



CELEBio

D4.4

NATIONAL BIOECONOMY DOSSIER: CROATIA

IVONA HULENIĆ, DINKO ĐURĐEVIĆ,
BILJANA KULIŠIĆ, ŽELJKA FIŠTREK,
ANA MANDARIĆ
EIHP

SCIENTIFIC COORDINATION:
B. ELBERSEN, WUR
C PANOUTSOU, IC

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 838087

12/2020



EXECUTIVE SUMMARY

Work package	4
Activity	A.4.2.2
Task	n/a
Deliverable No	D.4.4
Deliverable Title	National Bioeconomy Dossier: Croatia
Responsible partner	EIHP, CEI-ES
Author(s)	Ivona Hulenić, Dinko Đurđević, Biljana Kulišić, Željka Fištrek, Ana Mandarić
Editor(s)	Alice Pappas, Peter Canciani
Quality reviewer(s)	Calliope Panoutsou, Berien Elbersen, Julien Voogt, Peter Canciani
Due date of deliverable	M18
Actual submission date	M18
Level of dissemination	PU
Publishable executive summary in English	<p>Technical reports produced in WP2 and WP3 have been edited to be used as dissemination materials to the benefit of Bioeconomy stakeholders and potential investors, highlighting the strengths of the Target Countries.</p> <p>Six specific dossiers have been prepared for each Target Country, each of them including: (Part A) an updated assessment of sustainable biomass potentials, including techno-economic information regarding infrastructures logistics and relevant costs, as well as an overview of the legislative provisions; (Part B) a map (listing of relevant stakeholders according to the general template for 6 targeted countries; (Part C) presentation of a set of 3 value chains according to uniform criteria for 6 countries provided by the coordinator and workpackage lead and time-based guidelines for the development of a national Action Plan proposing concrete measures to foster investments in the Bioeconomy basing on different development scenarios.</p>
Publishable executive summary in national language	<p>Tehnička izvješća izrađena unutar ranih paketa 2 i 3 uređena su kako bi bila korištena kao diseminacijski materijal, koji će koristiti dionicima bioekonomije i potencijalnim investitorima, naglašavajući snage razmatrane zemlje.</p> <p>Pripremljeno je šest specifičnih dosjea, za svaku ciljanu zemlju unutar okvira projekta, od kojih svaki sadrži: (A dio) ažuriranu procjenu potencijala održive biomase, uključujući i tehno-ekonomske informacije u pogledu infrastrukture, logistike i relevantnih troškova, kao i pregled zakonodavnog okvira; (B dio) popis relevantnih dionika bioekonomije na nacionalnoj razini prema kriterijima i uputama koordinatora; (C dio) prezentaciju 3 seta vrijednosnih lanaca odabranih prema kriterijima koordinatora i vremenski definiranih smjernica za razvoj nacionalnih akcijskih planova, u kojima se predlažu konkretne mjere za poticanje investicija u bioekonomiji, temeljene na različitim razvojnim scenarijima.</p>

DISCLAIMER

The information provided by the CELEBio project does not necessarily reflect the official opinion of the institutions and bodies of the Republic of Croatia. The Government of the Republic of Croatia does not accept any liability or obligation arising from or related to the information in these documents.

This document is a product of project Central European Leaders of Bioeconomy Network (CELEBio), funded by BBI JU under the EU Horizon 2020 research and innovation programme.

TABLE OF CONTENTS

TABLE OF CONTENTS	4
Summary	8
Methodology.....	12
1. SUSTAINABLE BIOMASS AVAILABILITY IN CROATIA.....	13
1.1. Short characterisation of the country	13
2. BIOMASS SUPPLY: AGRICULTURE	18
2.1. Introduction.....	18
2.2. Characterisation of current agricultural sector	18
2.3. Crop production.....	21
2.3.1. Cereals.....	23
2.3.2. Oil crops.....	24
2.3.3. Permanent crop production.....	25
2.3.4. Livestock, related fodder production and use of pastures.....	26
2.4. Biomass potentials from residues and unused lands	28
2.4.1. Lignocellulosic residual biomass potential from crops.....	28
2.4.2. Residues from permanent (woody) crops	31
2.4.3. Dedicated crop potentials from unused lands	31
2.4.4. Residual biomass potentials from livestock.....	33
2.5. Agricultural processing industries	34
2.5.1. Main agri-food processing industries.....	34
2.5.2. Side-products from agri-food processing	35
2.6. Cost of main biomass sources	37
2.7. Summary and conclusions in relation to SWOT elements	38
3. BIOMASS SUPPLY: FORESTRY	39
3.1. Introduction.....	39
3.2. Primary biomass resources from forestry, current and planned harvest levels and uses	45
3.3. Secondary biomass resources from forestry: wood processing industries.....	51
3.4. Forest biomass mobilisation options.....	54
3.5. Summary and conclusions in relation to SWOT elements	55
4. BIOMASS SUPPLY: WASTE	57

