in relation to efficiency of produced electrical energy and other measured parameters. From the acquired continuous data (per days), data sets that include a certain type of successful periods for electric energy production of the power plant and photovoltaic modules respectfully are given. The data sets also include pre-calculated parametric values as ratios of two or more measured values. The raw database is calendar-base structured allowing to browse a given day displaying a table of all measured data in a row of minutely averaged values. Figure 9.8 shows the calendar and a preview of the measured days.

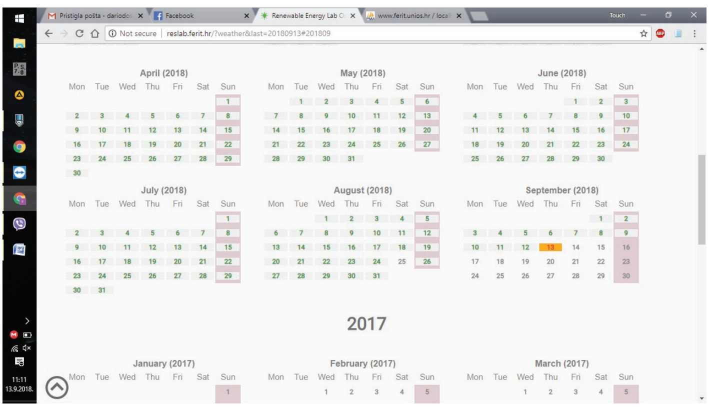

Figure 9.8. Calendar-based preview of the measured days.

With expectations of a long-term and perennial measurement period, the summarized sets of data are being made to display the behaviour of the photovoltaic power plant (also different modules) in relation to the seasons of the year as well as climate changes and effects. Also, it is planned to completely observe the energy flow by measuring data consumption of the Faculty building.

9.1.2 Other equipment used for the classes

The personal computers, used for simulations, using different software tools and other electrical equipment used for various experiments are placed in the indoor part of the Laboratory. The following equipment is acquired as a part of this project. The equipment will be used for simulations and experiments in classes as well as conducting scientific research:

- programmable electronic DC loads PeakTech 2280 (Figure 9.9);
- real-time simulator of electrical networks Typhoon HIL 402 (Figure 9.10);
- network analyser a-eberle PQ-Box 200 (Figure 9.11).

Figure 9.9. Programmable electronic DC loads PeakTech 2280.

Figure 9.10. Real-time simulator of electrical networks Typhoon HIL 402.

Figure 9.11. Network analyzer a-eberle PQ-Box 200.
Sources: Photos by the authors

9.2 Didactic equipment for learning about electrical energy production from renewable energy sources

For the implementation of one of the RuRES project activities, namely the training, the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek (FERIT), as a lead beneficiary of the Croatia-Hungary cross-border cooperation program, has purchased valuable equipment for photovoltaic (PV) systems, cells and the application of power electronic converters for the connection of renewable energy sources (RES) to typical alternating energy loads. That being said, the text describes three didactic systems, namely a small scalable PV system, a scaled fuel cell system and a cascade of power electronic converters for the supply of low power loads from RES. All three systems have the ability to connect to a computer with installed software that can use virtual measurement instruments to record the characteristic parameters. The PC is further connected to a projector giving a multimedia character to these systems. The purchased didactic-multimedia systems represent a small-scale RES integration lab and, due to lowered voltage levels below 50V are smart systems because handling such systems is safe for the user. Each system is described in detail and basic experiments to be conducted through trainings to gain basic knowledge on how electrical energy production from the PV system depends on influencing parameters as well as how electrical energy production from fuel cells depends on their influential parameters are suggested. In addition, some characteristic conditions of the operation were recorded. For an electronic energy converter, more precisely an inverter, trainings are suggested explaining the energy efficient operation of AC motors.

9.2.1 Small scalable didactic photovoltaic systems

Electrical energy production from the PV system as RES has steadily been increasing (Ahteshamul et al. 2013; REN21). The major reason of the increased electrical energy production from RES is the global energy crisis and climate change which conventional sources of fossil fuels are not satisfied any more (Srinivasa et al. 2013; Branids & Pelin 2017; Hirschenhofer et al. 1998). As a result of this trend, there is an increasing awareness and interest among RES's technical staff, especially on PV systems. In addition to the theoretical knowledge of converting solar energy into electrical energy through the PV system, for the better training of future engineers, a training that includes recording PV module/string v-i characteristics when changing influential parameters, such as the slope of PV module installation and light intensity, studying the connection between the PV modules in strings, setting operation point on the PV module/string v-i characteristics for different loads, etc. is also required. However, the practical learning labs on PV systems are primarily impractical due to the space to be provided for the installation of PV modules as well as the dependence of measurement results on external weather conditions. As an alternative, small scalable didactic PV systems for practical learning (Fuel Cell Handbook 2004; Kondratyhev et al. 1998) are required with their own, artificial sources of light.

One system for training about the electrical energy production from the PV modules, irrespectively of external weather conditions (temperature and intensity of solar irradiance) is presented with didactic-multimedia equipment as is illustrated in Figure 9.12. The equipment consists of scaled components/devices needed to design an island type of the PV system.

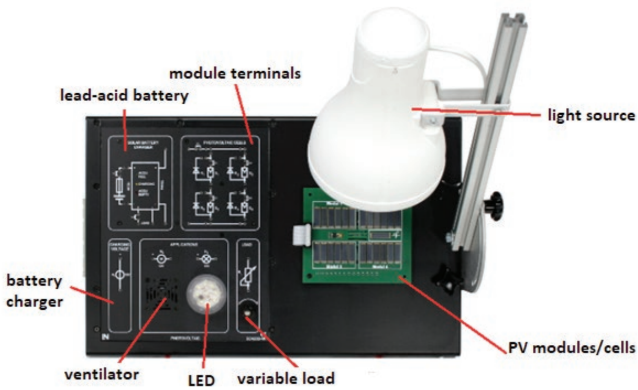

Figure 9.12. Scaled, portable, didactic PV system.
Source: Photo by the author

The scaled FN system consists of:

- supply;
- interface;
- artificial sources of light;
- operation board with PV modules, loads and sensors.

The maximum power that a single PV module can deliver is not only dependent on solar irradiance but also on the load. The open and short circuit tests and the operating states between these two points are defined by the PV module v-i characteristic or, when multiple PV modules are connected, by the PV string v-i characteristics. Recorded v-i PV module characteristics are indicators for estimating the electrical energy production from the PV system. Figure 9.13 shows the *v-i* characteristic of one PV module, which is on the didactic operation board and consists of 6 PV cells, while Figure 9.14 shows the way of connecting the operation board with the interface for the recording the *v-i* characteristics of PV modules.

