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Made in Danube

Transnational Cooperation to transform knowledge into marketable products and services for the Danubian sustainable society of tomorrow

Deliverable

Local Action Plan for Biofuels

Due date of deliverable: 31/12/2017 **Actual submission date: 29/12/2017**

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1 Content

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List of Abbreviations

AF	Application Form
AN	Activity Number
BC	Black carbon
BOKU	University of Natural Resources and Life Sciences, Vienna
CA	Co-operation agreements
CHP	Combined Heat and Power
CIP	Continuous Improvement Process
CO	Carbon monoxide
DLUC	Direct Land Use Change
EDGAR	Emissions Database for Global Atmospherics Research
FAME	Fatty Acids Methyl Esters
GFEC	Gross final energy consumption
GHG	Greenhouse gases
ILUC	Indirect Land Use Change
IIH	Innovation Information Hub
IPA	Innovation partnership agreement
JRC	Joint Research Centre
ktoe	Kilo Tons of Oil Equivalent
LAP	Local action plan
LCA	Life cycle assessment
LCB	Lignocellulosic bioethanol
LVP	Limit values of pollutants
MiD	Made in Danube
Mtoe	Million Tons of Oil Equivalent
PM	Particulate matter
RED	Renewable Energies Directive
RES	Renewable Energy Sources
SME	Small and Medium Enterprises
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
WP	Work Package

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2 Executive Summary

This local action plan is one of the deliverables in the project “Made in Danube”, part of the Interreg Danube Transnational Programme. Goal of the project is to improve framework conditions for the cooperation of SMEs and research organisations (RTO) in order to develop marketable products and services in the Danube region.

The European Commission’s Joint Research Centre has identified bio-economy as an innovation-driven part of society, which could have positive impact on many other areas too. In specific forestry, sustainable agriculture and bioenergy were identified as priority areas. This is why the “Made in Danube Project” chose, in each of these priority areas, one local initiative as pilot action. They should serve as test areas and develop into innovation hubs, generating know-how that can be transferred to other parts of the Danube region too.

Novi Sad in Serbia was chosen as one of the pilot action areas because the local Faculty of Technical Sciences has in depth know-how in renewable resources, “particularly solid biomass and specially biomass from agriculture, within the field of agricultural engineering and sustainable rural development” (read the full profile of the Faculty of Technical Sciences in the MiD Application Form, p. 35).

At the beginning of the document the terms “biomass” and “biofuels” are defined and a short introduction to the project “Made in Danube” is given. Then, the project context with its relevant EU regulations is presented: One of them being the “EU Strategy for the Danube Region” (EUSDR), which encourages more sustainable energy production. Biofuels belong to the group of renewable energy sources, therefore the EU’s Renewables Energy Directive (RED) is applicable here too.

According to RED and related proposals, a set of sustainability criteria, such as values for greenhouse gases emissions savings, are defined. The most relevant criteria for biofuels are listed in this document. Another sustainability criterion cited here is, that the feedstock for biofuels production should neither be food nor feed. Only then they can be classified as “Second Generation of Biofuels”. The usage of waste and by products, such as crop residues, for biofuels production, fall into this category. The initiative in Novi Sad puts a special focus on them.

One of the negative environmental aspects of biofuels is the airborne pollution occurred when biomass is combusted. This is especially true for small appliances in the residential heating sector and has to be included in the overall judgment of such solutions.

In chapter 3.4. background information on the local initiative in Novi Sad is presented. First, a short overview of the energy policy in Serbia is given. Second, the potentials of renewable energy sources in Serbia are put forward: Following the National RES plan, biomass represents the biggest potential, with crop residues being the biggest part of it. However, when planning to use crop residues for energy purposes, the topic of soil fertility and the impact of crop residues off-take on it, has to be discussed and included in the computation of the potential.

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Approximately 40 to 45% of gross final energy consumption (GFEC) of renewables in Serbia are needed by the sector heating&cooling - electricity and transport represent a smaller share. Almost 95% of the RES needed for heating&cooling can be attributed to households, most of them found in the sector small residential heating.

Availability of crop residues for energy production differs largely between small and big farms: While on big farms residues are already utilized, the unused potential can be found in the group of S&M sized farms. In Serbia, most of the arable land is in the hand of S&M.

Looking at the different types of crop residues (Table 3) and their potential for future use, research shows that most of the corn cops are already used, while corn stover represents the biggest unused potential as feedstock for LCB and biogas production.

One of the possibilities to use crop residues is to burn them. Depending on the type of crop they have different combustion characteristics. Using them in small appliances the emission of pollutants is generally to high, when stricter regulations (such as common in Germany, Austria,….) are applied. Alternative ways of using crop residues would be the combustion in CHP units, or using residues for co-firing or as co-substrate for biogas.

In chapter 3.4.3 Usage of crop residues– the effects of residue offtake on the soil fertility and on erosion prevention is discussed. A general conclusion is that a sustainable management of corn stover offtake should be provided, while there is no prescribed method for calculating the amount of crop residues that can be collected as the topic is very complex, having numerous influencing factors. Further research will be needed in order to make valid recommendations.

Before using the relevant parts of the corn plant, the appropriate harvest methods needs to be applied. The available methods and therefore listed, and indicated which of them are efficient and profitable and which are best suited for the purpose. The different method's drawbacks and unsolved problems are addressed here too. Another question discussed is the storage of the raw materials and the use of corncobs for residential heating purposes. The topic of agricultural biogas production and its potential is put forward by presenting the results of relevant studies.

The whole local action plan is based on a so-called "continuous improvement process" consisting of the following phases: 1.) planning of tasks, 2.) implementation of tasks and 3.) reflection on results. Furthermore, it is foreseen that a peer consultation takes place. The resulting feedback should support the last step 4.) adaptation of tasks. By introducing the "continuous improvement process", a continuous cycle of "tasks definition-implementation-adaptation" is introduced in order to lead to improved results.

The task list for the local initiative comprises, among others, steps of analysis, measures in the fields of harvesting corn stover, planned performance improvements for small biomass appliances for residential heating and small biogas plants.

A central role plays the idea of rolling out the concept of corn as a substrate for biofuels on a regional, even European level and to increase cooperation between players, building a network which should comprise farmers, producers of technical appliances and research institution in the field, fostering innovative solutions for the future.

In chapter 6.4. a supporting tool for the Local Action Plan is presented: The TIN eTool is developed within the “Made in Danube Project” in order to make available a platform for companies and research institutions where technology offers are posted and cooperation partners can be found.

Conclusion and recommendations state how important is to create awareness about the significance of biofuels, their proper production and the necessary framework conditions for innovations needed in this area. To tap the full potential of corn- stover and corn cobs in Serbia and beyond is among the main targets of the initiative. Besides technical challenges have to be tackled especially in the field of residential heating appliances and agricultural biogas plants. Finding the partner to transform the scientific know-how available will be another important step toward marketable products in the form of biofuel production.

Target group of the plan is the local initiative, which should use it as a working instrument (introduction of continuous improvement process, task list). Apart from that, the local action plan plays an important role within the “Made in Danube” project: Together with the results of the questionnaire, it serves as basis for elaborating a roadmap related to improved framework conditions. Based on the roadmapping and the policy dialogue results a common strategy will be developed which has the goal to bring R&D results on the market. To relevant stakeholders in the region the LAP will serve as an information source, where they will find a concise overview of the initiative’s activities, it’s goals and it’s environment.

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3 Introduction

As an introduction to the Local Action Plan several relevant terms are introduced. Firstly the term "Biofuels" is explained, then the project "Made in Danube" is presented and finally the position of the European Union concerning "Biofuels" is described and relevant EU policies specified.

3.1 Definition of biofuels

The term biofuels used here is related to diverse fuels based on biomass, unprocessed and processed, used for all sectors, not only for transport (as commonly treated). The term biomass, concerning its use as a fuel, comprises three state of aggregation, state of matter:

1. Solid, like wood and crop residues in different forms.
2. Liquid, like biodiesel (FAME, fatty acids methyl esters) and bioethanol.
3. Gaseous, like biogas.

The term biofuels includes all three states, independent on their use. Biomass can be used for all three sectors:

1. Electricity generation, e.g. biogas, solid biomass power stations and CHP (combined heat and power) units.
2. Heating & cooling, boilers, stoves, cookers, typical solid biomass, but biogas as well.
3. Transport, typically liquid biomass, biodiesel, bioethanol, biomethane (upgraded biogas).

Biomass utilization as renewable energy source plays, nowadays, an important role within bioeconomy. Its utilization contributes indeed to the reduction of CO_2, and thus has positive effects related to climate change, i.e. global warming. This is in line with the well known intentions to reduce emissions of Greenhouse Gases (GHG) and replace fossil fuels with Renewable Energy Sources (RES).

3.2 Project "Made in Danube"

The project "Made in Danube"'s aim is to improve framework conditions for innovation in the Danube region. It focuses on the capabilities of the region's SMEs and the collaboration between research organisations and these companies.

Within the project 3 regional initiatives where chosen as pilot areas in order to develop innovation hubs in bio-economy in three different fields: sustainable forestry, smart agriculture and bioenergy.

3.3 Project context EU

The EU Strategy for the Danube Region (EUSDR) supports the Europe 2020 strategy by contributing to smart, sustainable and inclusive growth in the region, as laid out in the pillar „connecting the Danube Region". One of the strategy's priority areas is the encouragement of more sustainable energy. Among the efforts undertaken in this area is the increase of renewable energy.

Besides the European Commission's Joint Research Centre (JRC) has identified "Bioenergy" as one of the priorities for the Danube territory (MiD, 2016 p.1).

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The targets, on the European Union level, are defined in the so called RED (Renewable Energy Directive) Directive 2009/28/EC. Member states are, according to this Directive, obliged to follow targets, perform Action plans, and monitor their progress. In most of the countries, biomass was identified as energy source having the biggest potential, Figure 1.

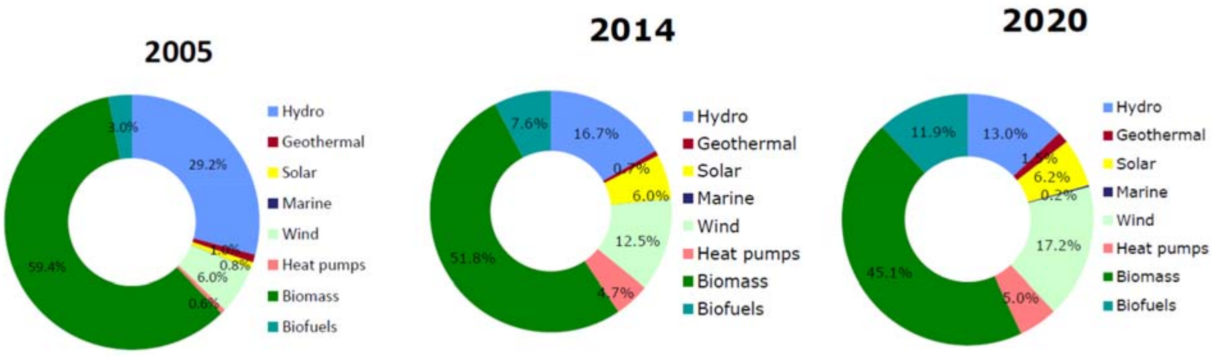

Figure 1: RES mix in European Union, from 62 Mtoe in 2005, 108 Mtoe in 2014 to 140 Mtoe in 2020 (Scarlat and Dallemand, 2017)

It was also identified that potential has different level. Theoretical potential has almost no importance. Technical potential is used for applicable amounts, and nowadays it is important to be sustainable. This means, that all environmental, economic, social and ethic aspects should be considered too.

Besides, more adequate technologies for biomass utilization as a fuel should be developed. Technological advancements in the field of biomass, biofuels, production and utilization are supported, followed and disseminated by the EU and in the region.

However, costs of energy play an important role as the profit represent the crucial motivation for investors. By this costs of production play a relevant role in the decision process of biofuels projects. Unfortunately, costs of biofuels are in many cases higher than those of fossil fuels and, in order to support their use, subsidies are needed. On the European and national level it is desirable to minimize financial burdens on society for this purpose. Research and development efforts showed positive results also in this regard, but new innovative solutions are sought. Figure 2 shows the comparison of costs of biomass energy on the current level of technology, which should be considered by policy makers as well.

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Figure 2: Levelized Cost of Energy for biomass technologies (Scarlat and Dallemand, 2017)

The Joint Research Center (JRC), institution of European Commission, tackled and is still working, on defining sustainable potentials for the EU in general. Currently there is a focus on doing so for macro regions.

As an example for biomass available for energy production in EU27, Figure 3 shows total crop residues.

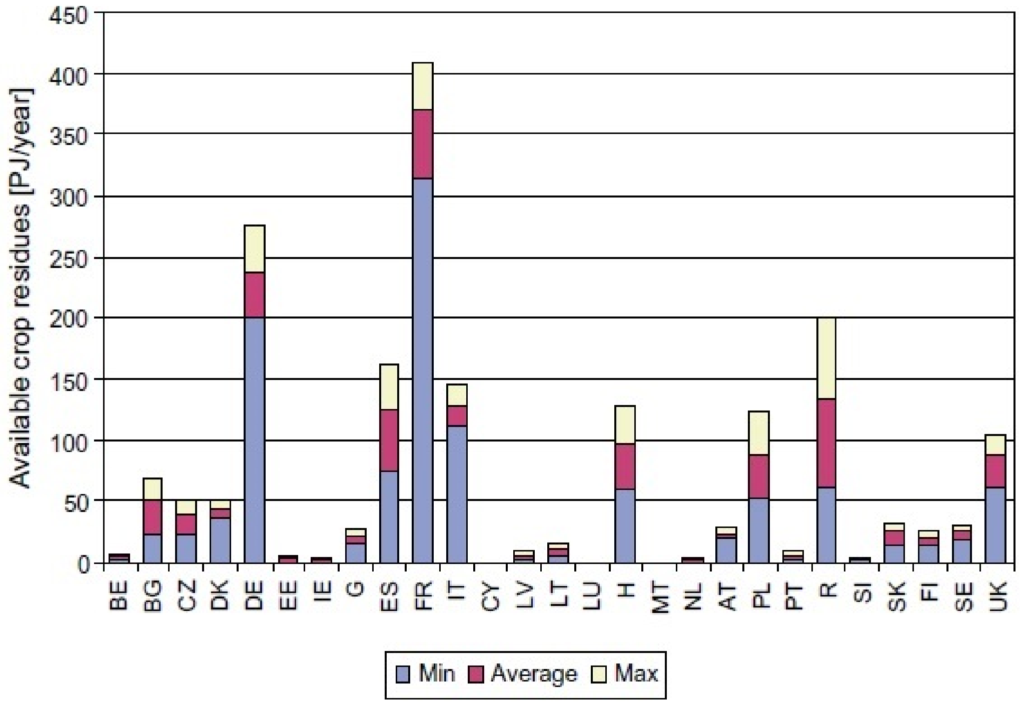

Figure 3: Total crop residues available for bioenergy production in EU 27 (Scarlat et al., 2010)

A overview map showing biomass potentials of European macro regions can be found in the publication of Scarlat (2017). According to this publication, utilization of biomass, i.e. biofuels as RES, plays an important role in the EU and the Danube Macro Region. Proper utilization could contribute to fulfilling energy targets defined by the European Commission.