4.1.	Introduction.....	57
4.2.	Waste from biological resources.....	59
4.3.	Current waste treatment and unused potential estimates	65
4.3.1.	Existing waste treatment facilities.....	65
4.3.2.	Estimates of waste potential	68
4.4.	Summary and conclusions in relation to SWOT elements	70
5.	BIO-BASED PRODUCTS INDUSTRIES AND MARKETS	72
5.1.	Current bio-based industries.....	73
5.1.1.	Bioplastics	73
5.1.2.	Wood processing industry	74
5.1.3.	Food and feed ingredients industries.....	74
5.1.4.	Pharmaceutical and cosmetic industry.....	75
5.1.5.	Valorisation of secondary materials from waste sector	75
5.2.	Advanced bio-based initiatives: demo and pilot plants and major innovation activities	76
5.3.	Future Biomass valorisation options.....	79
5.4.	Summary and conclusions in relation to SWOT elements	80
6.	INFRASTRUCTURE, LOGISTICS AND ENERGY SECTOR	81
6.1.	Existing industrial hubs and harbours	81
6.2.	Existing railway	84
6.3.	Existing road infrastructure	87
6.4.	Energy sector	89
6.5.	Summary and conclusions in relation to SWOT elements	92
7.	SKILLS, EDUCATION, RESEARCH AND INNOVATION POTENTIAL	94
7.1.	Availability of skilled operators and service providers.....	94
7.2.	Research infrastructure	97
7.3.	Educational infrastructure.....	101
7.3.1.	Secondary education	101
7.3.2.	Higher education.....	102
7.4.	Environment for start-ups	102
7.5.	Public-private partnerships	104
7.6.	Summary and conclusions in relation to SWOT elements	106
8.	POLICY FRAMEWORK: REGULATIONS, LEGISLATION, RULE OF LAW & TAXES AND TARIFFS	107
8.1.	Introduction.....	107

8.1.2.	Smart specialisation strategy 2016-2020.....	107
8.1.3.	Industrial Strategy of the Republic of Croatia 2014.-2020.	108
8.1.4.	CAP: Croatian Rural Development Programmes 2014-2020.....	108
8.2.	Summary and conclusions in relation to SWOT elements	113
9.	FINANCING	114
9.1.	Introduction.....	114
9.2.	Summary and conclusions in relation to SWOT elements	116
10.	ACTORS IN AGRICULTURAL AND AGRO INDUSTRIAL SECTOR	118
10.1.	Actors in primary agricultural sector	118
10.2.	Actors in agro industries	121
10.3.	Other actors related to agriculture & agro-processing chain.....	125
10.4.	Clusters and organisations	128
11.	ACTORS IN FORESTRY AND FOREST INDUSTRY.....	129
11.1.	Actors in wood pellet production	133
11.2.	Clusters and organizations.....	134
12.	ACTORS IN THE WASTE SECTOR.....	135
12.1.	Clusters and organizations in by-products creating sector	136
12.2.	Clusters and organisations creating by-products.....	142
13.	ACTORS IN FISHERIES, AQUA-CULTURE AND OTHER SECTORS	146
13.1.	Actors in fisheries and aquaculture	146
13.2.	Clusters and organisations	154
14.	ACTORS IN BIO-BASED INDUSTRIES AND MARKETS	156
14.1.	Bioplastics	156
14.2.	Chemical and petro-chemical industries.....	158
14.3.	Energy	160
15.	ACTORS IN KNOWLEDGE AND INNOVATION	173
15.1.	Campus, incubators and technology parks & hubs	173
15.2.	Scientific and research institutions	174
16.	GOVERNMENT AND NGOs.....	179
17.	FINANCIAL ORGANISATIONS & BANKS.....	182
18.	GUIDELINES FOR CROATIAN BIOECONOMY ACTION PLAN	184
19.	BIOECONOMY IN CROATIA	185
19.1.	Current state	185

19.2.	Strengths, opportunities and barriers	186
19.3.	Policy mechanisms relevant to bioeconomy in Croatia	188
19.4.	Sector-specific framework	190
19.4.1.	Agriculture	190
19.4.2.	Forestry	192
19.4.3.	Biowastes	193
19.4.4.	Other legislation framework related to bioeconomy	194
20.	VISION AND IMPLEMENTATION PLAN	197
20.1.	Strengthen and scale-up the bio-based sectors, unlock investments and markets	198
20.2.	Deploy local bioeconomies rapidly across Croatia	199
20.2.1.	Agriculture	199
20.2.2.	Forestry	200
20.3.	Understand the ecological boundaries of the bioeconomy	201
21.	VALUE CHAINS FOR THE CROATIAN BIOECONOMY	204
21.1.	Poultry meat streams	205
21.2.	Short rotation crops in marginal land	206
21.3.	Forest based value chains	207
21.4.	Biowaste value chains	208
22.	IMPLEMENTATION PLAN	210
23.	REFERENCES	215
24.	TABLE OF ILLUSTRATIONS	216

Summary

The main objective of CELEBio is to contribute to strengthening Bioeconomy-related activities in Bulgaria, Czech Republic, Croatia, Hungary, Slovak Republic, Slovenia, and the neighbouring countries. To this end one of the key activities is to develop six comprehensive reports for the target countries and the wider neighbouring region on the availability of sustainable biomass, logistics, costs, and biomass business opportunities assessed through an analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT). The documents represent a good start but not full overview of the bioeconomy potentials for Croatia to transit to circular and sustainable bioeconomy.