The PV module *v-i* characteristic is determined with the following parameters:

- I_{SC} – short circuit current;
- U_{OC} – open circuit voltage;
- MPP – maximum power point, which is determined with current I_{MPP} and voltage U_{MPP}. The maximum power point defines the maximal area under the curve which is limited with current I_{MPP} and voltage U_{MPP};
- P_{MPP} – maximal power.

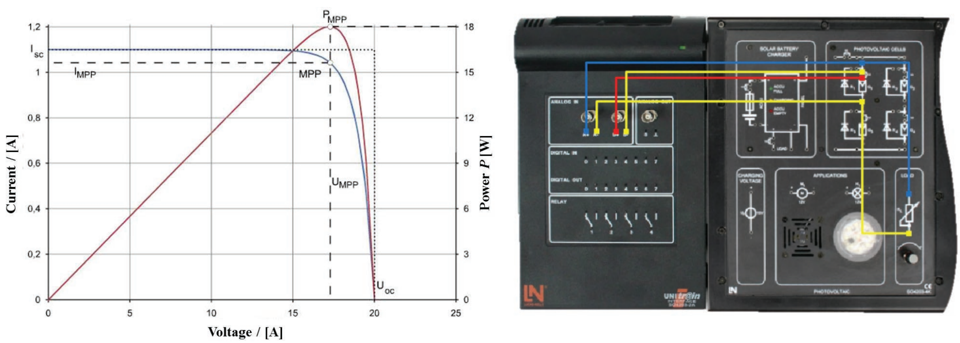

Figure 9.13. Recorded characteristics v-i characteristic (blue line), instantaneous power (red line) and connection to the operation board (right).
Source: Own contribution

With the didactic equipment procured, the training is carried out concerning the dependence of the PV module power output, intensity of the artificial source light and influence of the serial connection of the PV module on the parameters of v-i characteristics. The recorded v-i characteristics are shown in figure 8.14, with a fixed inclination angle of 90°, a light intensity of 1000 W/m^2 (left) and 500 W/m^2 (right). Figure 9.15 shows the *v-i* characteristics and the *v-p* characteristics for one PV module (left) and the PV string that consists of four modules connected to the series (right).

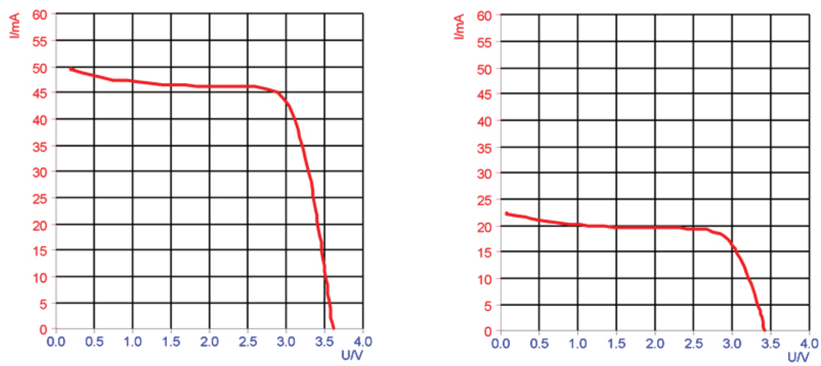

Figure 9.14. v-i characteristic for E_1=1000 W/m^2 (left), E_2=500 W/m^2 (right) on angle 90°.
Source: Own contribution

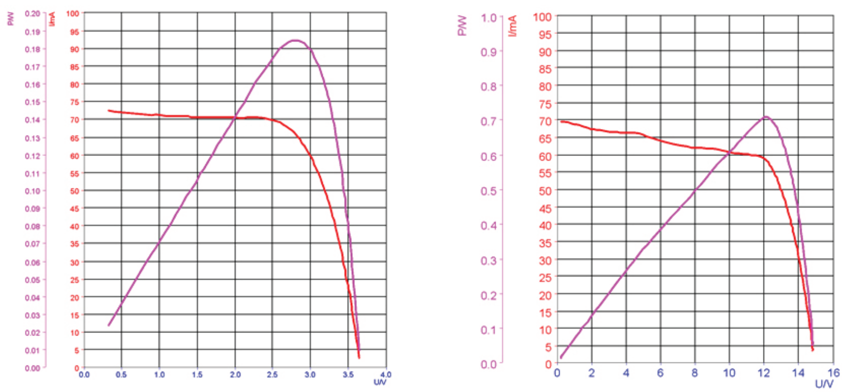

Figure 9.15. v-i characteristic (red), p-i characteristic (pink) for one module (left) and for 4 modules connected in series (right).
Source: Own contribution

A comparative analysis of the obtained characteristics, depending on the influencing parameters, involves the design of energy-efficient PV systems.

9.2.2 Didactic scalable system with fuel cells

Systems for the efficient use of additional energy forms have been intensively explored and developed over the last 20 years. In addition to RES, a fuel cell is one of the possible alternatives to electrical energy production and is also considered to be an environmentally friendly source of energy. Fuel cells are electrochemical energy converters that convert chemical energy directly to the electric and thermal energy without moving parts and combustion. According to their principle, fuel cells are similar to batteries but unlike them, fuel cells require a constant fuel and oxygen supply. Hydrogen, synthetic gas (a mixture of hydrogen and carbon dioxide), natural gas or methanol can be fuelled therefrom and the products of their reaction with oxygen are water, electricity and heat, whereby the whole process is actually contrary to the process of water electrolysis.