3.3.1 Sustainability criteria

In the RED sustainability criteria for RES are introduced, including biofuels. First, and most significant, is to define RES according to their saving of GHG emissions. In article 17 has been stated (citations here only for biofuels and bioliquids):

> *The greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall be at least 35 %.*
>
> *With effect from 1 January 2017, the greenhouse gas emission saving from the use of biofuels and bioliquids taken into account for the purposes referred to in points (a), (b) and (c) of paragraph 1 shall be at least 50 %. From 1 January 2018 that greenhouse gas emission saving shall be at least 60 % for biofuels and bioliquids produced in installations in which production started on or after 1 January 2017.*

Here are emissions of GHG, expressed as CO_2 equivalent (considered should be CO_2, CH_4 and N_2O), and compared with fossil fuel comparator. This comparator is, nowadays, 93 g CO_{2eq}/MJ.

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The most important role of agriculture, which is logical, is to produce enough food for humans, globe wide. EU countries can produce or purchase enough food for all needs, but it is an ethical issue, to think about having enough food for all people. As reaction to this request, came the new directive (Directive 2015/1513) which has tackled this problem, expressed as "Direct and Indirect Land Use Change" (DLUC, ILUC). Its impact is expressed by adding GHG emissions in cases of utilization of food as feedstock for fuel generation.

For example, in the case of utilization of plant oil for fuel generation, 55 g CO_{2eq}/MJ have to be added (taking a mean value, range is 33 to 66 g CO_{2eq}/MJ). By this intervention the construction of new plants for production for the most significant liquid biofuels for transport, biodiesel and bioethanol is eliminated.

New EU documents include proposals for a Renewable Energy Directive RED upgrading (Anonymous 2016a[1] and 2016b[2]). In the new RED an introduction of sustainability criteria for all other biofuels is foreseen. Related to GHG emissions savings in Article 26 is specified:

> *7. The greenhouse gas emission saving from the use of biofuels, bioliquids and biomass fuels taken into account for the purposes referred to in paragraph 1 shall be:*
> *(a) at least 50 % for biofuels and bioliquids produced in installations in operation on or before 5 October 2015;*
> *(b) at least 60 % for biofuels and bioliquids produced in installations starting operation from 5 October 2015;*
> *(c) at least 70 % for biofuels and bioliquids produced in installations starting operation after 1 January 2021;*
> *(d) at least 80 % for electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021 and 85% for installations starting operation after 1 January 2026.*

Furthermore, values of fossil fuels used as comparators are defined:

> *For biofuels, for the purposes of the calculation referred to in point 3, the fossil fuel comparator E F(t) shall be 94 gCO_{2eq}/MJ.*
> *For bioliquids used for electricity production, for the purposes of the calculation referred to in point 3, the fossil fuel comparator EF shall be 183 gCO_{2eq}/MJ.*
> *For bioliquids used for the production of useful heat, as well as for the production of heating*

[1] Proposal for Directive of the EU Parliament and Council on the promotion of the use of energy from renewable sources

[2] Annexes to the Proposal for Directive of the EU Parliament and Council on the promotion of the use of energy from renewable sources

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and/or cooling for the purposes of the calculation referred to in point 3, the fossil fuel comparator EF(h&c) shall be 80 gCO_{2eq}/MJ.

and as a special case, coal replacement:

For biomass fuels used for useful heat production, in which a direct physical substitution of coal can be demonstrated, for the purposes of the calculation referred to in point 3, the fossil fuel comparator ECF(h) shall be 124 gCO_{2eq}/MJ heat.

It seems now, that only biomethane, upgraded biogas (in case that biogas production fulfils sustainability criteria), and lignocellulosic bioethanol – LCB (feedstock are lignocellulosic wastes and by-products, e.g. crop residues), can be treated as renewable energy biofuels for transport. These belong to the, so called, **Second Generation of Biofuels**, as mentioned in the Directive 2015/1513, and are biofuels for which production is not used food or feed. According to the same source, their share is calculated double for replacement of fossil fuels for transport.

As for example for biomethane, if the dominant substrate for biogas production are energy crops, typical corn silage, cf. Figure 4, the previously mentioned criteria cannot be fulfilled. This would be, for sure, if future biogas plants have substrate situations like in Austria, Germany and Latvia. In the case of utilization of manure, GHG emissions are calculated as negative, –45 CO_{2eq}/MJ, due to prevention of methane emission by such process.

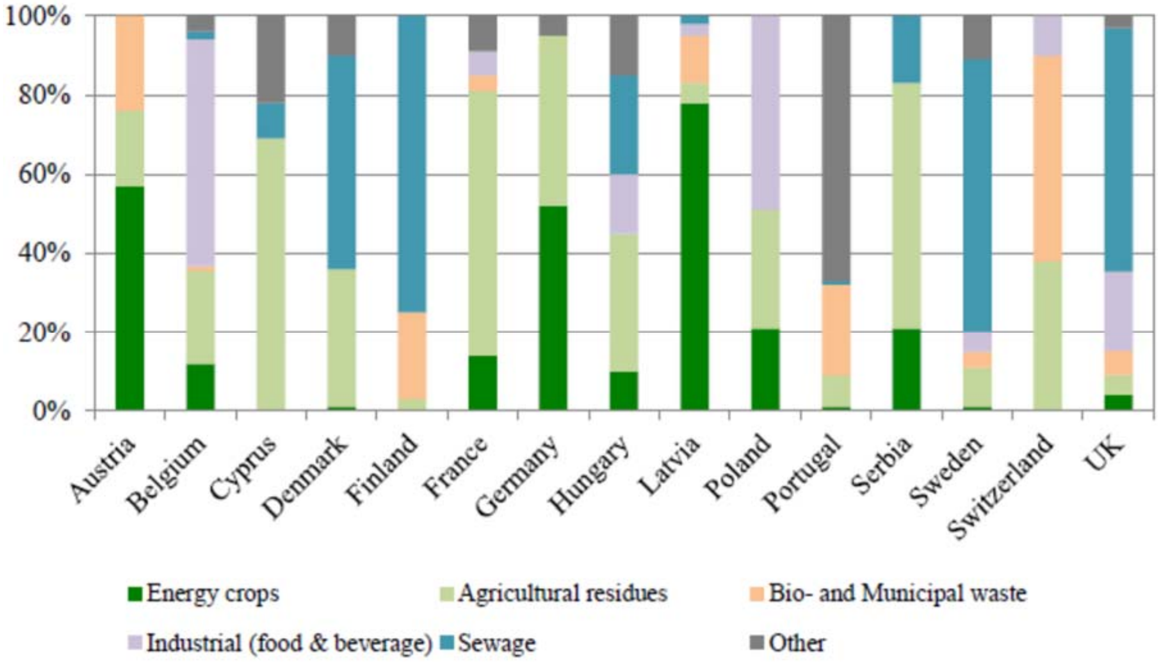

Figure 4: Feedstock used for biogas production in Europe (Scarlat, 2017)

3.3.2 Pollutants emission

Both on world and European level, it has been identified that biomass combustion results with higher emission of pollutants. This has been measured and published (Kubica et al., 2004, Nussbaumer et

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al., 2008, Nussbaumer, 2010 etc.), and identified as serious airborne pollution. European Commission scientific institution JRC introduce program EDGAR (Emissions Database for Global Atmospherics Research), to quantify the problem and initiate solutions. Activities are still in progress.

In EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP –European Monitoring and Evaluation Programme, EEA -European Energy Agency) it is stated:

> *For solid fuels, generally the emissions due to incomplete combustion are many times greater in small appliances than in bigger plants. This is particularly valid for manually-fed appliances and poorly controlled automatic installations.*

There are few definitions for *small appliances*, but, for residential heating sector, small are those with thermal power up to 50 kW. This type of appliances of these using biofuels, boilers, stoves and cookers are dominant. Based on the previously mentioned such appliances are defined as intensive airborne pollution sources.

It is clear that utilization of biofuels contributes to savings of GHG emissions, but on the other hand, they increase airborne pollution, what is a negative impact on the environment. Therefore, it is needed to establish a **trade-off** between these two effects of biofuels, the biomass utilization in the sector of heating & cooling. Society, the European Union as well as every country or region should have interest to solve this contradiction. It is also very clear that appliances with lower efficiency, meaning higher fuel consumption for same heating effects, also have higher pollutants emissions.

In accordance with the EMEP/EEA air pollutant emission inventory guidebook the relevant pollutants are SO_2, NO_x, CO, NMVOC, particulate matter (PM), black carbon (BC), heavy metals, PAH, polychlorinated dibenzo-dioxins and furans (PCDD/F) and hexachlorobenzene (HCB).

For solid fuels, the emissions are many times greater in small appliances than in bigger plants, due to incomplete combustion. This is particularly valid for manually-fed appliances and poorly controlled automatic installations. Due to lower combustion temperature, NO_x is for small appliances significantly lower than for big ones, whereby the amount of NO_2 is a little bit higher. Most significant are emissions of CO and content of PM_5 (5 micrometers) and PM_{10} (10 micrometers) (Nussbaumer, 2017). Reduction of these, most critical, emissions is priority for all small biomass appliances used for household heating.

3.4 Background information on local initiative

3.4.1 Energy policy in Serbia

Serbia, as member of Energy Community, is obliged to follow the European Union's energy policy, including tasks related to the introduction of RES. These provisions are included in the national Energy Law, and supported, especially for biogas, by adequate decrees. Other incentives supporting this cause are in preparatory phase. E.g. this could be the co-financing of purchase of biomass appliances with higher efficiency and thus lower pollutants emissions.

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In 2013, the National renewable energy action plan of the Republic of Serbia (Anonymous, 2013) was created, which includes all issues relevant to status and prospects of RES utilization and policies. The needed measures for supporting the utilization of RES are mentioned as well.

3.4.2 Potentials of renewable energy sources in Serbia

According to National RES plan, the biggest potential of RES in Serbia presents biomass, cf. Figure 5. It is about 5.6 Mtoe (millions of tons of oil equivalent) per annum, which could have a considerable contribution to a lesser utilization of fossil fuels and achievement of defined targets regarding the share of renewable sources in the GFEC (Gross Final Energy Consumption), as well as regarding the reduction of GHG emissions. The biomass potential amounts approximately to 3.4 Mtoe per year, whereby 2.3 Mtoe is unused and 1.1 Mtoe used.

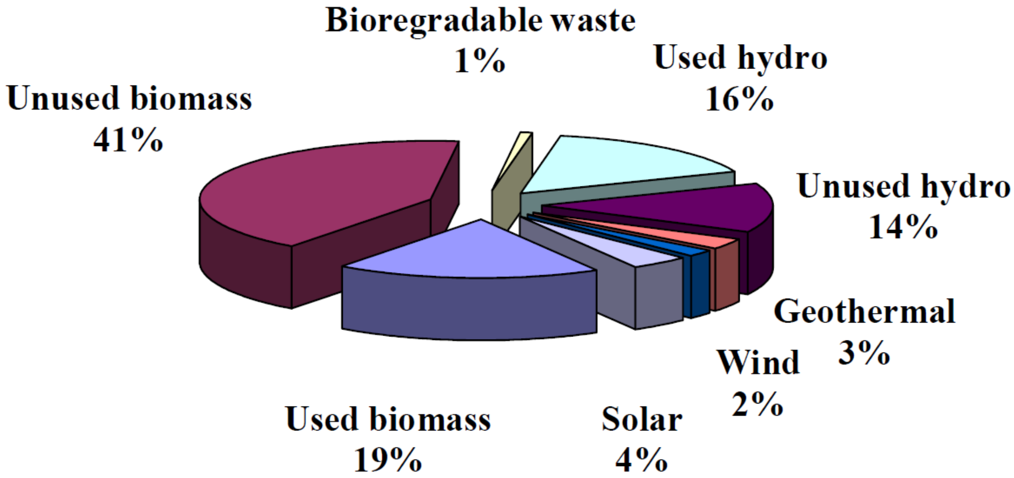

Figure 5: Share of RES potentials in Serbia (Anonymous, 2013)

The assessment of the potentials is mostly based on the publication of Ilić ed. (2003). Here are applied, as usual in that time, more technical potentials not sustainable ones. Currently, the sustainable potentials should also be included and respect environmental aspects and, economic viability. Rough estimation is that sustainable potentials are approximately 10 to 20% lower.

The biggest part of unused potential relates to crop residues, and, therefore the impact of residues off-take on soil fertility preservation should be elaborated, not only in Serbia, but in general. Including this aspect, this could result in a reduction of the sustainable-realistic potential of agricultural biomass. As it was cited in the publication previously mentioned, it amounts to 1.7 Mtoe, whereas the sustainable potential could be around 1.3 to 1.4 Mtoe.