Technical reports produced in WP2 and WP3 have been edited to be used as dissemination materials to the benefit of Bioeconomy stakeholders and potential investors, highlighting the strengths of the Target Countries.

Six specific dossiers have been prepared for each Target Country, each of them including: **(Part A)** an updated assessment of sustainable biomass potentials, including techno-economic information regarding infrastructures logistics and relevant costs, as well as an overview of the legislative provisions; **(Part B)** an exhaustive map listing of relevant stakeholders; **(Part C)** presentation of a set of value chains and time-based guidelines for the development of a national Action Plan proposing concrete measures to foster investments in the Bioeconomy basing on different development scenarios.

Part A. of this desktop report aims to provide the necessary background information needed to evaluate the possibilities for setting up bio-based production chains in three different sectors: agriculture, forestry, and waste management in Croatia.¹

Croatia is a small country in the EU according to land surface with 4 million inhabitants, with over 60% living in the rural areas, and around 20% living in urban areas. However, there is a threat of the outflow of skilled labour, which in turn has a negative impact on economic performance and the economic situation in general.

¹ The information structure and analysis presented in this report was developed by building on the method designed and applied by Van Dam et al. (2014) and was further refined through the execution of interviews with bio-based business developers and other experts. In these interviews further information was obtained on key factors that guide the choice of setting up bio-based activities in countries. Most of the experts stressed that all the identified factors are important and that a system approach is key in developing bio-based initiatives. If one link in the chain is missing, the bio-based initiative will not succeed. The identified factors are mapped in this report and will be the basis for performing a SWOT analysis for development of bio-based production chains.

Forest area makes up 49.3% of Croatia's land area, which is mostly located in the central and northern parts of the country. Agricultural land makes up 27% of the land area, mostly in the southern parts of the country with a typical Mediterranean agriculture and on the North, grain and industrial crops (sugar beet, oil crops) and vineyards.

Croatia is a significant part of Trans-European Transport Network (TEN-T), with 6 important coastal ports and a significant potential within inland marine ports. Its strategic geographical position is exceptionally favourable for supplying markets in Central and Eastern Europe and has a high impact on markets as a leader in the Balkan area. The ports are well connected with railway and especially the road network. Furthermore, the energy sector is well connected all along the country, but also with neighbouring countries through the transmission network.

Agricultural biomass production, harvesting and collection in Croatia is a challenge for various reasons: bulkiness, dispersed production, considerable amounts of water in the biomass, etc. The concept of bio-hubs came to life only in Istria, where local farmers are currently in the process of setting up a hub. However, biomass from agricultural sector in Croatia has a large potential for future development (e.g. unused potential available from primary residues, secondary residues and unused lands), but there are also several threats to this development (e.g. lack of market for high added value biomass).

Regarding forestry sector, Croatia has a relatively large forest potential for the small-sized country it is. Forests are considered as one of the most important resources for Croatian economy, both as energy source and feedstock for wood processing industry. Forestry and wood processing sectors have a long tradition and are well developed. However, statistical data are sometimes weak or contradictory, especially in the case of fuelwood and wood residues from wood processing industry. Moreover, it is necessary to improve infrastructure to mobilise biomass in areas that are more remote and establish a group of private forest owners to manage their land more successfully.

Waste management sector in Croatia is improving each year (amounts sent to landfills decrease and reuse and recovery of waste increase), however, the progress is very slow. Moreover, raw materials are lost with lack of energy and material recovery systems. Generated waste is treated in various ways, but the largest share is still going to landfill. Biodegradable waste is treated through landfilling, anaerobic digestion and composting, which presents a lot of opportunities, in regard to its improved utilization (e.g. energy and material recovery). However, due to lack of knowledge on Bioeconomy principles (especially low public awareness) and its possibilities, a significant amount of waste that could be energy/materially recovered ends up unused.

Although current bio-based industry is relatively small and there is no Bioeconomy strategy, Croatia has great potential to foster bioeconomy development. With a strong foothold in wood processing and food and beverage industry, there is room for significant innovation activities and new business models. This is fostered by a large number of stakeholders, that have the potential to implement bioeconomy principles in Croatia. These stakeholders are mentioned in **Part B**, which includes an overview of all actors and actor groups that need to be involved when setting up biomass delivery chains. The actors presented can be specific persons, companies, and other type of organisations (e.g. farmers organisations), for which the following information was obtained: Company/person name; location; type of activity/function; specific number of employees; existing involvement in bio-based activities.

In order to utilize the opportunities and potentials available in the country, Ministry of Agriculture took the lead in the development of Bioeconomy Strategy and Action Plan. To assist the Ministry of Agriculture in development of the aforementioned documents, within this project, a specific document was developed, that specifies the steps and activities that need to be taken, in order to realise the potentials of Croatian bioeconomy. **Part C** covers this part and focuses on the existing problems and bottlenecks existing in the current bioeconomy implementation process – e.g. a

lack of communication between important stakeholders and leaders of the bioeconomy sector; establishment of organisations/agencies that are oriented solely on bioeconomy; connecting all stakeholders; introducing financing for environmentally friendly practices; etc. Implementation of these measures and steps could contribute to quality implementation of vast resources and potentials that Croatia contains, and could deliver the following results (presented in the following table):

Potential environmental impacts of the Croatian Bioeconomy Action Plan



Reduce emissions by 55%²



Contribute to the sustainable management of natural resources and foster efficient water use.