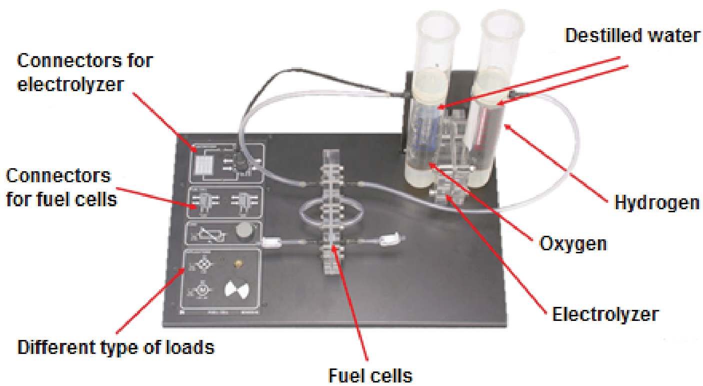

Figure 9.16. Didactic scalable equipment with fuel cells.
Source: Own contribution

Meanwhile, carbon dioxide has been confirmed as one of the main causes of global warming (Kyrill et al., 1998; Barr, 2007). Consequently, great efforts are being made to reduce carbon dioxide emissions. In everyday life, we are surrounded by technical devices and systems that inevitably emit carbon dioxide, for instance internal combustion engines, plants and factories, etc. Fuel cells can contribute to the reduction of carbon dioxide emissions with their good performances. The didactic equipment for learning about fuel cell characteristics is shown in Figure 9.16. The experiments which are suggested are related to recording i-p and i-v characteristics of fuel cells in the case of a single cell and a cell connected in a series in the so-called stack (connecting two cells in a series). The left-hand side of Figure 9.17 shows *i-v* characteristics (red) and i-p characteristic (blue) of one fuel cell. The way of connecting the equipment for recording *i-v* characteristics is shown on the right-hand side in Figure 9.17.

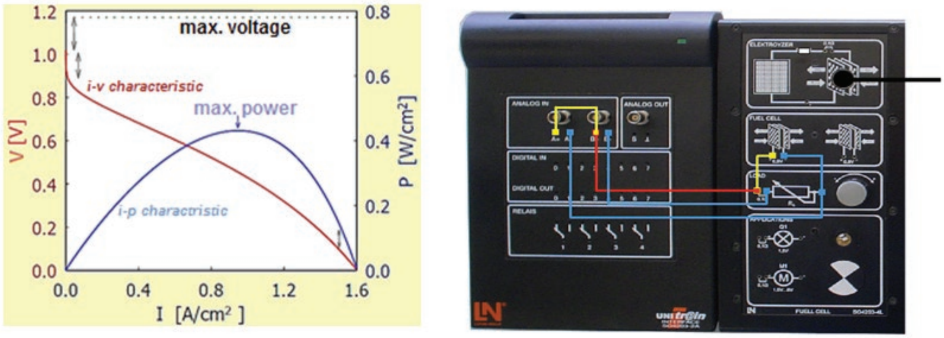

Figure 9.17. i-v (red) and i-p characteristic (blue) for one fuel cell (left) and connection on the operation board (right).
Source: Own contribution

The recorded characteristics for a single fuel cell and stack are shown in figure 9.18.

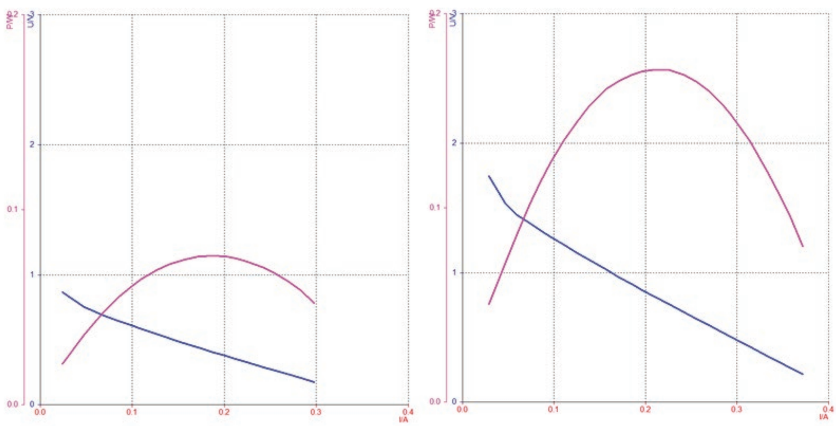

Figure 9.18. i-v characteristic (blue) and i-p characteristic (pink) one fuel cell (left) and characteristics for 2 fuel cells serial-connected (right).
Source: Own contribution

The analysis of the fuel cell characteristics contributes to the understanding of the fuel cell stack operation. Further, through the application of the didactic equipment, the necessary knowledge about the design of the fuel cell system is obtained.

Stationary fuel cell stacks are used as the main or emergency-standby sources of electrical and thermal energy of residential blocks and are also used as energy sources in areas where no grid is being built, such as spacecraft, hydrometeorological stations, rural settlements and specific military applications. The fuel cell and, more specifically, vehicle applications are being explored. Although there is no commercial model yet, more than 20 prototype hybrid vehicles, which use a combination of a classic engine with internal combustion and fuel cells as a drive mechanism as well as a power supply system, have been built since 2009. The limiting factor in car applications is the lack of hydrogen storage infrastructure. Hybrid cars showed 40-60% higher energy efficiency in the tests than internal combustion engine cars (Fuhs, 2008). As concepts of a power supply of small power electronics, so-called hydrogen batteries, small water tanks powered by portable electronic devices, laptops, mobile phones, small multimedia devices.

9.2.3 Power electronic converters for the connection of PV systems and fuel cell systems with AC loads

Inverters like power electronic converters are used for connecting DC and AC electrical systems. RESs, which are realized with devices such as PV modules and fuel cells, are acting as DC sources according to their voltage-current characteristics. Alternating systems in this connection are considered to be loads. Loads with larger power (> 2 kW) are normally designed in a three phase connection, and today, in all major industrial applications, asynchronous and synchronous electric machines dominate. For an energy efficient AC machine operation, the inverter should power the electric machine with the highest quality of voltage in terms of a harmonic content. The supplied voltage is determined by the states of the inverter switching components. The tendency is to control the inverter switching components in such a way that the significant harmonic of the voltage in the entire frequency range of the control is to be moved away as far as possible from the basic harmonic of the voltage, which is achieved by applying a pulse width modulation. The symbol for a three-phase inverter is shown in figure 9.19.

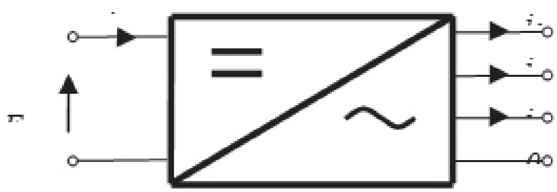

Figure 9.19. The symbol for a three-phase inverter.
Source: Own contribution

The purchased didactic equipment, along with the way of connecting power electronic converters with a low power motor, is shown in Figure 9.20. The didactic equipment consists of a total of 3 electronic cards, namely DC card (rectifier), AC card (inverter) and AC three-phase load. The three-phase rectifier here serves as a DC power source and replaces RES such as FN modules and/or fuel cells.