In Table 1 a) and b) are presented actual (2009) and planned (2020) share of renewables in three sectors, for two scenarios. The highest share can be found in sector heating&cooling, where biomass plays a significant role.

a) **Scenario without energy efficiency measures** (share means of **total RES**)

Year	GFEC, ktoe	Electricity, ktoe	Share, %	Heating/ cooling,	Share, %	Transport, ktoe	Share, %

				ktoe			
2009	**9,149.7**	3,079	33.6	4,144	45.3	1,926	21.1
2020	**10,330.6**	3,425	33.2	4,231	40.9	2,675	25.9

b) **Scenario with energy efficiency measures**

Year	GFEC, ktoe	Electricity, ktoe	Share, %	Heating/ cooling, ktoe	Share, %	Transport, ktoe	Share, %
2009	**9,149.7**	3,079	33.6	4,144	45.3	1,926	21.1
2020	**9,495**	3,148	33.2	3,888	40.9	2,458	25.9

Table 1: Gross final energy consumption (GFEC) – total and divided by sectors for years 2009 and 2020, with (a) and without (b) energy efficiency measures

In Table 2 is presented the usage of renewables energies for heating&cooling in Serbia and the amount of biomass used. Biomass used for household, residential, heating makes almost 95 % of the total (Anonymous, 2013):

	2009, ktoe	2020, ktoe
Geothermal	5	10
Solar	0	5
Biomass	1054	1152
Biomass: of which Solid	1054	1142
Biomass: of which Biogas	0	10
TOTAL RES	1059	1167
Of which DH	0	25
Of which households	994	1001

Table 2: RES utilization for sector heating & cooling in Serbia

According to a recent study performed in Serbia (publishing planned for 2018), the amount of biomass used in this sector is higher, as in previous assessments crop residues were not included. After including biomass, baled residues, corn cobs, pellets & briquettes, and pruning residues, the total of used biomass amounts to 1.286 Mtoe. Comparing with the data in Table 1, this makes about 31 % of the sector heating and cooling, what means, it constitutes a rather large share of it. According to Table 2, biomass, biofuels, are mostly (over 95 %), used for small residential heating.

3.4.3 Usage of crop residues

Crop residues are a promising feedstock for biofuels. Utilization of crop residues has positive effects, related to ILUC, but other environmental effect should be considered as well.

Potential of field crops residues in Serbia is presented in Table 3. Acreage and determined potential are distinguished between big and S&M sized farms. For corn, the largest share of arable land is

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cultivated by S&M farms where the second harvest technology is dominant. In contrary to this, corn cobs on big farms are exclusively produced during seed production. This potential is comparably significantly lower and already completely utilized on-site as a fuel for seed drying.

Crop	T	Acreage, 1,000 ha	Big farms, 1,000 ha	S&M farms, 1,000 ha	Sustainable potential, 1,000 t		Energy potential, 1,000 t	
					Big farms	S&M farms	Big farms	S&M farms
Wheat	↓	797	178	619	374	1,080	355	970
Ray	–	8.6	0.8	7.8	2	14	2	14
Barley	–	135	46.6	88.4	80	154	80	138
Corn	↑	1,358	133	1,225	s 130	s 735	**s 130**	**s 660**
					c 15	c 1,200	**c 15**	**c 1,200**
Sunflower	–	160	74.9	85.1	0	0	0	0
Soybean	↑	83	54.8	28,2	105	50	105	50
Oil rape	↑	1.4	0.7	0.7	2	2	2	2
Total					708	3,235	689	3,034
					3,943		**3,723**	

Table 3: Potential of crop residues in Serbia (Ilic et al., 2003; Martinov and Tesic, 2008)

T– trend of growing acreage, S&M– small and medium farms, s– corn stover (for the S&M not calculated harvest of on field remained mass, only if universal harvester is used), c– corn cobs (harvest with picker-husker, typical for S&M farms and seed production)

Here are not included pruning residues, and residues of primary processing (e.g. pre and post drying cleaning residues).

Soybean straw is very convenient for combustion, 50 % of the available potential is already now used, which is today about 70 ktoe (one toe is about 2.8 tons of air dried straw, moisture content about 15 %, net calorific value about 15 MJ/kg). The similar situation can be found with wheat straw, actually less than 10 % on big, and up to 20 % on small and medium farms is used. Still, it makes about 80 ktoe. The potential of corn cobs is, nowadays, about 1,000 kt, and almost the entire amount is used, what makes ca. 340 ktoe. Corn stover represents the biggest unused potential, about 1,050 kt, or ca. 370 ktoe, whereby, the now used amount can neglected, it is less than 1 %. This is promising feedstock for LCB and biogas production in the future.

A very important issue, related to combustion of crop residues, are their relevant combustion characteristics. In Figure 6 a comparison between wooden biomass and straw is presented, whereby, other crop residues have similar characteristics. The ash content of straw is almost ten times higher than its equivalent of wood. Content of nitrogen is five time higher (what can contribute to higher NO_x emission), potassium ten time higher (what can cause high temperature oxidation and have considerable problem in steam boilers) and a 19-time higher content of chlorine can be found, what indicates a higher level of creation of halogen compounds.

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The lower ash softening temperature of straw, can cause problems in the combustion process, limit the temperature in the first combustion stage. All characteristics mentioned make crop residues less suitable for combustion, especially in small appliances. That is why crop residues are not used for this purpose in Germany, Austria and other countries with strict regulations related to pollutants emissions. Crop residues used in big boilers, as can be found in CHP units, is the dominant technology developed in some countries, for example Denmark. One possibility can be also co-firing, but with a lower share, up to 10 %.

On the other hand, crop residues, can be good feedstock for some other technologies and therefore its use as co-substrate for biogas will be considered here.

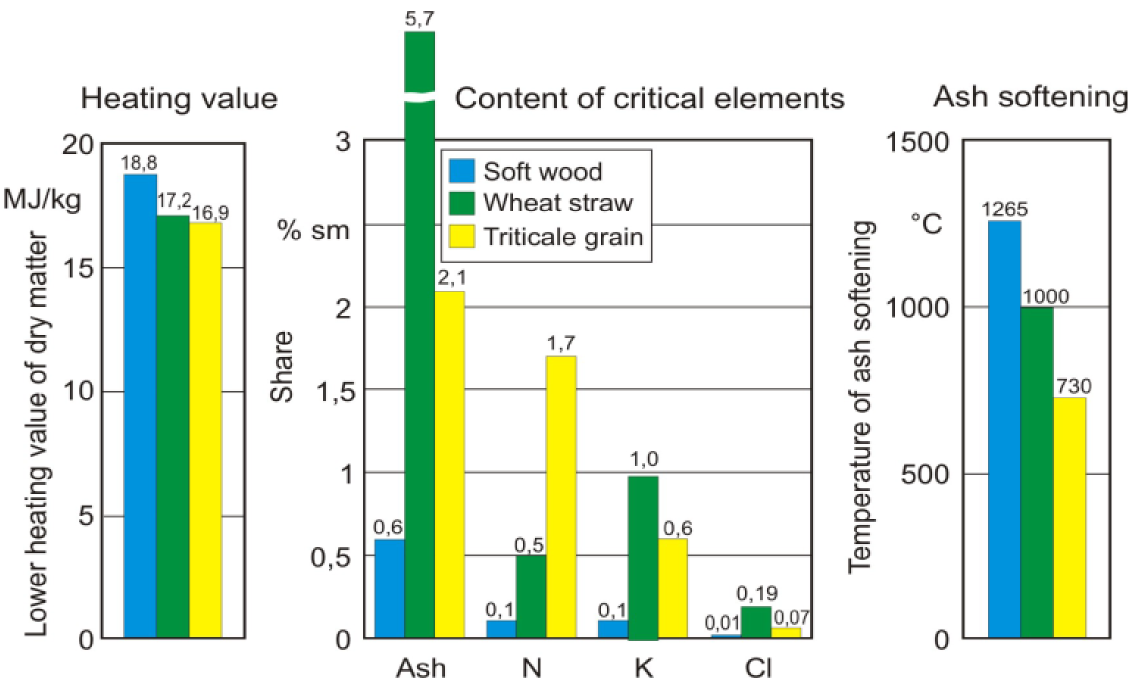

Figure 6: Comparison of wood and straw characteristics (Hartmann, 2013)

Another very important, sustainability issue is the preservation of soil fertility. Agricultural soil is considered as a non-renewable resource. In reality, spoiled soil can be remediated, but for this process a time longer than average human lifespan is needed.

The removal of crop residues should be considered from all aspects, and one of the most significant is its impact on soil fertility, on productivity, including all other environmental and ecological by-effects (Blum et al., 2010; Gerzabek, 2014). Powlson (2006) focused on the issue of soil fertility related to crop residues, primarily straw, and its impact on SOM (Soil Organic Matter), and SOC (Soil Organic Carbon) changing, and gave some general recommendations, i.e. need of establishment of proper soil management related to the soil and climatic characteristics and practice of crop rotation.

The effects of residual corn biomass offtake have been investigated by many researchers. The most significant effects are: the removal of nutrients available in the stover, the impact on SOC, the effects on reduction or elimination of erosion and soil compaction protection cover, the impact on soil

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structure. This should be considered in order to preserve soil fertility, productivity, by taking adequate measures. Wilhelm et al. (2004) presented a thorough literature review related to these issues. Some of the investigations resulted in the conclusion that the removal of residual biomass is followed by a reduction of grain yield in following years. Some long-term investigations did not confirm this statement, and as most significant were considered the impact of climatic and pedological conditions and crop rotation (Blum et al., 2010; Rampazzo et al., 2010). The general conclusion was that sustainable management of corn stover offtake should be provided.

Nowadays, the prevailing opinion is that the best measure for soil erosion prevention represents conservation tillage, as defined in ASAE EP291.3 (Anonymous, 2005). In this publication, any tillage or seeding system that maintains a minimum of 30 % residue cover on the soil surface after planting in order to reduce soil erosion by water; or where soil erosion by wind is the primary concern, maintains at least 1,100 kg/ha of flat small grain residue equivalent on the soil surface during the critical erosion period, is considered as conservation tillage.

The value of nutrients removed with corn stover and SOM (soil organic matter), i.e. SOC should be taken into account, quantified and expressed as additional costs of biomass removed. Nutrient removal in stover is quantified in the range of 0.5 to 3.2 kg for phosphorus and 5 to 16.5 kg for potassium for every t of corn stover DM (Cook and Schinners, 2011; Hoskinson et al., 2007; Karlen et al., 2011; Sheehan et al., 2012). Some researchers also quantified nitrogen removal, 5 to 9.1 kg/t, and some concluded that due to stover removal, the following crop needs less nitrogen due to high C:N ratio of corn stover (Avila-Segura et al., 2011; Cook and Shinners, 2011; Coulter et al., 2008). Still, this is valid only for the first and occasionally for the second following year. The lowest nutrient content was measured in cobs (Avila-Segura et al., 2011), and therefore lowest losses due to its removal. A thorough measurement of nutrients removal was performed by Johnson et al. (2010) for eight sites in the USA. N, P, K and C were measured in three groups of stover, below ears, above ears and cobs. The total nutrients content was largest in stover below ears, and smallest in cobs. On the other hand, the content of carbon was the opposite. It is known that more than half of the SOC source of the corn plant is located in the root and rhizosphere. Allmaras et al. (2012) specified it to be over 80 %.

One of the general measures for soil fertility preservation, beside reduced residue off-take, is a proper management of it. Soil and weather properties play an important role, but crop type as well. In the Table 4 the impact of crop on SOC stock is presented. Obviously, oilseed rape is very useful in this regard, and can contribute when used in crop rotation, if the crop residues stay on the field.

SOC stocks in 0 to 20 cm depth (t ha^{-1})

		Winter Wheat			Spring Barley			Oilseed Rape		
		End Value after 40 Years			End Value after 40 Years			End Value after 40 Years		
	Start Value	100% Straw Removal	50% Straw Removal	No Straw Removal	100% Straw Removal	50% Straw Removal	No Straw Removal	100% Straw Removal	50% Straw Removal	No Straw Removal
Rothamsted	30.4	19.1	24.8	30.3	17.5	21.8	25.8	34.4	40.9	47.3
Ultuna	45.0	27.9	38.5	49.1	38.3	43.0	47.6	47.3	55.5	63.7
Fuchsenbigl	39.8	39.0	44.8	50.7	37.2	41.5	46.1	54.2	60.9	67.6

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Table 4: Impact on SOC by crop residue management for three crops and three field locations (Blum *et al*., 2010)

Sekulic *et al*. (2010) analyzed the impact of crop residues removal on soils in Vojvodina. They concluded that the removal of crop residues can be performed from fields that are rich in SOC. Generally, it can be concluded that consultancy with experts in agropedology can be useful and constructive. Scarlat et al. (2010) gave general opinion, that, in average, one third of crop residues (total above ground residual mass), can be removed, but this should be followed by other measures such as for instance an adequate crop rotation. Other impact and conditions should be considered as well, so the amount of offtake can either be bigger or smaller.

The issue of soil fertility is important for the farmers, but all users of crop residues should consider this, as potential obstacle for feedstock potential and supply. It is also important to have positive reaction of the society on crop residues collection and utilization. Some negative reactions appear frequently, and can make tremendous harms.

Preservation of soil fertility is serious issue, and, until now, there is no universal and unidentified answer as "prescription". For the LCA (Life Cycle Assessment) the removal of nutrients, SOC and SOM should be calculated. Unfortunately, this issue is difficult to elaborate, while proper results can be obtained only after experiments performed continuously for several decades.

The issue of crop residues offtake and their utilization as energy source should be elaborated on European level.

3.4.4 The potential of corn stover and cobs as energy source

Due to agro pedological and agro climatic conditions, many of Danube region countries can be included in "corn belt" of Europe, biggest region of corn grain production. Corn stover represents, in these countries, the biggest not used potential of biomass, and this is, especially, the case in Serbia, where the share of corn stover is about 40 % of all field crops.

In Figure 7 is presented a corn plant. As energy source all aboveground residues can be used, whereby the lowest 15 to 20 cm of stalks are, due to high moisture content and other reasons, treated as undesirable. The characteristics of individual parts are different. In this regard most desirable are cobs, with lowest structural ash content, 2.2 to 2.5 % of ash, and lower content of NPK nutrients.

According to own measurements harvest index is, with good climatic conditions, about 0.5, what means same yield of grains and aboveground residues. If the lowest stalk part is subtracted the amount of available corn stover is about 0.85 of grain yield, with the same moisture content. Harvestable amount depends on the harvest procedure.

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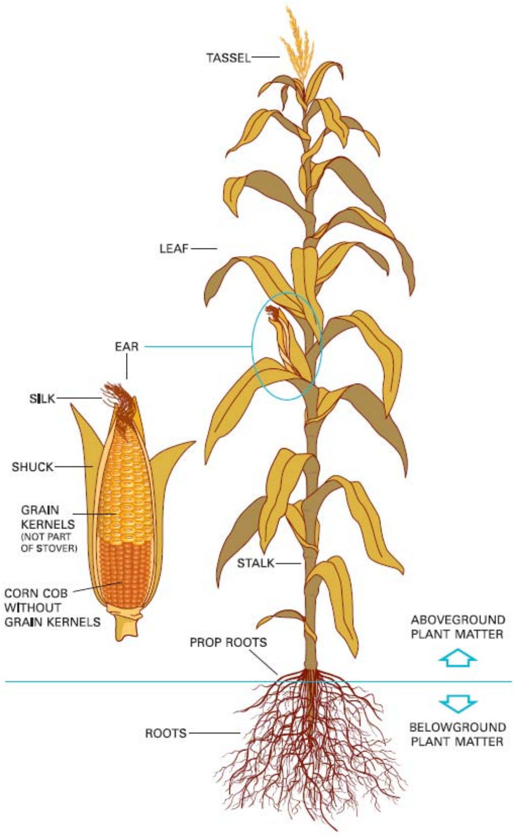

Figure 7: Corn plant fractions

There are a few possibilities of corn harvest and postharvest processing methods. In Serbia are practiced two different options:

1. Harvest with universal combine harvester, snapping of ears and threshing, picker-thresher. The result of harvest is grain. Harvest residues, i.e. corn stover remains on the field available for baling. This technology is practiced by big and medium sized farms.