Biodiversity



Local resources for products, energy and fuels

Potential socio-economic impacts of the Croatian Bioeconomy Action Plan



Create 1,000 new jobs in agriculture, forestry and food processing industry^{3,4,5}



Leverage 50 million € private investments within ten years⁶



Cluster creation.
At least ten new collaborations between raw material providers and industrial actors



Eight new biobased value chains embedded in agriculture, food, and forest industries.

Produce ten new patents and IP rights, Support the creation of ten spin-offs and start-ups.

² European Green Deal. 2020. https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en#:~:text=The%20Commission%E2%80%99s%20proposal%20to%20cut%20greenhouse%20gas%20emissions,more%20ambitious%20path%20for%20the%20next%2010%20years.

³ S2Biom project; www.s2biom.eu

⁴ Robert Pollin, James Heintz, and Heidi Garrett-Peltier June 2009. *The Economic Benefits of Investing in Clean Energy* Department of Economics and Political Economy Research Institute (PERI) University of Massachusetts, Amherst.

⁵ Panoutsou, C.; Chiamonti, D. *Socio-Economic Opportunities from Miscanthus Cultivation in Marginal Land for Bioenergy*. *Energies* 2020, 13, 2741. <https://doi.org/10.3390/en13112741>

⁶ BBI JU, <https://www.bbi.europa.eu/projects>



PART A

SUSTAINABLE BIOMASS AVAILABILITY AND SUPPLY IN CROATIA

Methodology

The information gathered in this document are based on the desktop research that compiles relevant data on different elements of bioeconomy in Croatia, based on the templates provided by the coordinator and work package leads. The compilation provides a rough insight in the most abundant biomass sources available in Croatia as well as capacity of other aspects of an economy, such as infrastructure, education, stakeholders, legal framework etc necessary for transition to circular and sustainable bioeconomy. However, the conclusions and selections of value chains, status, needs and priorities as well as overall conclusions are the sole responsibility of the CELEBio project and do not necessarily reflect the opinion of the Republic of Croatia.

This is due to the limitations of the project, both by timeframe and budget, which were addressed by creating designated templates for 6 targeted countries: Bulgaria, Croatia, Czech Republic, Hungary, Slovak Republic and Slovenia. This led to several shortcomings across the implementing countries. For Croatia, those were missing assessment of blue growth and maritime bioeconomy as well as limited value chains for such versatile ecosystems and possible cross overs from primary sectors to (future) bio-based industry, to start from.

The work package leaders provided template and methodology while the target countries provided data according to their instructions. Therefore, this document does not represent the true situation of bioeconomy status in Croatia but is an overview of collected available data and information, which are summarized within specific templates, provided by the project partners.

It should also be noted that this document encompassed the data and focused on three sectors: agriculture, forestry and waste management. It is important to stress out Croatian potentials for transition to circular and sustainable bioeconomy are beyond those three sectors assessed in this project. Fisheries, aquaculture, hunting, waste, food preparation and processing waste, nature capital, tourism and service sector... are also considered as elements of Croatian bioeconomy but are not assessed as being out of the scope of the project and the templates provided.

The full presentation of bioeconomy sectors and status in Republic of Croatia is currently being developed under the lead of the Ministry of Agriculture (In cooperation with other relevant ministries), within the development of Croatian Bioeconomy Strategy.

1. SUSTAINABLE BIOMASS AVAILABILITY IN CROATIA

1.1. Short characterisation of the country

Croatia is a small country in the EU according to land surface with 4 million inhabitants (See Table 1). The average income level is relatively low in comparison to the average of the EU. The export value expressed in €/capita is still relatively low.

Table 1 Population, land surface, GDP and trade characteristics of Croatia benchmarked against EU average

Category	Croatia	EU	Unit
Population	4.1	512.4	million (2018)
Area (total)	5.7	447	million ha (2018)
% population in urban areas	19.6	44.9	% of total population (2018)
% territory predominantly rural	62.9	43.8	% of total territory (2018)
% territory predominantly urban	1.1	10.7%	% of total territory (2018)
Agricultural Area	1.6	173.3	million ha (2016)
Forest area	2.76	164.8	million ha (2016)
Population density	73	115	n°/km ² (2018)
Agricultural Area per capita	0.38	0.34	ha/capita (2016)
Forest area per capita	0.67	0.32	ha/capita (2016)
GDP/capita	13,251	30,956	at current prices in 2018
	20,510	30,956	GDP at purchasing power in 2018
GVA by Agriculture, forestry and fishing	3.6	1.6	% of total GVA (2018)

GDP = Gross Domestic Product; GVA = Gross Value Added

Source: Eurostat most recent statistical data sources (Accessed August/September 2019) (<https://ec.europa.eu/eurostat/data/database>)

With the Adriatic Sea on the east (border with Italy), Croatia is surrounded in the North with Slovenia and Hungary, and in West with Serbia and Southwest with Bosnia and Herzegovina.