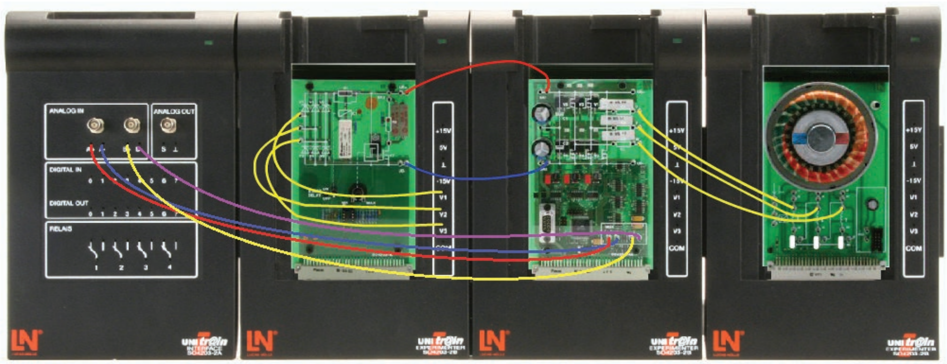

Figure 9.20. Way of connecting the didactic equipment subsystems.
Source: Own contribution

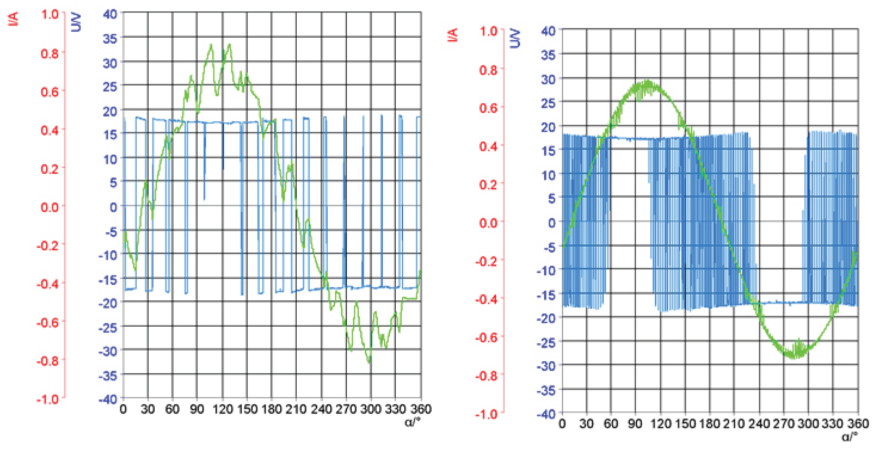

Figure 9.21. Phase voltage (blue) and current (green) waveforms for SPWM and switching frequency; fs=977Hz (left) and fs=7810Hz (right).
Source: Own contribution

With the acquired didactic equipment, experiments are proposed to record characteristic waveforms of current and voltage, i.e. waveforms of phase unfiltered and phase-filtered voltages as well as waveforms of one-phase current obtained at two different switching frequencies of a control drive and with different modulation techniques for control of MOSFETs inverter as given in Figure 9.21. The most commonly applied modulation technique, regarding the simplicity of control circuits design, is the Sine Pulse Width Modulation (SPWM). It is also recommended to carry out a harmonic analysis of the phase voltage as well as phase current as provided in figure 9.22. Performing a harmonic analysis is software embedded in the equipment through a virtual wave analyser and is very useful because the wave analyser is a measurement equipment that is very sensitive to work in terms of the need for selecting parameters for a periodic window to conduct a fast Fourier transformation based on a harmonic analysis.

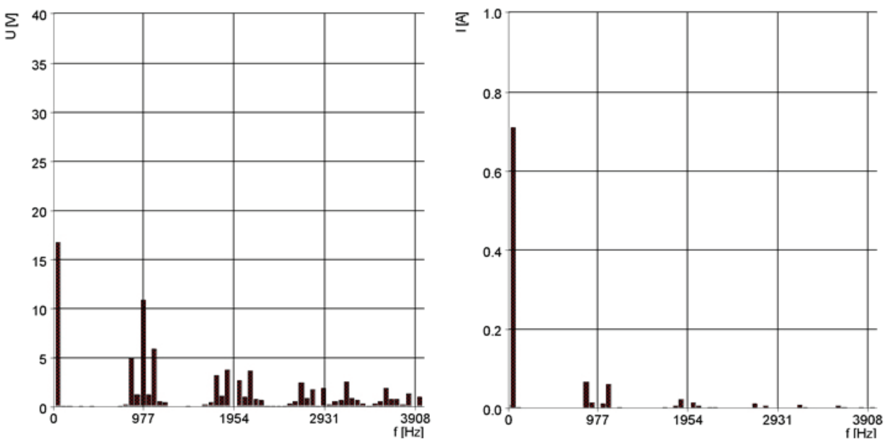

Figure 9.22. Harmonic analysis of phase voltage (left) and phase current (right) for SPWM and switching frequency; fs=977Hz.
Source: Own contribution

Knowing the harmonic content of phase currents and load phase voltage by using different modulation techniques as well as selected switching frequencies enables users to carry out experiments in such a way to acquire the basic knowledge in the field of energy efficient control of AC machines as well as supply AC loads form RES such as PV modules and fuel cells.

10 ASSESSING THE IMPACTS OF POTENTIAL INVESTMENTS IN RENEWABLES AND ENERGY EFFICIENCY

Viktor Varjú, Péter Póla, Danijel Topić, Réka Horeczki

This chapter is aiming to provide an overview about the impact that should be taken into consideration while policy makers or decision-makers are planning to increase the share of renewable energy use and energy efficiency. In this chapter – besides the new analysis – we are revisiting and evaluating the work that has been done in Pelin et al. (eds. 2014).

What we are aiming here is not a method or a tool to assess the potential impact of renewable energy use and energy efficiency but to give the reader a framework to further thinking what can be important in a rural, sometimes depressed area.

10.1 Theoretical frame for a sustainability assessment

As Gibson (2013) pointed out, the reason of sustainability assessment is quite obvious: what we are doing on Earth is wrecking the place (Gibson, 2013:3). Certainly, a sustainable assessment should not only take into consideration the negative effect but has to take on board the positive ones as well.

In his work, Gibson (2013) defined eight requirements for progress towards sustainability (Table 10.1) that can be a theoretical framework for sustainability assessment.