2. Harvest of ears by using picker-sheller (husker). Results of harvest are ears without shucks, i.e. husks (corn cob and grain). Ears are stored in traditional or contemporary drying bins, sheds (US corn cribs) to perform natural drying. First after drying is performed grain shelling. This technology is practiced predominantly by small and medium sized (S&M) farms.

Using the first grain harvest option leads to the following significant problems of corn stover harvest:

- Depending on FAO maturation group of hybrids and weather conditions moisture content of stover is between 12 to over 50 %.
- Soil contaminations, soiling, depends on weather conditions and applied harvest, collection procedure. Sometimes the total ash content is over 20 % (average structural ash content of stover is about 5.5 %, other is soil).

In the case of second grain harvest options, after drying and grain shelling, on farm yard remain dry cobs with only structural ash, and moisture content of about 15 %. That means, they are suitable for

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diverse utilizations as energy source. In contrary to the mentioned positive effects, the second grain harvest option comes with the need for additional operations during harvest, a limited space for dying and storage, and grains are market ready after natural drying, usually first at beginning of March. That is why this harvest option is applied mostly on small farms, and has reduced in the last decade.

3.4.4.1 Corn stover

There is not a dominant, superior, corn stover harvest, collection, procedure. Proper collection procedure should comply with the following demands: the harvest productivity must not be reduced by more than 10 %, the additional grain losses must be less than 1%, and the soiling up to 5 %.

It is also desirable to perform stover harvest in less passes, and to harvest as much as possible corn cobs. Of course, to practice a positive procedure adequate mechanization is needed, but the purchase of a special grain harvester, only for corn, is not profitable for farmers.

Potential harvest procedures, according to harvest passes, are described by Keene *et al.* (2013), Straeter (2011), Shinners *et al.* (2012):

1. **Single-pass, cobs and husks harvest:** Cobs, husks and parts of leaves, MOG (Material Other than Grain), that exit combine separator are harvested. As solution, pressing of material by trailed round baler powered by combine, described in Keene *et al.* (2013), has been considered. By these solutions contact of stover and ground is avoided, *i.e.* contamination by soil. Complete amount of cobs and husks is harvested, and some of leaves.

2. **Two-pass harvest – windrower:** Grain harvest in combination with ear snapper corn header and integrated shredder-cornrower. The stover is picked up from windrow by a round or big rectangular baler. Cutting height is 0.2 m. Percentages of harvested fractions are 70, 90 and 90%, for stalks+leaves, cobs and husks, respectively.

3. **Three-pass harvest:** Snapper header with integrated shredder. Second pass is racking, formation of windrower, and third balling. It can be harvested up to 70 % of stalks+leaves and up to 30 % cobs+husks.

Single-pass procedures result in considerable reduction of grain harvest productivity, and therefore a special harvester is needed, only aimed for corn. It has positive effects, no soiling, harvest is done in one pass, but due to previously mentioned negative effects, this procedure is not applicable in practice, yet.

For two-pass procedures a special header is needed, with an integrated shredder which simultaneously forms a windrow (swath) of stover, Figure 8. It is very positive that cobs, husks and some leaves which leave the combine separator are falling in a formed windrow. They deliver results with good productivity, due to the reduction of passes, and modest soiling. First solutions of this type were developed in the USA, but due to specific corn growing conditions, not applicable in Europe, c.f. Figure 8 a) and b). Recently the company Geringhoff developed a similar system for Europe, Figure 8 c). After the first pass is performed, the balling of stover from the windrow is done.

a)

b)

c)

Figure: 8 Corn headers with integrated chopper and windrower, a) and b) New Holland, USA, c) Geringhoff, Gemany

The negative aspect of such a solution is that a new expensive header is needed, and that this one which is applicable only on an universal harvester with higher weight and engine power. This has a negative impact on the costs of stover collection. However, this is currently the superior solution for corn stover harvest.

For a three-pass procedure a header with shredder is used, but not the type that forms a windrow. That is why additional raking is needed. This operation is performed by using rakes, as shown in Figure 9, and leads to results with increased soiling. Weather conditions, moisture of soil, but also the applied raking, have an impact on stover soiling. By using finger-wheel rakes, which are simple, inexpensive and a widely used solution, soiling is, due to finger contact with soil, considerably higher. According to own measurements (Golub et al., 2016), performed under convenient dry conditions, soiling was 3.4 and 11.7 %, when finger-wheel rakes were used and a belt-merger. It should be

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underlined that the price of a belt merger, with the same working width and productivity, is about twenty times higher.


a)


b)

Figure: 9 Raking of shredded corn stover, a) finger-wheel rakes, b) wide pickup belt merger

In third pass the balling of the formed windrow is performed. By this procedure, depending on many impacts, about 50 % of stalks-leaves, and less than 30 % of cobs-husks can be harvested. Even if the collection costs are lower, this is the only advantage of the three-pass collection procedure.

At the moment there are no headers available for the two-pass procedure in Serbia. It is expected that some will be purchased, but a more suitable and affordable corn stover procedure is still sought.

If the stover is planned to be used as co-substrate for biogas, harvest of it can be performed by forage harvester. Storage of such material, e.g. making silage, has not been thoroughly tested till now. The question of proper storage of balled stover is still open.

The question of efficient and profitable corn stover harvest is still not solved. Available procedures and machinery either give insufficient results, or their costs overcome investments for profitable utilization. New solutions are sought.

3.4.4.2 Corncobs

The largest share of corncobs, after ears drying and grain shelling, is available locally at small & medium farm yards, namely in rural areas. Typically, prior to utilization, such biomass material is stored in sheds, as presented in Figure 9 a). The potential of corn cobs in Serbia is assessed to be about 1.2 million tons, according to Table 3 (application of this corn harvest and drying option is recently reduced, and available amount is estimated to be about one million tons), moisture content about 15 %, net heating value about 15 MJ/kg), or about 400 ktoe (kilo tons of oil equivalent).

Corn harvest technology using picker-husker with one or two rows machines (Figure 8) are used on S&M farms, for approximately 60 % of the corn in Serbia. Harvested ears are naturally dried in traditional or new-type ears drying barns (Figure 9), which are in the same the time storage for this commodity. After reaching the equilibrium moisture content of grains (typically at the beginning of March), about 14 %, the shelling of ears can be carried out. Dry corn cobs with similar moisture content remain on the farmer’s yard, the mass of which is about 20 % of grain mass.

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Figure 8: Corn ears picker-husker in operation

a)

b)

Figure 9: a) Corn ears drying and storage sheds (corn cribs), traditional; b) new constructed

This specific harvest and postharvest processing procedure was introduced in the time of the former Yugoslavia, when over 85 % of land was owned by small family farms and this tradition was kept alive in Serbia till nowadays. With some changes, this procedure is practiced on S&M farms in Romania, Croatia, Hungary and other countries in the region as well. Such technology requires increased labor input, but for social groups in rural communities this is not a problem.

The resulting by-product of corn harvest in Serbia are therefore relatively dry corn cobs (85 % dry matter content) that are locally available, abundant and cheap (practically no cost for farmers). Therefore, corn cobs are commonly used as a fuel for heating of rural households. Further reasons for their high utilization as a fuel is that they have more advantageous combustion properties as a fuel than other crop residues as cereal straw, corn stover, etc. In particular, this concerns the ash content and its composition.

This significant potential of corn cobs is, already now, in Serbia almost completely used as an energy source for household heating, on farms, or in vicinity of them. Unfortunately, corn cobs are mostly used in irrational, inefficient or an inappropriate way. As a fuel, this solid biomass in Serbia is almost exclusively combusted in outdated and inefficient heating facilities, i.e. in small boilers and stoves, which are simple and without equipment for controlling the combustion process. Therefore, the utilization is at a low technological level followed by low efficiencies and high airborne emissions.

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One of the possibilities to improve cobs utilization is chorusing or pelletization, which can enable aromatization of stoking, what can be followed by advancements in efficiency and pollutants emission. In the form of pellets also the remote users, in towns and cities suburbs will have access to it. The opening of new markets for this products will contribute to rural development, create additional income for small farms owners.

Development of adequate technology for corn cobs processing and using as residential heating fuel has environmental, economic and societal dimensions.

3.4.5 Residential heating

Few studies treated efficiency and emissions of biomass appliances in Serbia (Brkic and Martinov, 2006a, 2006b, Martinov et al., 2006), done for medium capacity appliances, up to 500 kW. Regarding efficiency, rather negative results were obtained, giving values lower than 60% and with a high level of emission of pollutants. One study about characteristics of wooden biomass boilers, stoves and cookers was performed (not officially published), and neither of the twelve appliance tested, of which four imported, reach an efficiency over 50 %. The CO content was in all cases over 1,000 mg/Nm^3.

In a recently performed study, which is still not published, was concluded that most of appliances belonging to the group of conventional stoves, cookers and boilers (groups 1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a in EMEP/EEA air pollutant emission inventory guidebook used for categorization 2016), were characterized by a low level of efficiency and high pollutants emissions.

National legislation regarding emissions of pollutants of small heating appliances is available for wooden biomass. The limit values stated there are at a very low level, taken from German regulation, Tab. 5, but these are given only for PM and CO, what is in the line with discussion in previous chapter 5.3.2.

Pollutant	Fuel	Thermal power, (kW$_{th}$)	LVP, (mg/Nm^3)
Particulate matter (PM)	Coal	≥ 4	90
	Wood, excluding wooden briquettes and pellets	≥ 4	100
	Wooden briquettes and pellets	≥ 4	60
Carbon monoxide (CO)	Coal and wood, excluding wooden briquettes and pellets	4-500	1000
	Wooden briquettes and pellets	4-500	800
	Coal, wood, wooden briquettes and pellets	≥ 500	500

Table 5: Limit values of pollutants' (LVP) emissions of new small solid fuels combustion appliances (measured for oxygen content 13 % in flue gases

It is very difficult to obtain LVP related to particulate matter for wooden biomass, including high quality pellets, and impossible for agro biomass, as crop residues. Balled straw and stover, loose cobs and cob grits are used only in rural areas, with much lower population, and therefore lower heating appliances density, what means, LVP can be higher: For example reaching values of 200 or even 300

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mg/Nm[3]. For agro biomass, straw, stover and cobs pellets and briquettes, almost the same is the case, the limit for PM can be, *e.g.* 150 mg/Nm[3]. The limit values for CO and other pollutants can be, for these cases, discussed. Professional and scientific consideration for these cases is needed.

All European CEN standards related to biofuels are accepted as national (SRPS) in Serbia. This is good help for this sector and legislations, but for manufacturers as well. Typical is the standard for "Heating boilers for solid fuels, manually and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking", excerpt in Tab. 6.

Stoking	Nominal power, kW_{th}	Limits								
		CO			OGC			PM		
		mg/m^3 for 10% O_2								
		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 3	Class 3
Manual	≤ 50	25,000	8,000	5,000	2,000	300	150	200	180	150
	> 50 - 150	12,500	5,000	2,500	1,500	200	100	200	180	150
	> 150 - 300	12,500	2,000	1,200	1,500	200	100	200	180	150
Automatic	≤ 50	15,000	5,000	3,000	1,750	200	100	200	180	150
	> 50 - 150	12,500	4,500	2,500	1,250	150	80	200	180	150
	> 150 - 300	12,500	2,000	1,200	1,250	150	80	200	180	150

OGC: organic gaseous carbon; PM: particulate matter.

Table 6: EN standards are adopted as national, SRPS, including EN 303-5

Here given limit values can be used for agro biomass, whereby for balled should be used values for class 1 and for pellets class 2.

As previously mentioned, utilization of biomass for residential heating is intensive. About one million toe of wooden biomass and about 300 ktoe is annually used. In the country there are more than twenty manufacturers of such appliances. Additionally, some EU manufacturers are on the market with their products.

Many appliances are also self made, or by unregistered handcrafters in rural areas, especially welded and tiled stoves, Figure 12. They are mostly on very low engineering level, low efficiencies and with high pollutant emissions.

There are also more advanced solutions of boilers and stoves offered, c.f. Figure 11. These can typically be found for pellets boilers and stoves.

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Figure 10: Simple, often self-made, manually stoked biomass appliances in Serbia

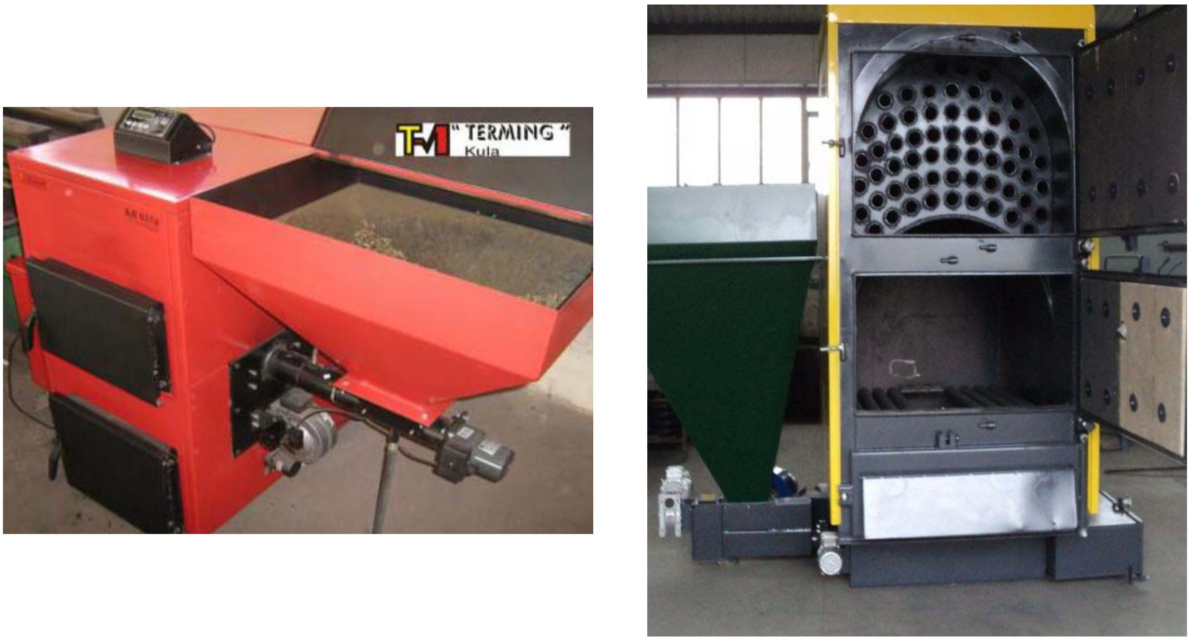

Figure 11: Examples of advanced pellets and grinded biomass boilers produced in Serbia

Many of the Serbian manufacturers are, already now, able to deliver better appliances, but at much higher costs. Some of them have cooperation with companies in EU, use their parts and components for boilers and stoves. This is specially the case for pellet stoves and boilers, burners and control units. Some of manufacturers export their products, or partly finished products to partners in EU countries. In such cases appliances they fulfill regulations related to pollutants emissions in these countries, but for such products it is difficult to find costumers in Serbia, due to the higher costs.