Over 60% of the Croatian population lives in rural areas, which is relatively high compared to the rest of Europe. Only close to 20% of the population lives in urban areas (Table 1), which is relatively high considering that only 1% of the land area is predominantly urban. The population density is also lower than the European average, and the GDP is significantly lower. Gross value added by agriculture, forestry and fishing is more than twice that of the European average.

Croatia's 5 largest urban centres are Zagreb, Split, Rijeka, Osijek, Zadar with 0.79; 0.18; 0.13; 0.11 and 0.08 million inhabitants.

Forest area makes up 40% of Croatia's land area, which is mostly located in the central and northern parts of the country. Agricultural land makes up 27% of the land area, mostly in the southern parts of the country with a typical

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Mediterranean agriculture and on the North, grain and industrial crops (sugar beet, oil crops) and vineyards. North to South road infrastructure is well defined with modern and fast highways from Zagreb to all end points of Croatia: Dubrovnik and Ploče (industrial port), Rijeka (port), Istria to Italy and Slovenia, Osijek to Danube (port) and Serbia, and to Varaždin and Hungary (Figure 1 and Figure 2). Train infrastructure needs modernisation but is well interconnected.



Figure 1 Major transportation routes in Croatia (source: Ministry of Transport, Republic of Croatia)

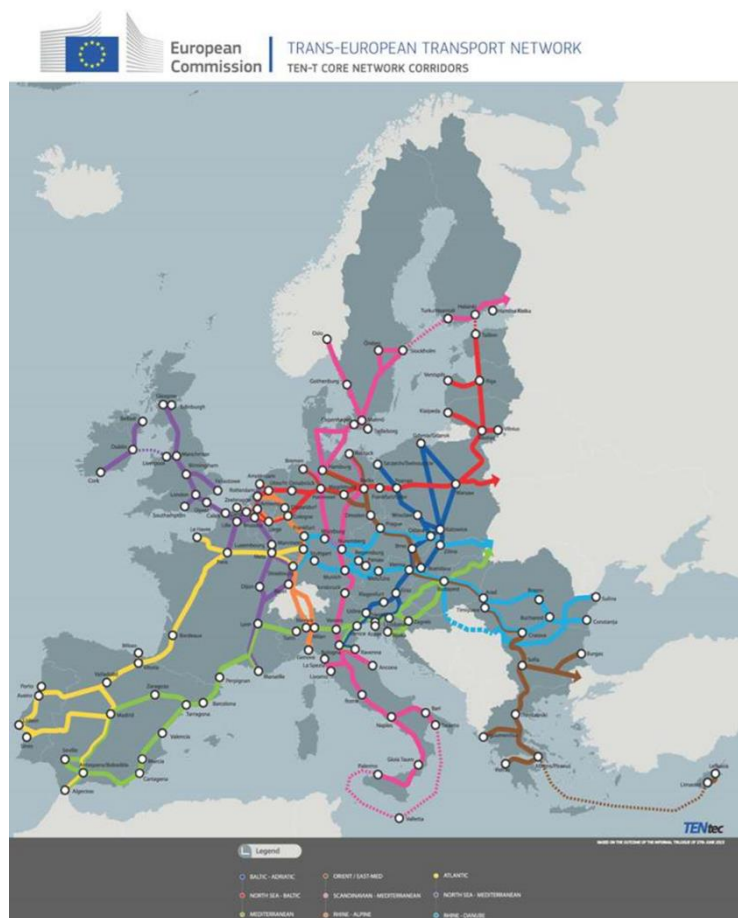
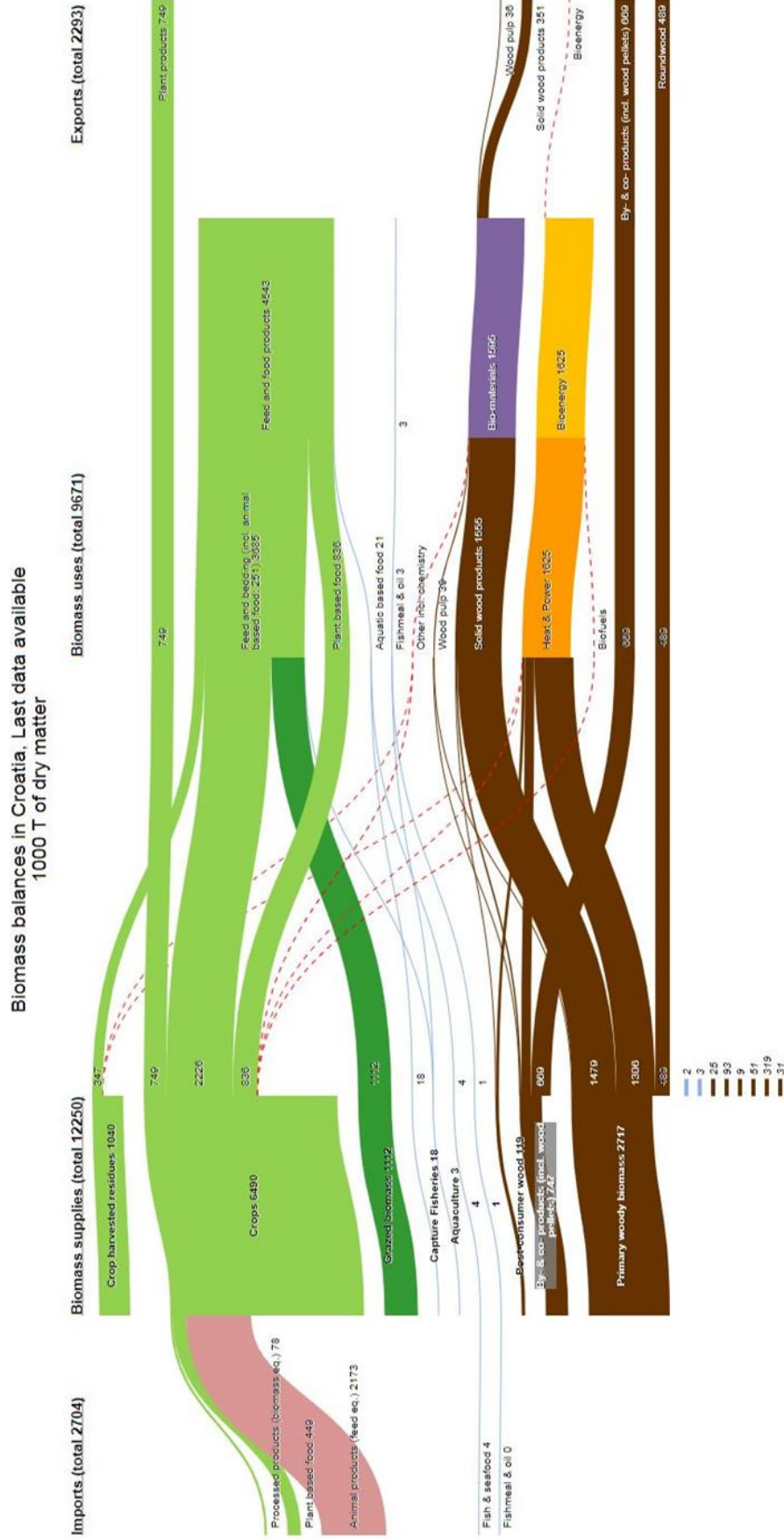


