

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

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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 Office⁴, from its territorial statistical module⁵ 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, TeIR⁶ (Országos Területfejlesztési és Területrendezési Információs Rendszer) managed by Lechner Knowledge Centre⁷, 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 indicators⁸ 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 partnership¹⁰. The EU directive concerning the sector¹¹, 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/m². 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/m² or J/m²/s, calculated in total amount of energy: MJ/m²/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/m². 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.

RENEWABLE ENERGY SOURCES AND ENERGY EFFICIENCY FOR RURAL AREAS

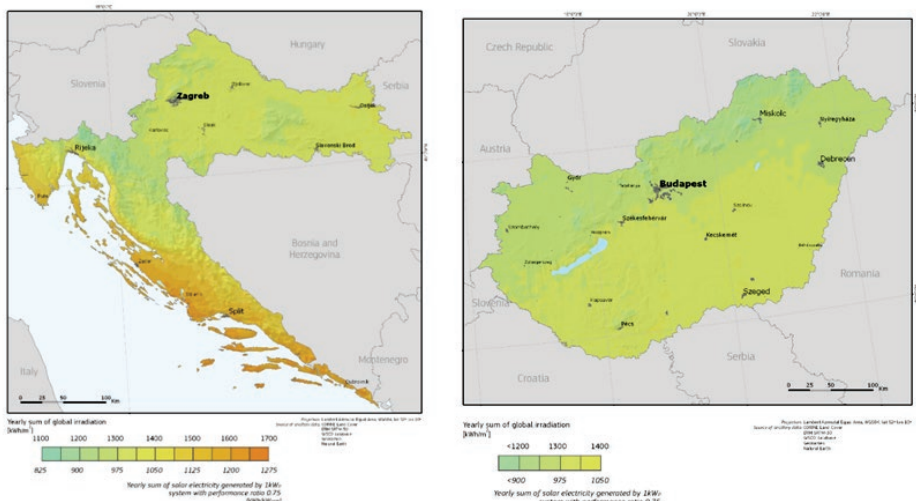


Figure 5.1. Annual solar irradiation in Croatia and Hungary
Source: PV GIS, 2018.

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)		
	Global	Direct	Diffuse	Global	Direct	Diffuse	Global	Direct	Diffuse
Month	kWh/m ² /day			kWh/m ² /day			kWh/m ² /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/m²) 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. On the basis of the results of our model, the irradiation value of the settlement is 1,526 kWh/m², which is slightly above the project average (1,522.53 kWh/m²) and significantly exceeds the national average (1,481.1 kWh/m²), 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 m² 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 do 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 originates 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.

$$BP = m \cdot oST \cdot p \cdot k \text{ [kWh/god]}$$

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 [$\text{m}^3/\text{t oST}$]

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 m³/t (of dry matter), by pigs 500 m³/t, by poultry 400 m³/t. Methane content is 62.5% on the average at all three types of manure in our calculations. Accordingly, 1 m³ 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).

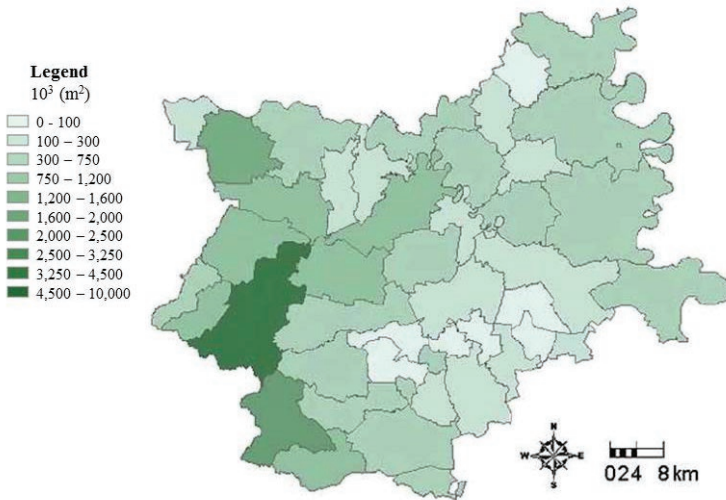


Figure 5.2. Distribution of wood stock in Osijek-Baranja County.
 Source: Food and Agriculture Organization of the United Nations, 2009.