A good example is presented in Figure 12. This type of boiler features a level of thermal power of 25 to 125 kW, and has efficiency, by nominal power and utilization of proper short wooden logs, over 90 %. In Table 7 are presented results of the testing of a boiler by accredited foreign institutions. The pollutants emissions are considerably under defined limits (c.f. Table 5 and Table 6).

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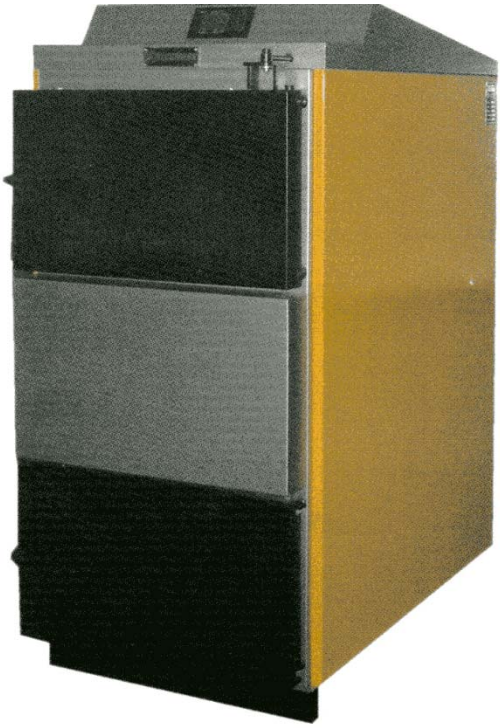

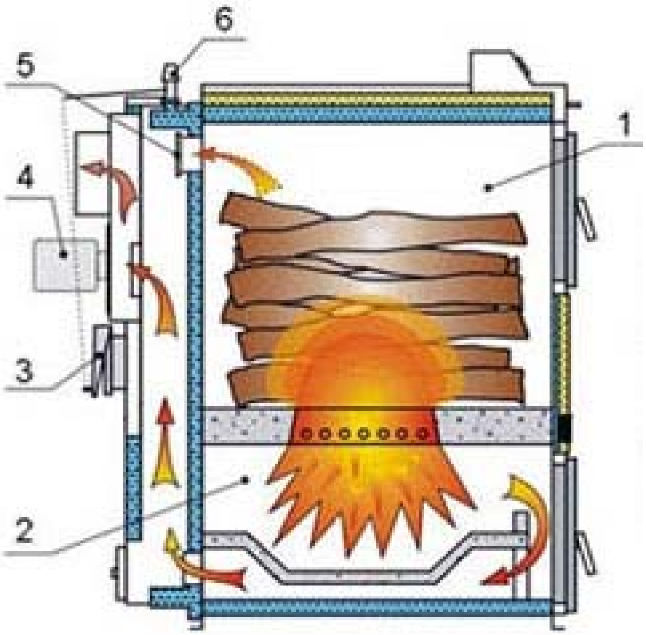

Figure 12: "Pyrolytic" wood logs boiler (separate gasification and secondary combustion space), 25 to 125 kW thermal power Domestic manufacturer, export to EU

Dust concentration	mg/Nm^{3}dry gas at 10 % O_2	11,2
Dust concentration	mg/Nm^3 dry gas at 13 % O_2	8,15
NO_x concentration (mean value)	ppm	187,4
NO_x concentration (mean value)	mg/MJ	116,9
NO_x concentration (mean value)	mg/Nm^{3}dry gas at 10 % O_2	172,64
NO_x concentration (mean value)	mg/Nm^3 dry gas at 13 % O_2	125,7

Table 7: Excerpt of measuring results, 100 kW, done by certified institution (foreign), considerably under mentioned limits of emissions

3.4.6 Biogas

After coming into force the newest Decree (third one) related to electricity generation from RES in 2016, the construction of new biogas plants boomed in Serbia. This happened because of a new *Feed-in* tariff that enabled profitable investment in biogas plants. Additionally, and as a positive aspect in this Decree, is that the share of corn silage was reduced to 40 %, expressed in dry matter. This rule can contribute to meeting sustainability criteria of biogas production and utilization, what means saving of GHG emissions by more than 80 %.

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There was a study done which proposed a method for the assessment of biogas potential, and this method was tested as a case study for Serbia (Martinov, 2015). The study states that the share of energy crops used should be reduced to the possible minimum, and expressed as a percentage of energy contribution. For the period till 2020 and after this, were proposed two scenarios, regarding a maximal share of energy crops, c.f. Table 8.

Period	Scenario	Share of energy crops, % related to			GHG saving, %
		Total energy	Fresh matter	Dry matter	
Up to 2020	1	60	17	40	110
	2	40	8	22	144
After 2020	1	40	8	22	144
	2	30	5.5	16	158

Table 8: Proposed shares of energy crops for agricultural biogas production and expected GHG savings

Based on these scenarios, and other data related to manure and other substrates availability, a sustainable potential of biogas for Serbia was calculated. It is expressed as electric nominal power of plants, for 8,000 hours of annual working time, and a electric efficiency of 39 %. The results for the mentioned scenarios (S), are presented in Table 9.

		Up to 2020				After 2020			
		EP, MW_e	AEP, GWh/a	ATE, GWh/a	BP, 10^6 Nm^3/a	EP, MW_e	AEP, GWh/a	ATE, GWh/a	BP, 10^6 Nm^3/a
Agricultural	S1	85.2	681.6	173.8	180.4	85.0	680.0	173.4	180.0
	S2	56.8	454.4	115.9	120.3	77.0	616.0	157.1	163.1
Industrial		20.2	161.6	41.2	42.7	15.1	120.8	30.8	31.9
Urban organic		11.6	92.8	23.7	24.5	13.6	108.8	27.7	28.7
Total	S1	117.0	936.0	238.7	247.6	113.7	909.6	231.9	240.6
	S2	88.6	708.8	180.8	187.5	105.7	845.6	215.6	223.7

Table 9: Review of biogas potentials in Serbia
S1– scenario 1, S2– scenario 2, EP– Electric Power, AEP– Annual Electricity Production, ATE– Annual

Based on defined conditions, potentials of thermal energy of biogas plants are calculated, as well as expressed in biomethane generation.

Agricultural biogas plants (based on substrates from agriculture), are dominant, making about 64% to 72% of total, in scenario 1 and 2, respectively. For the period after 2020, with the reduction of the share of energy crops, but the introduction of usage of crop residues as co-substrate this share is even higher, reaching approximately 77%. Spatial distribution of biogas potential is presented I in Figure 13.

It was concluded that a further increase of agricultural biogas potentials can be obtained by the expected development of small scale biogas units, and utilization of crop residues as co-substrates. These measures would result also in the reduction of the share of energy crops, but can also support rural development. Further urgent activities and measures should be oriented toward achievement of much higher utilization of biogas CHP plants thermal energy, generation of biomethane, and

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combined generation of electric/thermal energy and biomethane. More efficient utilization of digestate, in some cases, can be also desirable objective. Thermal Energy, BP– Biomethane Production

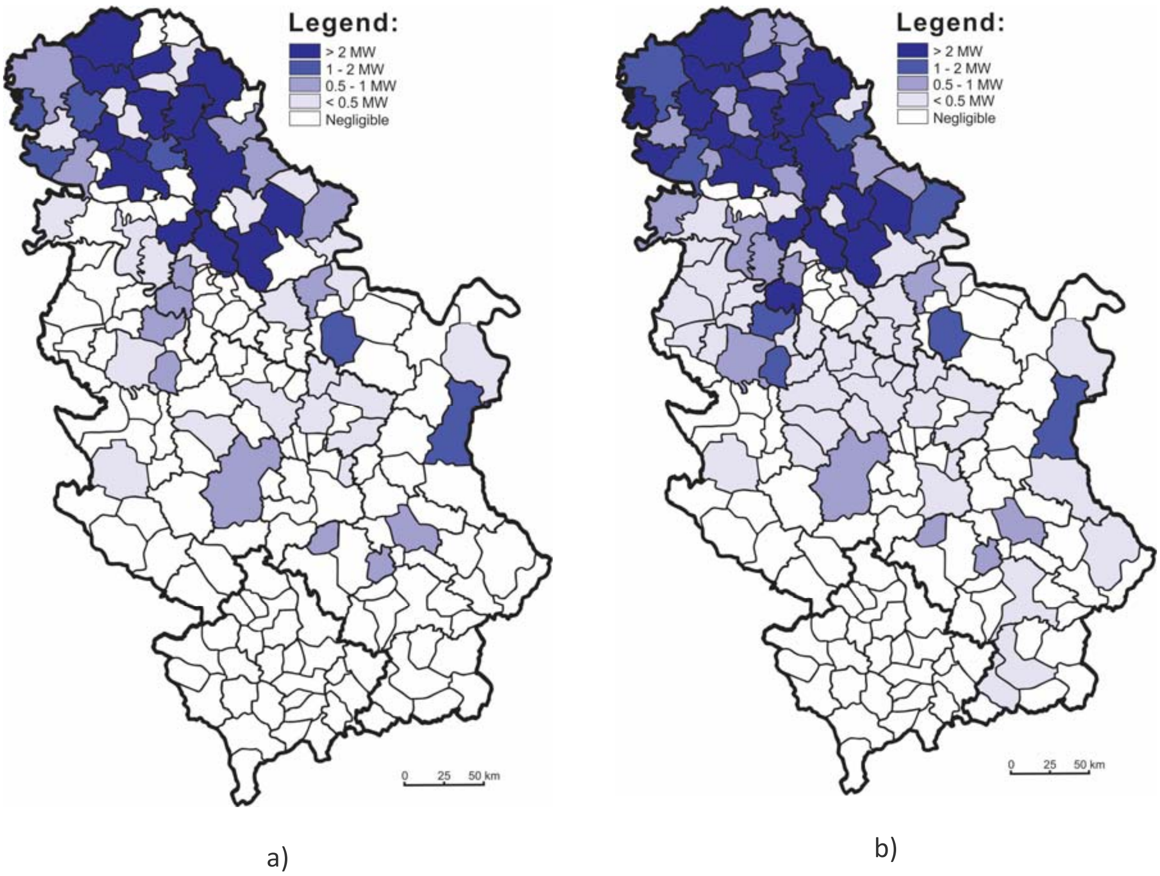

Figure 13: Spatial distribution of biogas potentials, expressed as CHP electric power output, a) up to 2020, b) after 2020

In the second study (Martinov and Djatkov, 2015), was stated that poultry manure and pig slurry represent a considerable biogas potential in Serbia. However, both substrates are rich in nitrogen what results in a reduction of C:N ratio under acceptable level. The second problem is a too high and too low content of solid matter, respectively, for their use in wet digestion process. Finally, the majority of poultry and pig farms are small/medium scale that would enable substrate utilization in small/medium size biogas plants. Therefore, the objectives to check the possibility of overcoming these demerits are:

1. Making a mixture of these with crop residues, *e.g.* corn stover and cereal straw, considered as more appropriate materials than energy crops. It is expected that these materials can also contribute to increase of C:N ratio reaching an acceptable range. However, the restriction to use larger quantities of crop residues is in their unfavorable substrate related properties, *e.g.* slow digestibility.
2. Estimation of theoretical biogas yield of relevant substrate mixtures.
3. Considering technical and economic viability of application of smaller biogas plants, 150 and 500 kWe, and dry technology with higher capital expenses.

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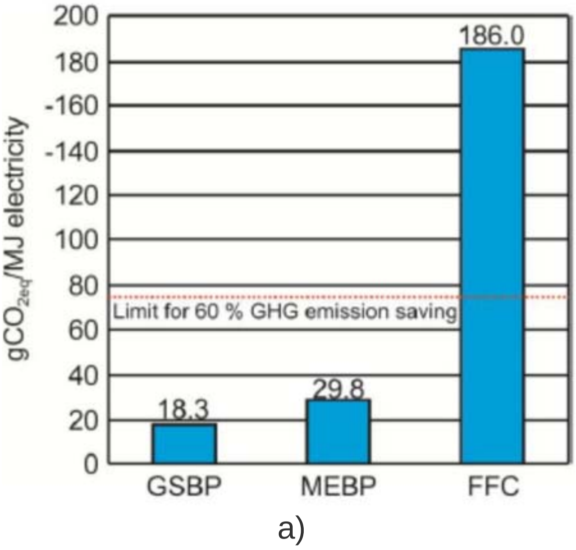
In the third relevant study (Martinov et al., 2016), sustainability issues were elaborated, related to savings of GHG emissions expressed in g CO_{2eq}/MJ, and performed in accordance to RED and EU documents COM(2010)11 and SWD(2014)259. The procedure of calculation is described, whereby the LCA (Life Cycle Assessment) is performed by using *CML 2015* impact assessment method. The software *GaBi* and alongside the primary data, databases *Ecoinvent v3.1* and *Thinkstep Professional* database were used as a sources. The case studies are performed for two biogas plants in the country.

Obtained results are presented for GHG emission and savings in comparison to fossil fuels (FFC) in Figure 14 .