Figure 2 Position of Croatia in the Trans-European Transportation Network

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087



et al., 2017: <https://datam.jrc.ec.europa.eu/datam/public/pages/index.xhtml>

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Explanation of Sankey diagram (Figure 3):

the Sankey biomass diagram is split into biomass supply (shown on the left of the diagram) and biomass uses (right portion of the diagram). Each of these areas shows different categories: agriculture, forestry and fishery (supply), as well as feed and food, biomaterials, bioenergy, and direct exports for each sector (uses). All supply and uses of biomass have been converted to Ktonnes dry mass before integrating in the diagram. It is important to know that some of the components of the diagram will be missing for a certain country and/or year if the corresponding data has been reported as zero. This implies that the flow data should be interpreted with care as not all diagrams cover all biomass supply and/or use categories present.

Further information on the method and source data in: <https://publications.europa.eu/en/publication-detail/-/publication/a19750d4-5498-11e7-a5ca-01aa75ed71a1/language-en>

From the Sankey diagram for Croatia (Figure 3) the following main observations can be made (quantities below are all expressed in million tonnes of dry matter). The main biomass supply produced in Croatia is from crops (6.49), grazed biomass (1.11) and primary woody biomass from forests (2.71). Most of the cropped and grazed biomass is used for food and feed production (4.54); and the woody biomass is converted to heat and power (1.63), and solid wood products (1.55). The largest export volume are plant products (0.75) and solid wood products (0.35). Imports consist mostly in volume of animal products (2.17).

The production of biomaterials and bioenergy is much smaller than food, feed and plant products. Bioenergy is produced in combined heat and power plants (CHPs) on biogas (46.42 MW in 41 plants⁷) and solid biomass (70.71 MW in 33 plants¹). Waste streams are slowly but steadily entering biogas feedstocks and pushing out maize silage (Figure 4). Very little solid biofuels are produced from crop residues in terms of agropellets (50 t/year capacity in 2018). Croatia holds 1% of the world's total pellet production and 3% of the total EU28 exports in 2016 (AEBIOM, 2017). Annual production of wooden pellets is 315,370 t/year production or 77% of the production capacities (EIHP, 2017), where only 15% stays for domestic consumption. The pellets are made both from primary and secondary residues, where secondary residues prevail.