Table 10.1: Eight requirements for progress towards sustainability

Requirement	***Description***
Socio-ecological system integrity	Build human-ecological relations that establish and maintain the long-term integrity of socio-biophysical systems and protect the irreplaceable life support functions upon which human as well as ecological wellbeing depends.
Livelihood sufficiency and opportunity	Ensure that everyone and every community has enough for a decent life and opportunities to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity

Intragenerational equity	Ensure that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, etc.) between the rich and the poor.
Intergenerational equity	Favour present options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably.
Resource maintenance and efficiency	Provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste and cutting overall material and energy use per unit of benefit.
Socio-ecological civility and democratic governance	Build the capacity, motivation and habitual inclination of individuals, communities and other collective decision-making bodies to apply sustainability principles through more open and better informed deliberations, greater attention to fostering reciprocal awareness and collective responsibility, and more integrated use of administrative, market, customary, collective and personal decision-making practices.
Precaution and adaptation	Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, plan to learn, design for surprise and manage for adaption.
Immediate and long-term integration	Attempt to meet requirements for sustainability together as a set of interdependent parts, seeking mutually supportive benefits.

Source: Gibson et al. 2005: ch.5 in Gibson 2013: p.8.

In his cited work – besides referring (in its second requirement) to the classic sustainability definition provided by the Brundtland Committee (WCED 1987) – Gibson (2013) is focusing on the society (or sometimes socio-ecological system) as a core element of his theory. Taking into consideration the above mentioned framework in the forthcoming part we use the classical 3E (Equity, Economy, Environment) classification to take into consideration the different elements of the above mentioned principles of sustainability.

10.2 Social impacts

If social impacts of development projects are ignored (including positive and negative effects of a RES investment) the economic advantages often accrue only to a limited group of stakeholders leaving the wider impacts to be resolved by others (Balkau et al. 2017). Therefore, when considering the impacts of renewable energy utilization, it becomes inevitable to also pay substantive attention to the assessment of its wider social impacts, even if it is positive or negative. More particularly, it is essential to examine investments in renewable or solar energy, to assess how their communication affects a given social group and in what ways such communication affects renewable/solar energy-related decisions made by that given group. (Social framework conditions for solar energy investments have been delineated in an earlier piece of work entitled "Napenergia és környezet" (Varjú (ed.) 2014"), i.e., Solar Energy and Environment.)

Transitioning to a low carbon energy system will require action at multiple levels (Britton 2018). As has been formulated by Csizmadia (2008), "The existence, lack, number, composition, applicability and value of social relationships exert a fundamental influence on the every-day life of an individual or that of a community" (Csizmadia 2008, p.27), by which these factors have important implications for the spread of environmentally conscious patterns including also the advance of renewable/solar energy investments (in addition to the economic and other framework conditions (Varjú (ed.) 2014). Consequently, where there are intense social relationships (e.g. typically the interaction between small groups or between small communities), solar energy investments by individual actors more significantly affect other actors' decisions.

Britton (2018) argued that the importance of municipalities in the energy sector may in fact be increasing rather than waning (Britton 2018: p.378). In the RURES project we explored motivations in our empirical investigations into the relationship among municipalities, local governments. Here what we would like to know is how individual organizations influence each other through the dissemination and exchange of their good practices. The main trait of the aforementioned relationships is its ad hoc nature. In case any news comes into the possession of local governments, they may decide to make inquiries about it, local governments in charge of implementation provide information but here active/relationship networking effects, which are present in the above referred business sphere, cannot be identified.

Local governments have a relatively significant effect on inhabitants. The development of a settlement is highly dependent on the personal competence of decision-makers, settlement leaders or on the interest-based network of local actors. "In relatively large settlements, there is always a complex organizational base present in the background of personal dominant influence." "The smaller a village is, the more dependent its success is on a given local government, on the capabilities of the mayor and his/her ambitions." "The lower the level of development, the more decisive the role of the individual is." (Varjú, 2014).

We thought the rural dwellers – or who work there or who have daily interaction – are able to speak about the main problems and the development possibilities of the villages. The important local player (i.e. mayor) can determine the organization of rural population/rural society, whose attitude, qualification, decision and aspiration can influence the dweller's opinion (Ragadics 2010). For small villages the role and responsibility of the decision-makers is really important. The main characteristics of the rural society – especially in Baranya county – are the pessimism, the lack of motivation, the feeling of vulnerability and the self-care skills degradation (Bognár-Csizmady 2005). The population of the villages voted for the mayor, so we think s/he/ has the main local prestige, legitimacy.

One of the examples of a good practice where a local government took initiative about investments in renewable energy sources is Güssing town in Austria. According to (Tajmel, 2018) the district of Güssing was the poorest district in Austria with the following problems: small structured agriculture, bad traffic infrastructure, 45 years alongside the iron curtain, no industry, high rate of unemployment, 70% commuters and high rate of migration. To solve these problems, the following strategies were adapted: measures for increase of energy efficiency, energy generation from local renewable energy sources (biomass, solar energy), foundation of *Europäisches Zentrum für Erneuerbare Energie Güssing (EEE – European Centre for Renewable Energy Gussing) and foundation of Centre of technology.* The main idea of the previously mentioned strategies is a decentralized local energy production with the existing renewable resources of a region. *''The goal is to get independent from fossil energy in order to strengthen the regional added value! This strategy can be adapted individually wherever resources are available''* (Tajmel, 2018).

Since 1990 they started with the measures for increase of energy efficiency and beginning with production of heat out of biomass. From 2001 generation of the electricity from biomass and solar energy has been started. Beginning of the research and projects and foundation of new research institute started in 2008. Another good example is a district heating system of Güssing which started in 1996 and continuously develops heating grid (more than 35 km). Local inhabitants supply this system with their own biomass and part of the heating bill can be paid in biomass.

According to (Tajmel, 2018), in 2010 in Güssing total demand for the heating energy was 60 GWh, for electricity 50.2 GWh and for fuels 29 GWh, respectively. Total production in 2011 from local based renewable energy sources (4 biomass-district heating plants & 3 CHPs) was 72 GWh of heating energy which is 120 % of total demand in 2010. Production of electricity from local based renewable energy sources (3 CHPs and PV systems) was 100 GWh which is 200 % of total demand in 2010. In addition, in 2011 8.4 GWh of synthetic natural gas was produced which was 29 % of the total demand for fuels in 2010.