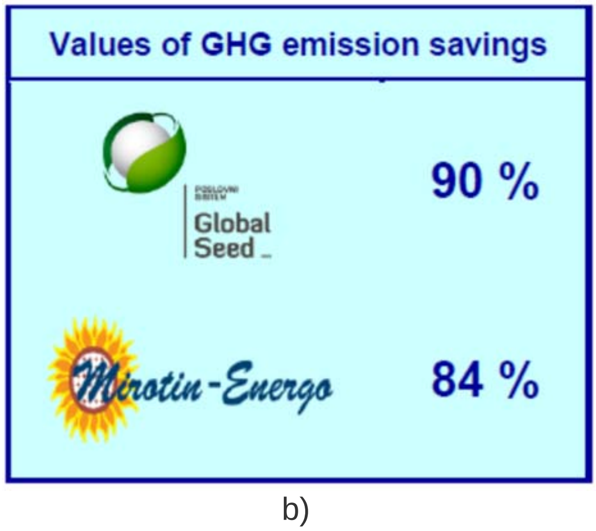


Figure 14: a) Total GHG emissions in producing electricity (ECel) for Global Seed and Mirotin Energo biogas plants, b) savings

According to these studies, related to the sustainability criteria, a utilization of crop residues, first of all corn stover, as co-substrates is foreseen as a possible solution. The needed pretreatment of these materials, in order to remove lignin and lignocellulosic barriers, is still in the development phase. It was concluded that some of the solutions are in early commercial maturity phase. e.g. steam explosion procedure is from engineering point of view successful, but its economic viability due to high costs of equipment is considered as a problem.

3.4.7 Biofuels for transport

As previously stated, first generation of biofuels for transport are no more eligible to be treated as RES. The sustainability criteria are also elaborated for Serbia (Denvir et al., 2016), and include all aspects, excluding these mentioned in new RED (Anonymous, 2016a). From the sustainability point of view, and especially ILUC, using corn stover and other crop residues for biofuel production is very positive.

A study of possibility of LCB production based on corn stover was performed (Martinov, 2015) which showed that this process is feasible from an engineering point of view. A couple of such plants are

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constructed in USA, and one in Italy. Report about assessment of their function and profitability are still not available.

One of the most crucial problems is the adequate collection of corn stover. Future efforts should be oriented toward the its solution. The other problem is feedstock supply with the vast amount of corn stover. Road transport would, for sure, cause traffic problems, and that is why water shipping was considered. Therefore, candidate sites with a river harbor are considered as locations for a possible LCB plant in Serbia. The selection is made by using *location-allocation-problem*. Considered locations are presented in Figure 15.

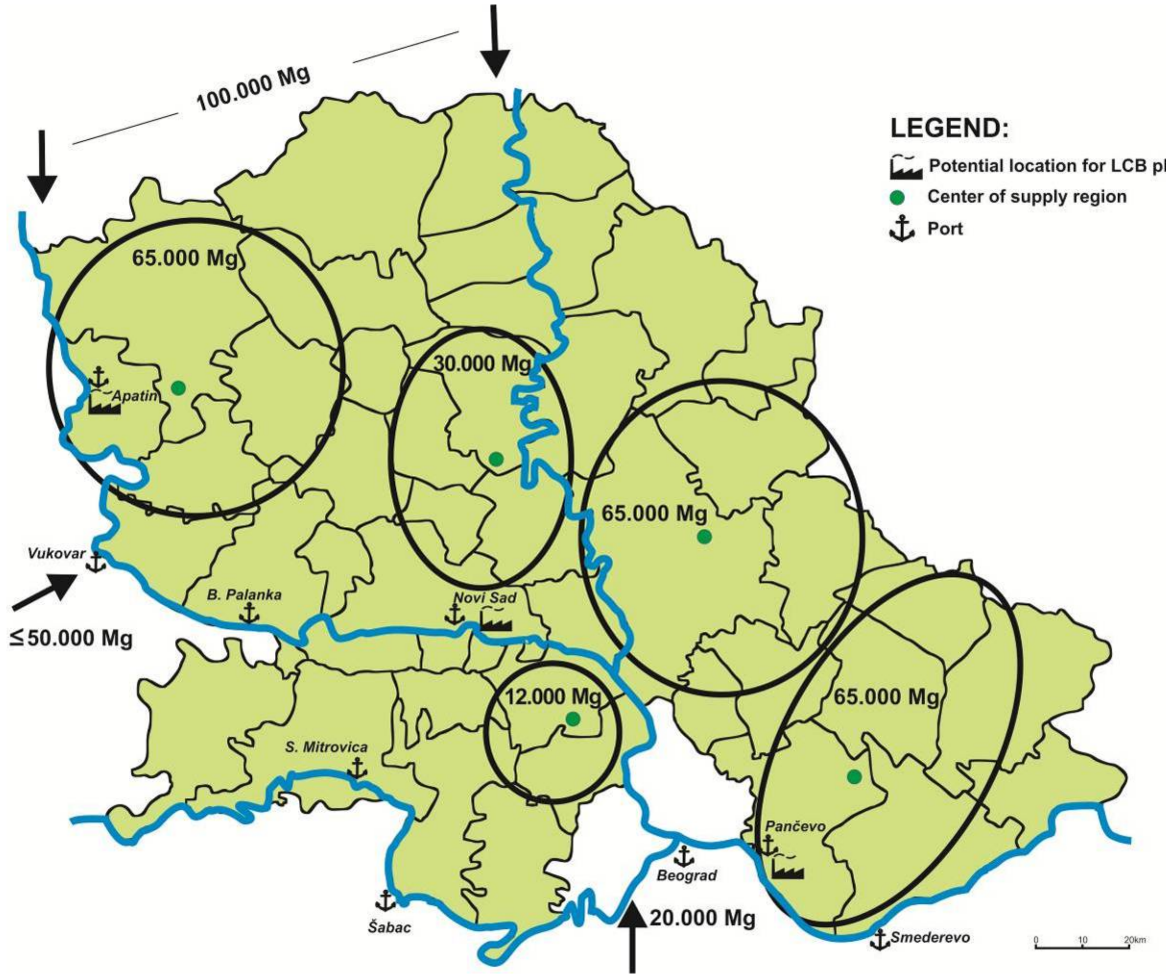

Figure 15: Supply regions with available amount of corn stover and potential locations of LCB plant in Serbia (Martinov, 2015)

Financial analyses were performed for two plant capacities, 40 and 50 thousands of tons of LCB per annum, and expressed by liquidity, project IRR, equity IRR and payback period (Martinov et al., 2017). The costs of feedstock, investments and inputs were varied to perform sensitivity analysis. In the best case, the production costs per ton, without profit, were under 650 €/t. This was compared with the price for bioethanol on the stock exchange, plus incentives for LCB included. For example, if the stock exchange price is 500 €/t, incentives should be 150 €/t.

About biomethane, produced by biogas upgrading and its utilization, was reported, but until now this technology is not practiced.

Due to the uncertain future of second generation biofuels for transport, these are not considered within project Made in Danube.

3.5 Vision of local initiative

The major vision of the Faculty of Technical Science is to contribute to the efforts of a wider and more proper utilization of renewable energy sources in Serbia and the Danube Region.

In particular, in Serbia the focus will be on the following issues:

- Finding solutions for proper harvest and storage of corn stover, what will enable to tap this vast not used potential in the country. The same is aimed for corn cobs, whereby, utilization of this fuel can contribute to rural development. It is foreseen to engage in activities targeted at the development of proper pelletizing process, and the improvement of stoves and boilers to be used for combustion. The second local need is to improve small biomass appliances, up to 50 kW of thermal power, aimed for residential heating. In Serbia they are on a rather low level, are of low efficiency, and have high pollutants emission. An improvement should contribute to cleaner air and better utilization of locally available energy sources. The third vision is to improve production and utilization of biogas in Serbia, with special focus on small units, whereby agricultural biogas is focused on.

All mentioned is always oriented towards a wider public, and, in agriculture, also towards family farms. The rural development should always be in focus too.

The mentioned objectives should be set out for the Danube Region, as well as on European level, while the EU requests and targets will be accepted, and international cooperation related to innovations and their flow will be applied. For example, in Serbia affordable new solutions will be introduced. From the point of view of functional cooperation, cooperation of industry and R&D institutions is expected, but with public authorities too.

One of most significant future objectives is to define sustainable utilization of crop residues, possibly on a global, a European level or on the level of the Danube Region.

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4 Local Action Plan

4.1 Objective of the Local Action Plan (LAP)

The LAP is one of the instruments to improve framework conditions. It offers a structure to the relevant stakeholders involved and foresees a process of continuous improvement (CIP). As the project evolves, the tasks will be adapted according to the current needs as well as further tasks defined in order to lead to an improved result.

Besides being an instrument for the local initiative the LAP has a central role within the "Made in Danube" project: together with the results of the questionnaire it serves as basis for elaborating a roadmap related to framework conditions. Based on the roadmapping and the policy dialogue results a common strategy will be developed which has the goal to bring R&D results on the market.

4.2 Elements of the Continuous Improvement Process (CIP)

The different steps as shown in Figure 168 comprise the following:

1. The process starts with the **definition** of the initiative and its goals. This definition should include the local goals that go in line with the overall goals of the project „Made in Danube".

2. Based on the initiative definition an in - depth **analysis** is made

3. Definition of tasks for local action

4. **Implementation** of tasks for local action

5. **Reflection** on generated results: What are the lessons learned? Where does the initiative need amendments in order to reach the goals?

6. **Peer consultation:** Reflection on results is supported by a peer partner. Each of the three local initiatives get support of one of the other local initiatives (on a yearly rotating basis). This support should comprise the discussion of the results, challenges met and innovative solutions found and therefore constitutes an **interdisciplinary learning** process in both directions. Regular meetings within the **DTC network** could serve an opportunity to present and reflect on experiences.

7. **Adaptation**: Based on the results of 5. and 6. a revised and extended task list is drawn up. These adaptations could also be a consequence of changes in EU policies.

8. **Reporting:** Local initiatives often depend on external support such as financial funding and/ or political support. Hence the report to political decision makers and other support institutions (such as clusters or partner initiatives) is foreseen as part of the process. This step is important to ensure that the legal framework is supportive and sufficient funding is secured, stakeholders are kept informed and the multiplying effect of the initiative is safe-guarded.

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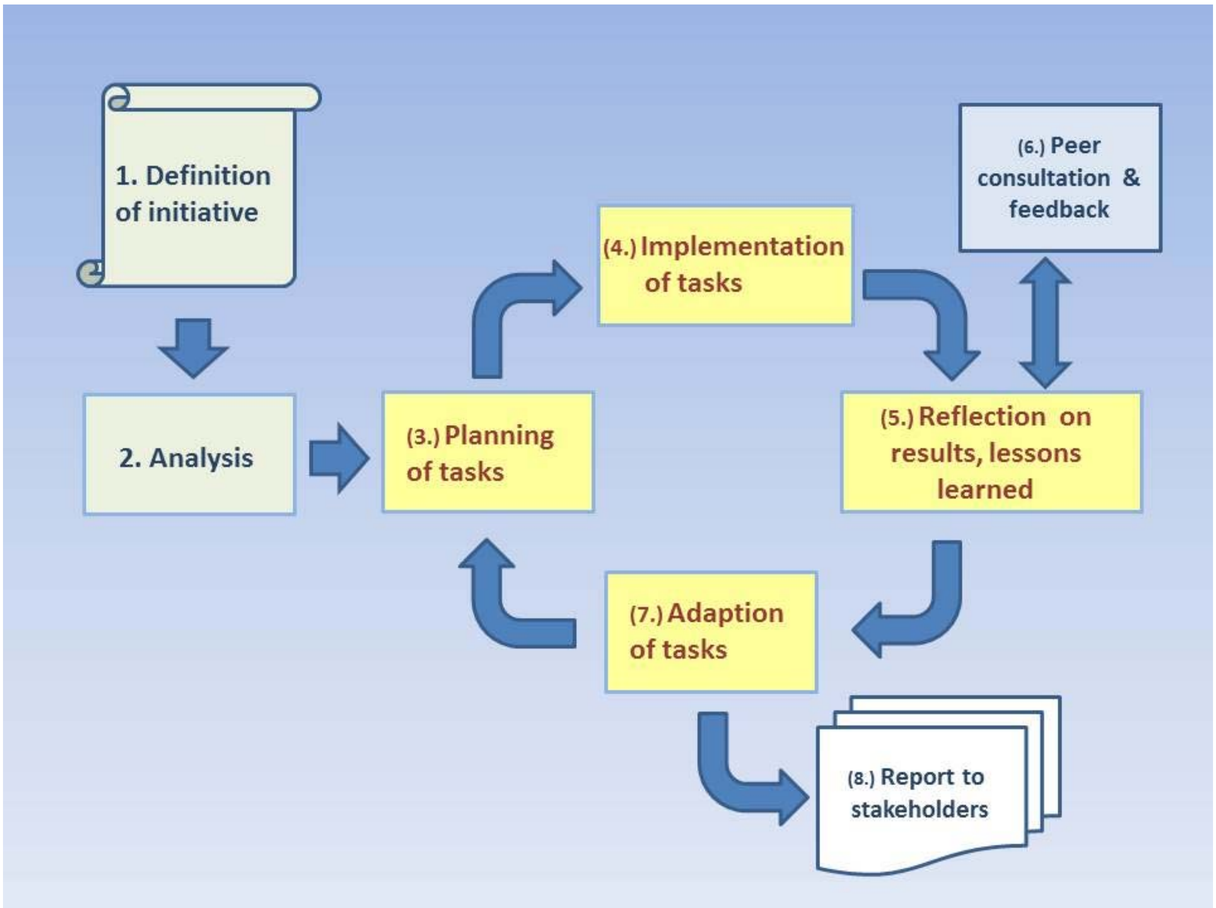

Figure 16: Overview Continuous Improvement Process (CIP)

In order to ensure a continuous and therefore sustainable process it is crucial to fix the following parameter in each step:

- what should be done
- who should do it
- until when
- which resources are necessary, which are available

4.2.1 Durability & transferability

As a continuing planning and implementation instrument the process does not end with the report to stakeholders (8.), but goes on with the planning of new and improved tasks (3.). This introduced process strengthens durability and quality standards. Experiences gained in the three local initiatives, which serve as pilot areas, will serve as basis for further implementation plans for other initiatives in the Danube region.