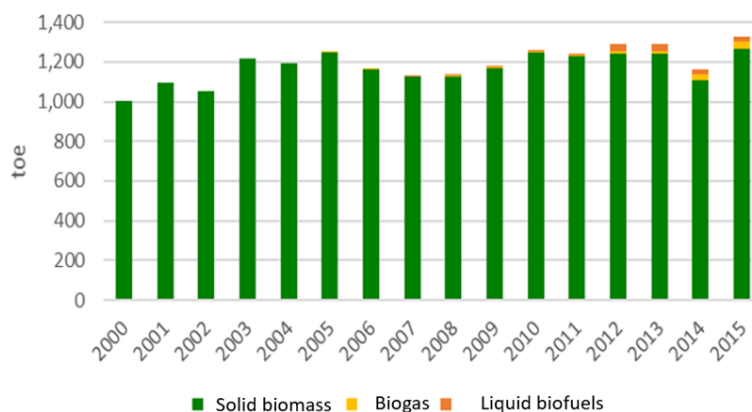


Figure 4 Production of solid, gaseous and liquid biofuels in Croatia (EIHP, 2017)

⁷ Croatian Energy Market Operator, data from August 2019.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Croatian Sankey is very similar proportionally to the EU Sankey in terms of biomass production, but it differs greatly by imports of biomass (2,704) which amounts ~40% of the plant-based biomass produced within the country. This reflects poor productivity and room for improvement of the national biomass supply. In terms of biomass uses, there are also many similarities except that Croatia uses much less wood pulp, and a lot of the woody biomass is exported. Whereas EU-total records exports of animal produce which generate a high added-value, the export from Croatia is dominated by low added-value-commodities such as roundwood, primary plant products and wood pellets.

Food, beverage and tobacco contribution is about half of the total turnover, second by agriculture (Figure 5). While the turnover from food & beverage sector remained stable in absolute numbers, the turnover from agricultural sector is steadily reducing over the decade, ending up at 73% in 2017, in comparison to the 2008 turnover (Figure 6). The 3rd sector by the turnover is Wood and wooden furniture industry that recorded a 26% growth within a decade, but its overall contribution is at 11% in 2017. Similar patterns apply to the bio-based electricity that recorded 2,974% growth since the supporting framework for electricity from renewable energy sources was launched in 2007. The structure of the total turnover of bioeconomy indicates low productivity of bio-based sectors.

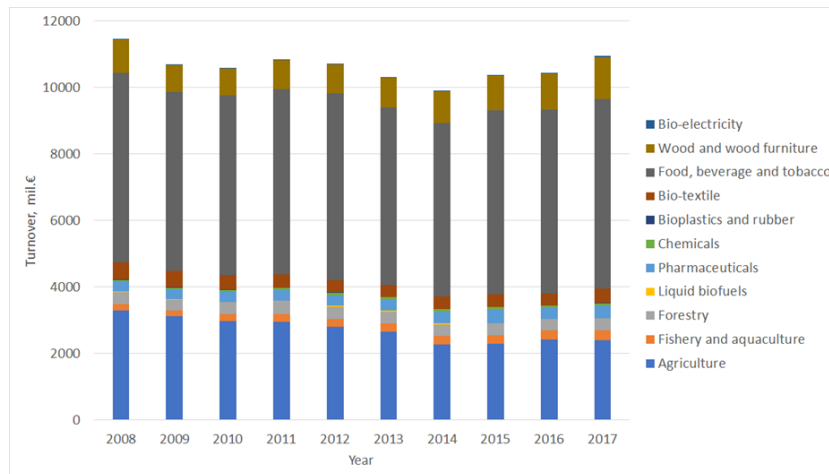


Figure 5 Timeline of bio-based sectors' turnover in Croatia (source: JRC, 2020)

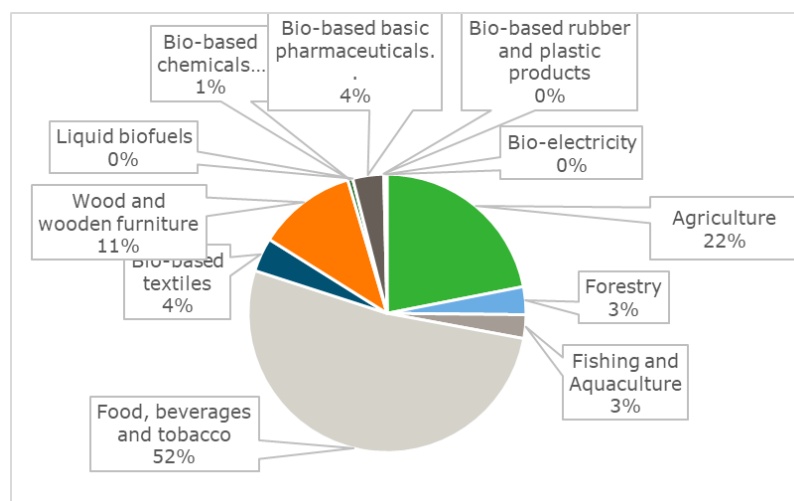


Figure 6 The structure of turnover from Croatian bio-based sector, 2017 (source: JRC, 2020)

2. BIOMASS SUPPLY: AGRICULTURE

2.1. Introduction

In this chapter the agricultural biomass production and main uses is described. A distinction will be made between the main economic products produced and their main process chains and residual biomass potentials from primary production and available as by-products of food processing industries. The residual biomass sources, certainly the ones from primary sources, are largely not used, as already became clear from Section 1.3. In addition to presenting the main biomass production, attention will also be paid to the importance and the structure of the agricultural sector and to the main environmental challenges associated with agriculture in Croatia.