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 [m ³]	Total annual increment [m ³]	Annual energy potential of wood biomass (including conifers) [m ³]		Theoretical annual energy potential of wood biomass (including conifers)			
				Planned cutting		Performed cutting	
		Planned cutting	Performed cutting	GWh	TJ	GWh	TJ
22,291,528	758,143	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 forests¹², 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 originate 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 m³, from which 17 MJ/m³ 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 what 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/m² as illustrated in Figure 5.3.

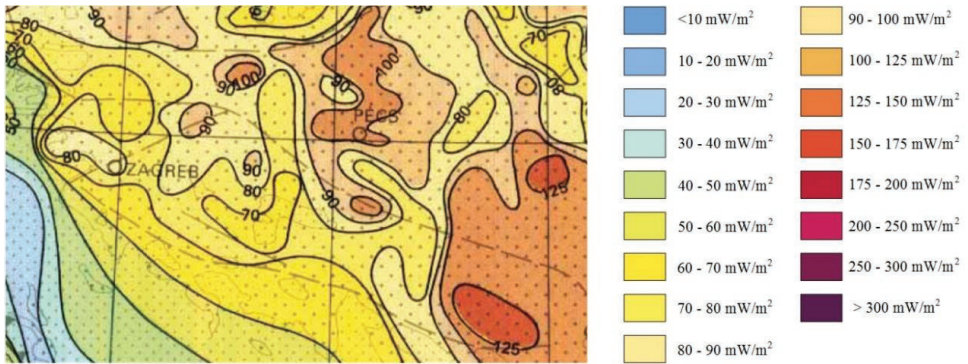


Figure 5.3. Thermal flux density in the former Pannonia sea area
 Source: Oktatási Hivatal, 2018; Potencijal obnovljivih izvora energije u Osječko-baranjskoj županiji, 2013.

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.

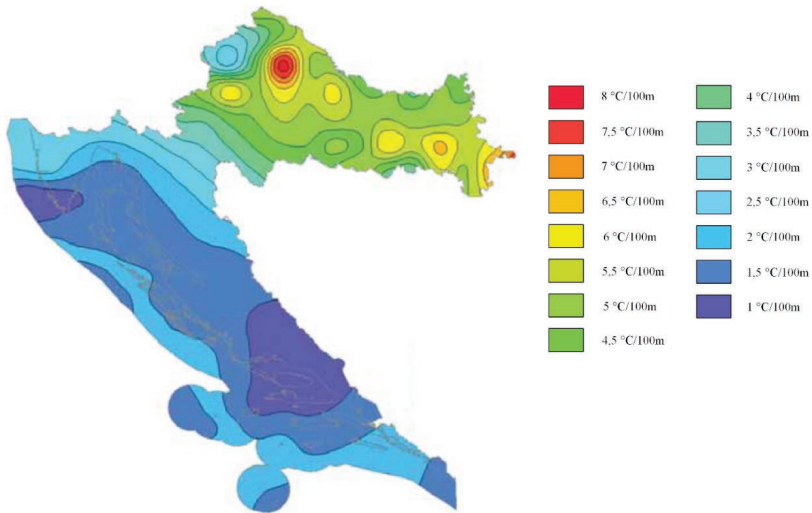


Figure 5.4. Temperature gradient of soil in Croatia
 Source: Jelić, Kevrić & Krasić, 1995.