Summing up the above mentioned and using Pálvölgyi and colleagues' (2014) work, going through the set of criteria established by them (Pálvölgyi et al. 2014 p.191), based on our previous experience of and research into photovoltaic energy, we can assess the social impacts as follows:

Table: 10.2. Potential effects of PV use on the society

Designation of social indicator	Expected effect
Human health	Minimal effects (see detailed in life-cycle analysis)
Quality of life	Due to the sense of independence for the supply system, no or minimal effect
Education, qualification, knowledge	Positive effect, involvement of students into research tasks for the purpose of disseminating results
Public awareness, approach, presenting good examples	Positive
Mitigation of social disparities	Negative impact: Access to PV systems is possible mainly for wealthy people and savings resulting from the use of such systems also contribute to their cost-benefits, thus creating possibility for a further increase in social disparities
Enhancement of co-operation between social actors, strengthening cohesion	Positive impact: see e.g. outputs of current IPA
Prevention of migration (job creation)	Exerting no impact: job-creation effect of PV systems does not appear in a given region (see detailed in the chapter about regional impacts)
Energy poverty alleviation	Positive impact: renewable energy not exploited as yet becomes incorporated in the energy system

Source: Own edition based on indicators by Pálvölgyi et.al. (2014)

As in Pálvölgyi and colleagues' work can be seen, renewable energy has a positive effect on quality of life. Bailis (2011) further argued that energy plays a role in facilitating individual and collective well-being. The simple argumentation is that particular forms of energy are required for economic activity, and that such activity contributes to wealth (Bailis 2011). Continuing this perspective, those tools that can be used independently, especially making energy from renewable (and easily available) resources can especially help in poor rural areas. Such a tool can be a mobile phone charger using PV cells to create energy for charging (Figure 10.1).

Figure 10.1. Mobile phone charger with PV cells – promotional material for the project
Source: Photo made by the authors

The EU wants to promote the Smart Village scheme to provide resources for localities that do not have access, or have limited access, to infrastructure support.

The Smart Village programme aims to improve the quality of life of out-of-town settlements, mainly in the areas of the economy, education, energy management, digitization, mobility and health care, by promoting a high tech and social environment.

It is true that the smart village concept and practical examples have only one element in intensifying the use of renewable energy sources and turning to smart solutions in order to increase energy efficiency, but in the smart village programme the smart energy solutions take the biggest element. We think that the smart village programme's solutions can be very interesting for the RuRES project too, some useful solutions can be applicable, adaptable in the RuRES area.

The main question of energy management in the future is the way how we get to sustainability. There are two ways. Traditional solutions (low tech) and high tech approaches. There are several examples that show us that the technological solutions in themselves are not always useful, as they cannot be ignored by the human factor as well. See for example, the "Jevons paradox": the use of technical solutions does not occur with the expected degree of environmental impact reduction.

The concept of the smart village can be successful only if that the attitudes, and knowledge of the society develops considerably. This requires different programmes like RuRES.

10.3 Environmental impacts

The design of a power plant – regardless whether its resource is renewable or not – requires special emphasis to be placed on specific factors, such as the selection of the appropriate land used for the construction, the assessment of environmental impacts, e.g. landscape effects, visibility in terms of the local landscape and natural heritage, furthermore it becomes necessary to ensure that the local community can formulate its views on the installation of the intended power plant (Hartung 2014).

For property protection purposes a fence is installed around the boundary of the plot of land, which also has an impact on the environment, consequently attention should be paid to the height and tightness of the fence. Application of bright colours is unfeasible. In the connection to the network it is reasonable to take into account the visibility of high-voltage power lines and that of high-voltage poles (Hartung 2014).

In fact, there is evidence that the growth rate of atmospheric carbon dioxide is equal to the growth rate related to the burning and use of fossil fuels, which has reached high levels ever since industrialization. Due to the large-scale rainforest deforestation started in 1970, atmospheric carbon dioxide concentration continues to rise to a great extent (Canadell et al., 2007, Le Quéré et al., 2009). In the use of renewable energy, minimal or no carbon dioxide emissions can be expected. The widespread use of these technologies may mitigate escalation tendencies in carbon emissions (Hartung 2014).

10.4 Economic impact

No matter whether they supply households and/or business undertakings with energy complementary in nature or, by being in possession of business firms, they produce energy for sale, renewable energy systems (RES) are seen as important local energy sources and as such they can exert positive impact on the development of a specific region. Deployment of such systems and/or RES investments can take place in urban regions alongside motorways and in underdeveloped, peripheral rural regions.

Although the commissioning of such systems also in urban regions (and in developed rural regions or in areas having the potential to develop) can be justified, in certain aspects, innovative developments in economically backward rural areas have relatively higher marginal utility. In resource-deficient rural regions, any (sustainable) developments, with special regard to investments of innovative nature, are of utmost significance, even though their job-creation capabilities are negligible. On the basis of urbanity and rurality, no difference can be revealed with regard to the currently available amounts of alternative energy including that of solar energy. Rural development must focus on the development of self-sufficiency in rural regions, an essential component of which is to accentuate the role of alternative energy production. There is a strong correlation between rural development and decentralized energy production. Decentralized energy production implies the use of local raw materials, local labour force and local investments and according to many, building a (green) country starts with villages.

In terms of energy utilization efficiency, the worst situation is to be found particularly in rural regions. It is an issue of great importance to supersede the approach to thinking solely in the context of large-scale supply systems. Instead, it is essential to create balance between small-scale power plants and large-scale supply systems. One aspect of the above balance is represented by the commissioning of RES, i.e. the emergence of local power stations in rural areas. Energy rationalization, while safeguarding environmental sustainability, also ensures sustainable economic development, therefore RES can certainly be regarded as developments congruent with community interests.

An outstandingly important aspect to be taken into account in relation with rural developments is to ensure that the deployment of RES should not result in land-use restrictions. In this context, a favourable situation is created by the fact that photovoltaic energy production can be combined with several other production methods (soil strength reinforcement, recultivation, pasturing, apiculture, viticulture, horticulture, etc.). The demand for land brought into use by investments may as well reach high levels but owing to the aforementioned particularity, such high demand does not pose any barriers to investments and in view of the rapid pace of innovations, the future is likely to see a significant decrease in specific land-use demand. It may be important to place special emphasis on the conscious design of RES sites where secondary land-use is also taken into account.

A solar RES established in a region is likely to offer opportunities to local businesses: an innovative environment may promote developments, ideally, synergy effects and positive externalities occur, entrepreneurial mindsets and entrepreneurial culture may develop in the neighbourhood of a successful and innovative business undertaking, and by all this, it indirectly creates potential for labour market recovery.