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4.3 Local Action Plan

4.3.1 First summary of local situation

During the working meetings with the representative of the local initiative of Novi Sad the following opportunities, challenges and threats were identified:

4.3.1.1 Strengths & Opportunities

- scientific knowledge in the field of „Biofuels“ at the Faculty of Technical Sciences, University of Novi Sad
- regional and transnational network of contacts of the Faculty of Technical Sciences, University of Novi Sad
- corn as an agricultural product with regional and international importance, corn stover as residual product with potential
- bioenergy as one of priority areas of the EUSDR

4.3.1.2 Challenges & Threats

- Availability of input materials (corn stover) depends on water supply (drought risk) and soil fertility: management of soil fertility as critical process in sustainable farming
- Varying supply situation: depending on region and climate
- Logistics of corn stover and cobs harvest and collection
- Storage facilities of input materials for future use as feedstock for biofuels
- Improving of the combustion process in order to reduction of flue gas pollutants for small boilers and stoves, especially for agro biomass
- Usability of crop residues as co-substrate for biogas production: necessary pre-treatment
- Different regulatory frameworks and funding and/or investment capital situation depending on region resp. country

4.3.2 Desirable innovations within the local action plan

As it has been stated, **biofuels play an important role in the field of bio-economy**, but, in the case of crop residues, preservation of soil fertility should be always kept in mind. How to off-take crop residues without negative impact on soil fertility is still an actual question. This is not the issue of this LAP, but should be always considered.

Another general issue is related to the **sustainability**, which includes environmental, economic and social aspects. In any evaluation of a new activity, connected with innovation and new technology, these aspects should be taken into consideration. This is primarily related to the existing and planned directives and regulations on European Union level. When speaking about sustainability, the respect for rural areas, their preservation and development is not to be forgotten.

Finally, all activities should have not only national, but **regional** (Danube Region) or even European dimension.

4.3.2.1 Harvest of corn stover

Corn stover, including cobs, present in Serbia and other Danube Region countries, *e.g.* Bulgaria, Croatia, Hungary, Ukraine, a vast unused potential for biofuels. Finding technology and machinery for adequate and economically viable **harvest and storage** of corn stover or sole cobs, can enable advancement in production of biofuels.

According to presented, a two phase harvest procedure of corn stover has priority, but this solution should be affordable for the majority of farmers.

Harvest and utilization of corn stover and corn cobs can contribute to farmers' higher incomes and thus to rural development.

4.3.2.2 Biomass for small residential heating

Performance improvement of small biomass appliances for residential heating is crucial and an urgent objective in the whole Danube Region and especially in Serbia. In this regard, low-cost solutions of appliances with an acceptable level of pollutants emission is sought.

Some approaches of flue gases treatment of small wooden biomass combustion appliances are presented by Weissinger (2017):

- Integrated of secondary emissions abatement system, after treatment, *e.g.* electrostatic precipitator.
- Fine particle (PM) reduction by extreme staged combustion.
- New approach stove – Candle burner.

Solutions for such approaches are already being developed, c.f. Figure 17, but also in Austria not applied due to their high costs. New innovative solutions sought should be affordable for a larger group of users. Alternative approaches in order to promote their application could be the introduction of incentives for their purchase, a kind of technological bonus. This can also boost further development of better innovative solutions of appliances with low emissions.

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a) b)

Figure 17: Example of developed solutions aimed to reduce pollutants emission, a) modular electric precipitator for flue gases b) solution of extreme staged combustion of wood pellets, with precise dozing of primary, secondary and tertiary air

Particular attention will be paid to innovations for the improvement of efficiency and innovations related to pollutants emissions in the field of agro business use and small and medium appliances for residential heating. In particular this is valid for the utilization of corn cobs as fuel and can have, in Serbia and some other Danube Region countries, significant importance. As previously stated and justified, the introduction of "milder" legislation for agro biomass with "milder" pollutants emission limit levels could be discussed for regions with lower population (and therefore a smaller number of heating units).

Beside innovation for small appliances, innovations for medium and big boilers, especially for residues, have to be considered. These can be used for technological heat generation or for district heating. Heating of greenhouses and drying of agricultural products would be typical examples.

4.3.2.3 Biogas

In this sector the new sustainability criteria defined in the proposed RED directive upgrade (Anonymous, 2016a) and the ones related to ILUC (Anonymous, 2015) are very important. The following objectives and innovations are foreseen:

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1. To mobilize the potential of smaller animal farms, whereby a techno-technological concept of profitable biogas plants that use manure as substrate should be developed. This means mini, 80 to 150 kW and micro units, up to 80 kW of nominal electric power.
2. To increase share of wastes and by-products, and reduce energy crops in substrate mixture used for biogas generation.
3. To close material flow by appropriate digestate utilization, dominantly for soil amelioration, and thus with minimized costs and environmentally sound disposal of this main by-product from biogas production.
4. To investigate and suggest appropriate possibilities for thermal energy utilization to highest possible extent, and at least 30 % of surplus amount.
5. To develop and introduce production of biofuel, biomethane, whereby the saving of GHG emissions should be as high as possible, and at least to fulfill criteria defined by European directives and other documents.
6. To assist administration and decision makers in creation of incentives and other support measures needed to achieve previously mentioned targets.

4.3.3 Task list Novi Sad

The definition of tasks and responsible persons has to be carried out on a local level in order to ensure that local know-how and expertise fully takes advantage of it. The discussion of tasks and results should involve different stakeholders, such as project and network partners to make the process as efficient and results as sustainable as possible.

The task list is not a stand-alone work tool, but one element within the project's activities that serve the overall project goal. Therefore, when fulfilling a task during the implementation phase, it is important to bear in mind which of the objective(s) should be reached by it.

Within the Made in Danube project, several tasks have already been defined. Based upon the identified need for further analysis, an in-depth framework analysis will be carried out, by:

- Conducting interviews with SMEs
- Conducting Interviews with HREs
- Conducting Interviews RPAs

Besides, workshops and working meetings will complement the gathering of information. This information will serve as a basis for the following steps:

1. Potential analysis of the regional SME`s innovation capability
    a. Establish Biofuels Innovation / Information Hub
    b. Creation of IIH / Communication Website X
    c. Collect Technology requests
    d. Identify Technology offers
2. Growth of business network of regional players in the Danube Region
    a. Initiation of 5 new innovation partnership agreements (IPA)
    b. Initiation of 10 new co-operation agreements (CA)
3. Documentation and dissemination of knowledge:

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a. Pilot implementation of the LAP for Biofuels Final Report

The final report on the implementation of the LAP may be the final point of the official Made in Danube project, but should serve as a boost for the future activities of the Novi Sad Biofuels initiative.

Activities that will be performed in next period are aimed to realize effective implementation of LAP biofuels. To find solutions for Serbia will be a focus, but implementation in whole Danube Region as well. The goals planned should be reached through following steps:

On national level

1. Until now a general vision on the topic was presented, in order to do needed improvements and refinements an **external expert** will be selected and consulted.

2. Evaluation of the **results** from the performed **questionnaires** will be carried out in Serbia and other countries, and based on them further necessary steps will be defined.

3. It is planned to establish a IIH (**Innovation Information Hub**) and a corresponding web site for it, within MiD. This website has the objective to inform all parties interested in innovations, also in the sector of biofuels. The partners involved should then be informed about the relevant innovations offers and potential users in their field.

4. Based on collected information so far, and in cooperation with an external expert, one to three **companies** will be **selected to start with a concrete activity** related to the implementation of an innovation. If possible, this depends on nature of innovation solution, it will be tried to finalize it during MiD project duration, or at least to bring activities to the highest possible level.

5. A close **cooperation with relevant public authorities** will be established, whereby most of them are already informed about MiD and participated in the questionnaire. Support for the implementation of innvations will be discussed with them, priorities in field of biofuels, and support models. One of tasks is to try to include biofuels activities in Smart Specialization of Serbia, RIS3 which is still under development.

To **initiate the introduction of regulations** related to pollutants emission for agro biomass, as well as obligatory testing of small heating appliances is also an important activity, and related to public authorities, and society. Introduction of subsidies, technology bonus, for advanced solutions, will be elaborated and proposed as well.

6. With relevant and interested **industrial partner a cooperation agreement** will be signed. This, in a first step, on national level, but, if possible and productive, later on with industry partners in the Danube Region. It will be considered a possibility to apply for national and EU projects, depending of on a call availability, with industrial partners, public authorities and NGOs (including farmers' organizations), related to sector biofuels.

On Danube Region level

7. Relevant providers and F of innovations in MiD partner countries will be **visited**. Their status will be studied and potentials evaluated. The connection between potential partners will be initiated.

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8. With most promising **R&D institutions** contact will be established, in the field of biofuels, in Danube Region the establishment of a network with R&D and other relevant institutions in Danube Region. Joint application for projects on bilateral or EU level, related to biofuels will be considered.

4.3.4 Peer consultation

First consultation partner for the initiative of Novi Sad is the initiative of Nitra (LAP Agriculture). In return Novi Sad will act as consultation partner for the initiative of Vukovar-Srijem County (LAP Sustainable Forestry).

Consultation should take place once a year, the first to be carried out in March 2018, at the occasion of the DTC Meeting in Nitra. A guideline for the consultation and feedback process will be provided by the BOKU beginning of 2018.

4.3.5 Reporting to stakeholders

A regular reporting to external stakeholders is recommended. This reporting serves the initiative to be known, appreciated and supported by local decision makers. Besides, it can be seen as a door opener to for additional funding and a strengthening of the regional network. In the case of the initiative in Serbia reporting will be done to:

1. Ministry of Mining and Energy of Serbia.

2. Ministry of Environment Protection of Serbia.

3. Provincial Secretariat of Vojvodina for Energy, Transport and Civil Engineering.

4. Provincial Secretariat of Vojvodina for Agriculture, Water Management and Forestry.

For this project, which is closely linked with rural development, it is important to be in contact with farmers' associations. The contact with Klub 100P+, association of advanced farmers (more than 400 members), has already been established. Information about MiD will be delivered, twice, on their Winter Seminar.

Further, it is foreseen to inform, about MiD, R&D community in Serbia and the region with the means of a publication presented on relevant meetings.

4.4 Supporting Tool to Local Action Plan

The DTC (Danube Transnational Innovation Cooperation) e-tool is a specialized online platform that can be used by actors operating in bio-economy in the Danube Region, interested in converting research and innovation into applicable and market successful solutions. The instrument is available to any interested potential user under the following link:

http://www.muri.utcluj.ro/tin-etool/index.php?page=login

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Here users can create an account and start exploring its functions, on an individual scale or as a group of potentially related organizations, such as the LAPs.

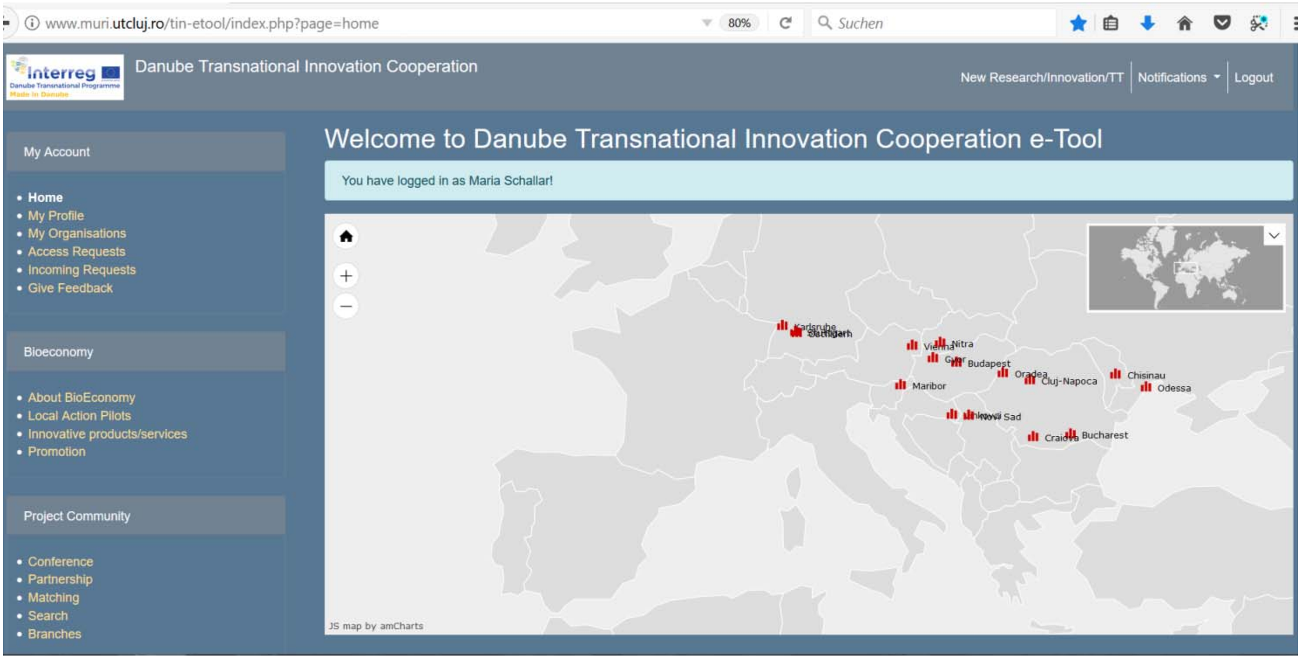

Figure 18: Screenshot TIN eTool: Welcome page

Among the most important features of the platform, the users will be able to present their knowledge offer and search for requests matching their interests and capabilities. They will be able to establish partnerships online and initiate direct collaboration or common involvement in project consortia. Also, within the platform there will be available instruments to help strengthen cooperation within the LAP, such as audio conferencing and project monitoring.

For a better connection to the developments in the field of bio-economy, the platform has a specialized section with information about the project, the LAPs, the specific tools developed by the "Made in Danube" project as well as a promotion and dissemination outlet. Also, the DTC is connected to relevant European data streams that provide useful news with applicability in their own settings. With continuous update and consistent use, the platform will offer the user organizations a quick and effective connection to a network of partners and knowledge that could help them be more competitive and achieve their missions better and have more impact.