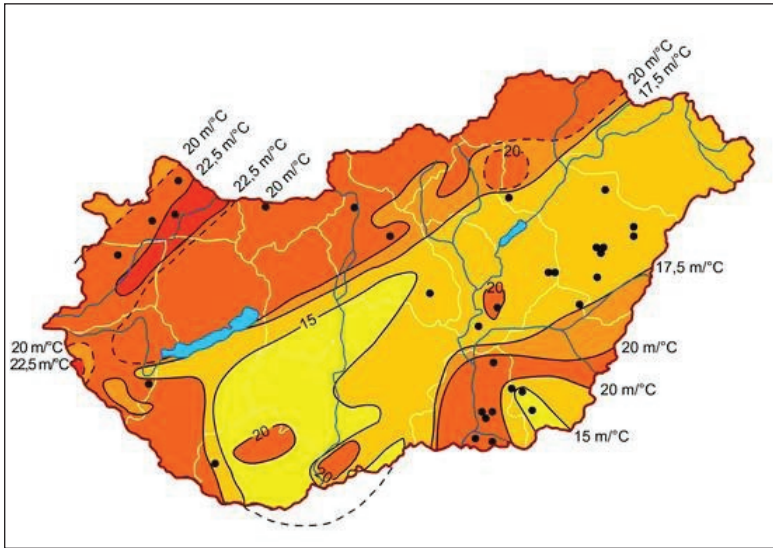


Figure 5.5. Temperature gradient of soil in Hungary
Source: Oktatási Hivatal, 2018.

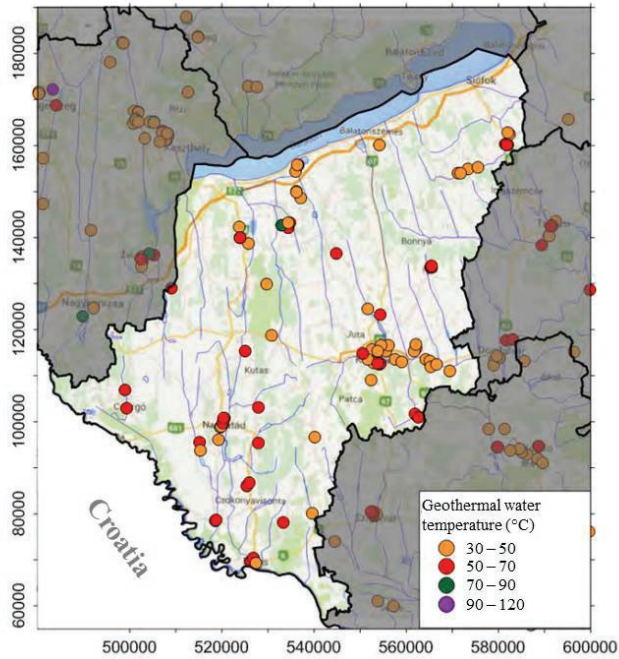


Figure 5.6. Geothermal water sources in Somogy county in Hungary
Source: MEKH, 2016.

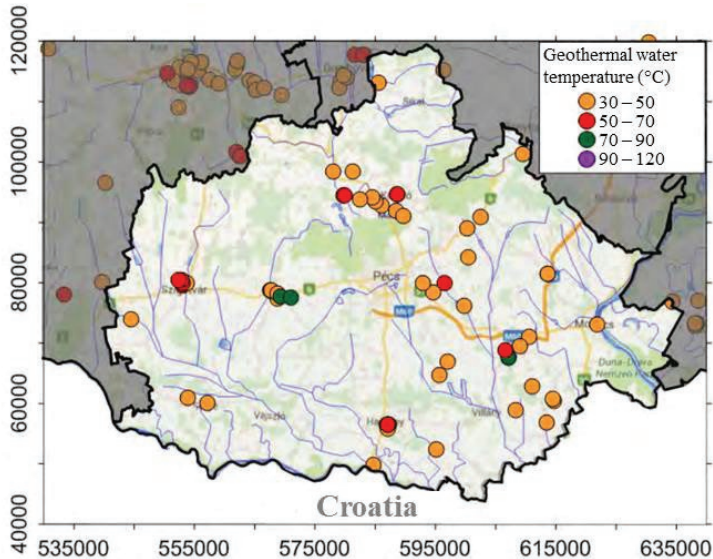


Figure 5.7. Geothermal water sources in Somogy county in Hungary
Source: MEKH, 2016.

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.