In parallel with opportunities, there are a number of problems to work on. Economic sustainability of local governments seems to be unstable, while at the same time settlements pay particular attention to local economic development (Mezei, 2008). Elements of sustainability do not carry equal weight in the task-orientation concepts of local governments. In the context of regional development, energy production-related projects may typically become successful if they are viewed as elements constituting a part of a well-designed complex system of development and if no short-term high returns are expected. In view of the technology-intensity of innovative industries, also RES usually require only a low level of labour force participation while at the same time both the local governments and the national government's development policy often gives preference to the support produced by major employers.

The spread of renewable energy sources, including also the expansion of RES, depends predominantly on the changes in the pattern of fossil fuel energy markets, therefore, the success of a RES site and its impact on a region pose serious external risks in the short to medium-term.

Another issue of concern is that members of local communities do not seem to be ready for the adaption of alternative and innovative solutions, thus, not only the shaping of public perception of RES but also the development of assistance schemes may become necessary. After the use of energy generated by RES has become common among local governments, entrepreneurs and local residents, at the time of constructions, business undertakings engaged in the execution of the relevant work processes will see a temporary upswing. Another problem is that the aforementioned businesses are not necessarily (typically not) local undertakings either.

11 CONCLUSION

Danijel Topić

RuRES project is a product of continuation of the cooperation among the project partners. First joint cooperation among three project partners started in 2010 within the project UNIREG-IMPULSE which was co-financed in frame of Hungary-Croatia IPA Cross-border Programme 2007 – 2013. Cooperation between FERIT and MTA KRTK was continued through the REGPHOSYS project financed within the Hungary-Croatia IPA II Cross-border Programme 2007–2013 which has general objective to develop optimal photovoltaic system configuration for climate conditions of cross-border region and investigation of influence of photovoltaic systems on power system, economy and environment.

There are three overall objectives of the project: development of a typical renewable energy system for energy supply in rural areas; set of recommendations for improvement of energy efficiency and waste management in the rural area and investigation of economic, social and environmental impacts of renewable energy source and energy efficiency in the rural area of the cross-border region. A short-term perspective is dissemination of information about renewable energy sources, energy efficiency and waste management in rural areas of the cross-border region. A long-term perspective is an increase in renewable energy sources usage, improvement of energy efficiency, improvement of sustainable waste management and reduction of fossil fuels usage, CO2 emissions and energy cost. Specific objectives are expansion of cross-border innovation and a research network, development of typical renewable energy systems for energy supply in rural areas for specific conditions and co-operation between institutions involved in the project.

RuRES project officially started on September 1st 2017, while practically started on September 20th 2017 with the kick-off meeting which was held in Pecs. On project meeting plans and responsibilities among the partners are defined in order to successfully implement the project. First activity in project realization was study visit to the Gussing (Austria). Gussing is community which own energy needs covers from locally available renewable energy sources. Goal of study visit was to see examples of good practice I usage of locally available renewable energy sources and gain experience which will be used for cross-border area of Croatia and Hungary. Beside the study visit to Gussing, part of RuRES project memebrs was in study visit to Koprivnica where they saw examples of good practice in the field of energy efficiency.

During the whole period of the project, project team members regularly held project meetings. On project meetings achieved results were presented and plans for realization of future project activities were defined. During the project period totally six project meetings were held. Each project partner had organized two project meeting. Through the RuRES project, team members collected relevant literature in the field of renewable energy sources and energy efficiency. Data about potential of renewable energy sources in cross-border area of Croatia and Hungary were collected.

Through the RuRES project, FERIT purchased valuable research and demonstration equipment which was used for research purposes of the project but it will be used and in the future scientific researches. This equipment was used for research on which results scientific papers were written. Equipment was used for workshops and trainings organized in the frame of project as well.

During the project period three workshops were organized. Through the workshops basic characteristics of renewable energy sources and energy efficiency and examples of good practice to local stakeholders were presented. Each project partner has organized one workshop. In addition, each partner organized one two-day long training for local stakeholders about renewable energy sources and energy efficiency in the function of rural development. Workshop and training participants gained new knowledge about renewable energy sources and increased their own competences in the field of renewable energy sources and energy efficiency. Examples of good practice in usage of renewable energy sources and application of energy efficiency to participants are presented.

Based on research conducted within the project scientific papers which were published on international scientific conferences and in international journals are written. In purpose of project dissemination purposes and promotion of renewable energy sources usage lectures and round tables were organized. At the 9th International Natural Gas, Heat and Water Conference (PLIN2018) held in Osijek round table titled Renewable energy sources and energy efficiency in the function of rural development was organized. On the round table project RuRES and research results to conference participants were presented. At the international conference Smart Systems and Technologies 2018 (SST2018) held in Osijek round table titled Smart Energy in Rural Areas was organized. Through the round table Smart Energy in Rural Areas project RuRES to the conference participants was presented. Members of project teams participated and presented papers at the following international conferences: Socio-economic, environmental and regional aspects of a circular economy conference held in Pecs, 9th International Natural Gas, Heat and Water Conference (PLIN2018) held in Osijek, Smart Systems and Technologies 2018 (SST2018) held in Osijek and 11th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MEDPOWER2018) held in Cavtat; Annual

Conference of the Hungarian Regional Science Association - Flows in spatial economy held in Kecskemét, 2018.

As a one of the main outputs of the project is this three-language book which summarize main project results. In the Introduction project background and main goals and challenges were described. In second chapter geographic description of research cross-border area was presented. Third chapter describes results of conducted survey and research among local people in rural areas of cross-border region about attitude and acceptability of renewable energy sources and energy efficiency. Investigation on influence of renewable energy sources on multi-functional rural economies and rural development strategies was described in fourth chapter. Potential of renewable energy sources in cross-border are and model which helps local stakeholders in decision on investments in renewable energy sources for power and heat generation was presented in chapter five. Detailed description of technologies for utilization renewable energy sources for power and heat generation was presented in sixth chapter. Set of recommendation for improvement of energy efficiency in cross-border area in seventh chapter are described, while concepts of application of renewable energy sources in rural areas in eight chapter are described. In ninth chapter examples of good practice are described, in tenth chapter developed is described, while in eleventh chapter results of investigation of influence of potential investments in renewable energy sources and energy efficiency on rural development are described.