Figure 18 and the following images show how the Tin eTool will look like:

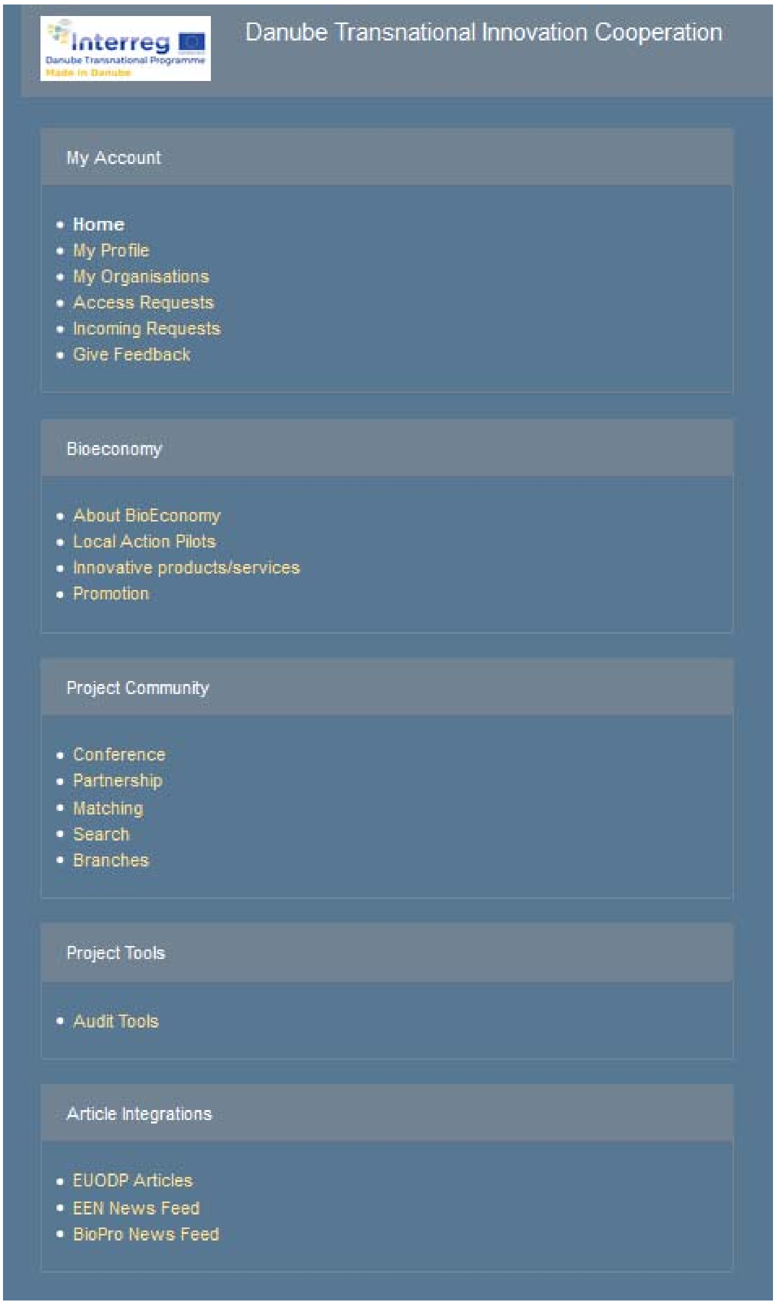

Figure 19: Screenshot TIN eTool: Menu sidebar

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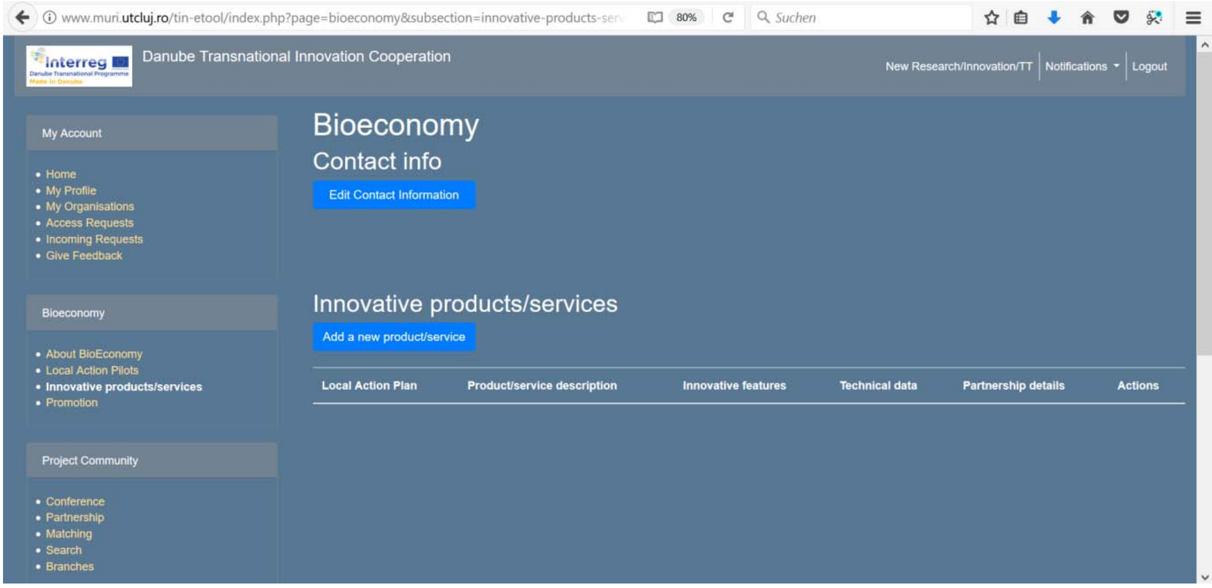

Figure 20: Screenshot TIN eTool: Offering innovative products/services

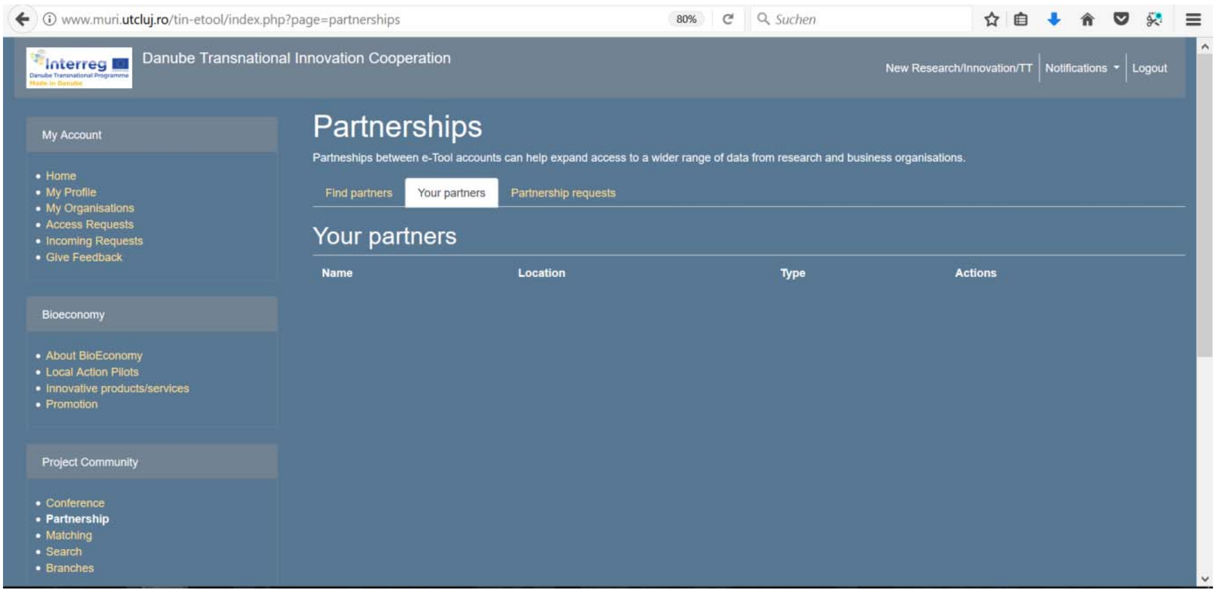

Figure 21: Screenshot TIN eTool: Searching for partners, building partnerships

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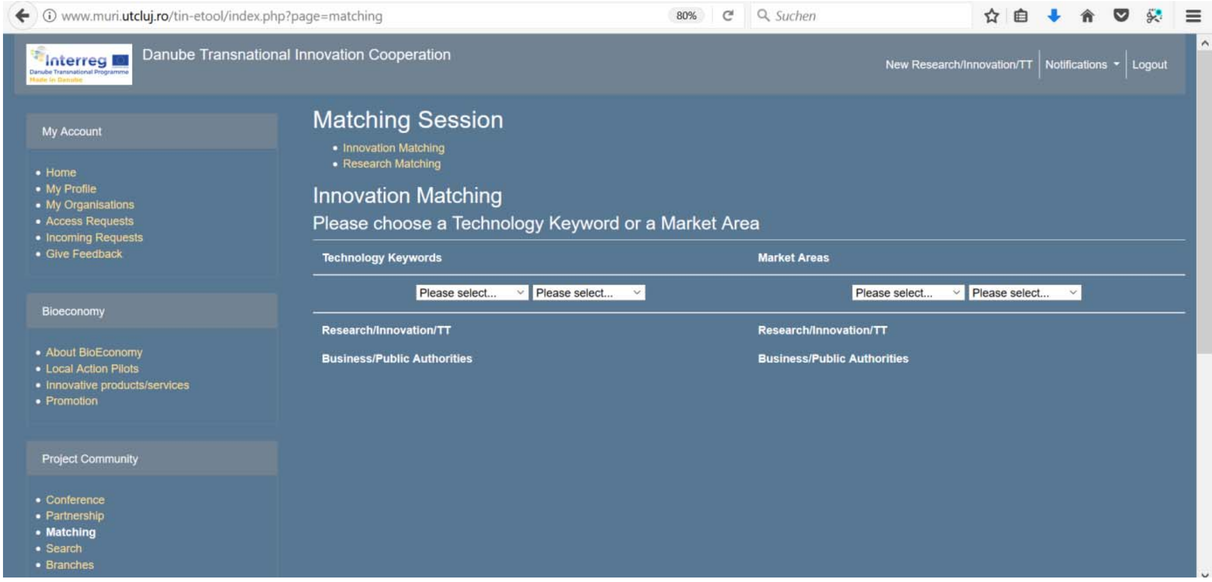

Figure 22: Screenshot TIN eTool: Innovation Matching

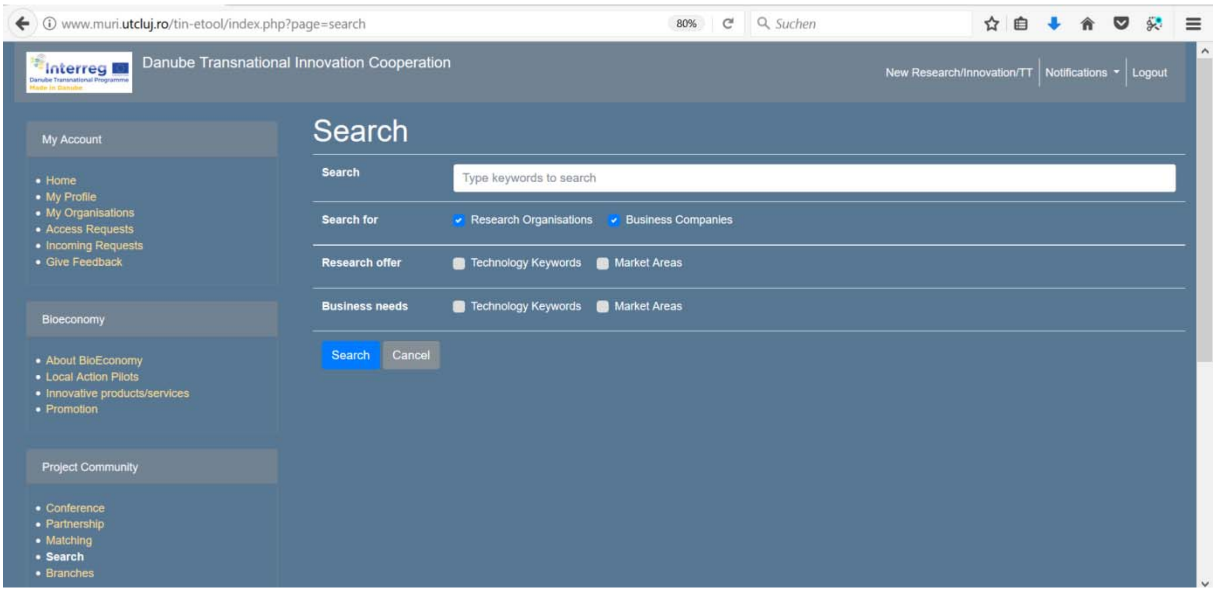

Figure 23: Screenshot TIN eTool: Search function

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5 Conclusions and Recommendations

The whole local action plan is based on a so-called “continuous improvement process” as described in the present document. The possible challenges that could be faced by the initiative are inadequate response of public authorities, SMEs and project partners as well as the lack of financial support for the realization of tasks and lack of adequate project/program calls needed for further implementation steps in order to reach wished (MiD) results.

Therefore, the project needs commitment by many partners and on many levels. Among the major objectives is the **creation of awareness** about the **significance** of biofuels, their proper **production** and utilization pathways, as well as the **improvements** necessary to be introduced by innovative solutions. The innovations should be boost by **linking innovation providers and users**, and getting society and public authorities’ support and incentives for their realization.

Within the LAP biofuels this will be put into practice as a kind of case study for Serbia, but simultaneously the **scope** will be wider, including the **Danube Region and Europe**. By that, experiences and findings will be applicable to the whole region and, to relevant stakeholders, the LAP will serve as an information source, where to find a concise overview of the initiative’s activities, it’s goals and it’s environment.

Mobilization of the still **unused potentials of corn stover and corn cobs**, in Serbia and some other Danube Region countries, is planned. This means finding answers to the questions of proper harvesting, storing and processing methods. Besides a sustainable soil management should be prerequisite for the following steps. Another challenge identified is the need for **improvement** in the area of **small residential heating** by biomass appliances up to 50 kW. In these cases corn stover and cobs are already used, but show low energy efficiency and have high emission rates of airborne pollutants. Searching for **innovative solutions**, possibly at low-cost, is among the objectives in this area.

Third objective is to define possible **improvements for agricultural biogas plants**, to achieve sustainable production and utilization. These objectives should be obtained by close cooperation by all project partners, that should identify potential innovation offers and their users, mostly SMEs.

In order to enable the rollout of the suggested biofuels production, it will be key that functional, not only formal, **networks** should be established. This will ensure that future teams will be able to realize the goals set by national, bilateral and EU projects. By this it will be secured that the **scientific know how available will be complemented by partners** from other fields (such as industry and agriculture) and lead the way to marketable products.

All tasks planned have clear **societal dimensions**, fulfill EU policy defined in the area of RES, while applying sustainable and affordable (costs) solutions, and support development of rural areas.

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