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13 CONTRIBUTORS

Dóra BÁLINT (Geographer) is a junior research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). In her research she focuses on the spatial and socio-economic effects of Infomation and Communication Technologies such as sharing economy, online platforms http://rkk.hu/hu/dti/cvs/balint_dora.html.

Ákos BODOR is a sociologist and research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). His research fields are social capital, social values, trust and social inequalities. E-mail: bodor@rkk.hu

Dario DOŠEN is a senior laboratory technician at the Department of Software Engineering, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek.

Krešimir Fekete received Ph.D degree in electrical engineering in 2013 from the University of J.J. Strossmayera Osijek, Croatia. He is assistant professor at the Department of Power System Engineering, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek. His research area includes power system analysis, electricity market, power system economics, integration of renewable energy sources, smart grids and microgrids. E-mail: kresimir.fekete@ferit.hr

Valéria FONYÓDI is a cartographer at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en) dealing with figure editing as well.

Zoltán Hajdú (Doctor of Sciences) is a geographer, historian teacher, professor, scientific advisor at the at Transdanubian Research Department of IRS CERS HAS. His main research topics are the history-geographical analysis of the Balkan countries and he is also the leader of the Institute's Border Research Group. E-mail: hajdu@rkk.hu; CV: http://www.rkk.hu/en/cvs/hajdu_zoltan.html

Réka HORECZKI (Economist, PhD aspirant) is a junior research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). Her research activities are focused to present the long-term developmental laws and characteristic features that heavily influence the economic, social and political life of the small town and the possibilities of measuring social capital in the rural areas. E-mail: horeczki@rkk.hu; CV: http://www.rkk.hu/en/cvs/horeczki_reka.html

Bernadett HORVÁTHNÉ KOVÁCS: works at Kaposvár University Faculty of Economic Science as associate professor. She works with Hungarian and international students in the field of statistics and regional analysis. Her research area is spatial patterns of social-economic-environmental indicators. E-mail: Kovacs.Bernadett@ke.hu

Zvonimir KLAIĆ is associate professor, head of Laboratory for Electromagnetic Compatibility (https://www.ferit.unios.hr/fakultet/imenik-djelatnika/klaic#anc) at the Department for Power Engineering of Faculty of Electrical Engineering, Computer Science and Information Technology Osijek. Scientific research fields: power quality, smart grid, lighting efficiency. E-mail: zvonimir.klaic@ferit.hr

Goran Knežević received Ph.D degree in electrical engineering in 2013 from the University of J.J. Strossmayera Osijek, Croatia. He is assistant professor at the Department of Power System Engineering, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek. His research area includes power system analysis, electricity market, power system economics. E-mail: goran.knezevic@ferit.hr

Sándor Zsolt KOVÁCS is economist and junior research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). His research fields are the different factors of local and regional development and he has more statistical and mathematical skills for economic modelling. E-mail:skovacs@rkk.hu; CV: http://www.rkk.hu/hu/cvs/kovacs_sandor.html

Cecília MEZEI (PhD of regional sciences) is a research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). Her main research areas are the local economic development theories and practice, the modelling of local resource based development potentials and the adaptive waste management solutions. E-mail: mezeic@rkk.hu; CV: http://www.rkk.hu/en/cvs/mezei_cecilia.html

Denis PELIN is a full professor, head of Chair Electric Machines and Power Electronics at the Department of Electromechanical Engineering at Faculty of Electrical

Engineering, Computer Science and Information Technology Osijek. Scientific research fields: nonlinear dynamics of power electronic systems, power electronic converters for RES. E-mail: dpelin@ferit.hr ; Web page: https://www.ferit.unios.hr/faculty/staff-directory/dpelin#anc

Péter PÓLA (PhD of economy) is a research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). His main research areas are rural development, institutionalization of regional interest, employment policy. E-mail: pola@rkk.hu; CV: http://www.rkk.hu/hu/cvs/pola_peter.html

Mario PRIMORAC B.Sc.E.E. is professional assistant of Laboratory for Renewable Energy Sources (http://www.etfos.unios.hr/reslab) and Laboratory for Electromagnetic Compatibility (http://www.etfos.unios.hr/?zavodi&Laboratorij-za-elektromagnetsku-kompatibilnost-ZEE) at the Department for Power Engineering of Faculty of Electrical Engineering Osijek. Scientific research fields: power quality, smart grid, renewable energy sources.

Damir ŠLJIVAC is a full professor at the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek. He is head of the Department for Power Engineering and head of Laboratory for Renewable Energy Sources (http://reslab.ferit.hr/). Scientific research fields: renewable energy sources, sustainable energy development, power system economics and reliability. E-mail: damir.sljivac@ferit.hr CV: http://www.etfos.unios.hr/reslab/tekst/en/7/SljivacCVenEuropass2014.pdf

Tamás SZABÓ is a cartographer and GIS expert He finished his study at University of Pécs, Faculty of Sciences, on geography major. His specialty is geographic information systems and their application in various research fields, building databases and implementations in map making. E-mail: szaboy200@gmail.com;

Alexander TITOV is a Ph.D student at the Kaposvar University from Russia. He got his MSc degree in Regional and Environmental Economics in 2016 at the Kaposvar University. Currently his research topic is the “Acceptance and potential of renewable energy sources based on biomass in rural areas of Hungary”. E-mail: alexander.titov62@gmail.com

Matej ŽNIDAREC received MEng degree in power engineering in 2016 from the Faculty of Electrical Engineering, Computer Science and Information Technology Osijek. Currently he is a P.hD student and works as an assistant at the Department of Power Engineering. His scientific research fields are: renewable energy sources, smart and microgrids.

Danijel TOPIĆ received Ph.D degree in electrical engineering in 2014 from the University of J.J. Strossmayera Osijek, Croatia. He an assistant professor at the Department of Power System Engineering, Faculty of Electrical Engineering, Computer Science and Information Technology in Osijek and he is head of Chair for Power plants and Energy Processes. His research activities include renewable energy sources, power generation, energy efficiency and power system reliability. E-mail: danijel.topic@ferit.hr

Viktor VARJÚ (PhD of geography) is a senior research fellow at Transdanubian Research Department of IRS CERS HAS (www.rkk.hu/en). His main research areas are social aspects of regional development, renewable energy and environmental issues and environmental sociology. He is also awarded by Bolyai János Research Scholarship, 2016-2019. E-mail: varju@rkk.hu; CV: http://www.rkk.hu/en/cvs/varju_viktor.html