2.2. Characterisation of current agricultural sector

Croatia can be divided into three geographic and climate zones: the lowland with a continental climate in the north of the country, the Mediterranean coastal zone in the south, and the mountainous zone across the central part. With a varying climate, landforms and soils, the country is rich in biodiversity and is in a favourable position to produce a wide range of agricultural products, from field crops to grapes and continental and Mediterranean fruits and vegetables. Agriculture, forestry and fishing generate 3.5% of Croatian GDP. About 1.5 million hectares are utilised agricultural land, of which 54.5% refers to arable land and gardens; orchards, vineyards and olive groves occupy 4.7%, and permanent grasslands covering 40.6% of the used surface (Croatian Bureau of Statistics, 2018a) (Figure 7). Cereals and oilseeds are mainly cultivated in the Pannonian region, which covers 55% of the national territory and is characterized by moderately warm and humid climates (Croatian Chamber of Economy, 2017).

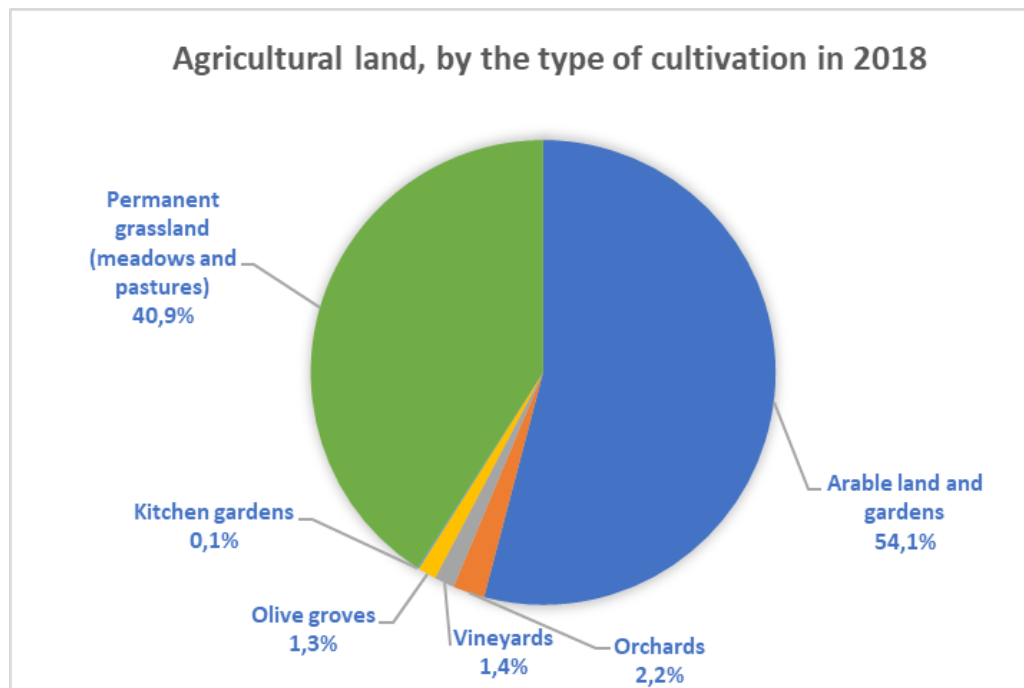


Figure 7 Agricultural land, by the type of cultivation in 2018 (Ministry of Agriculture, 2019)

The average farm in Croatia uses 11.6 ha of agricultural land which is significantly less than the EU-27 average (on average 15.2 ha). The arable land of most farms is very fragmented and often distant from each other, which is one of the reasons for the inefficiency of agricultural production; in 2011, the agricultural production was carried out on an average of 15 cadastral parcels. Farms of up to 20 ha continue to dominate the structure of farms. According to the organizational form of farms in 2018, most farms operated as family farms (OPG), or as many as 162,966 (95.5%), with average size of 5.3 ha per farm (Ministry of Agriculture, 2020). During 2019, Croatian farmers used a total of 1,145,070.6 ha of agricultural land. The holders of Croatian farms are older. As many as 66,683 farmers have holders over 65 years old (39.1% of the total number of farmers), while only 21,746 farmers have holders under 40 (12.7% in the total number of farmers) (Table 2).

The first producer group in Croatia was registered in March 2014, in milk and dairy products sector. Nowadays, there are 22 recognized producer organizations in Croatia. This situation of the small average farm size and organisational form of farms in Croatia indicates towards low economic sustainability.

Table 2 Key characteristics for the agricultural sector in Croatia

Category	Croatia	EU average	Unit
Agriculture in % of total employment	6.4	3.9	% of total employment 2017
Agricultural area per capita	0.38	0.34	ha/capita
Cereal yield	7	5.2	t/ha
Crop output in total output	60	57.5	% of total agricultural output value (2018)
Livestock output in total output	35	42.5	% of total agricultural output value (2018)
Agricultural income (2010=100)	125.83	124.5	Index 2010=100 (2018)
Livestock density		1.02	LSU/ha UAA
High input farms	29	29	%/total farms 2016
Low input farms	25	39	%/total farms 2016
Gross nutrient balance nitrogen	60	51	kg of nutrient per ha (average 2011-2015)
Gross nutrient balance phosphorus	5	1	kg of nutrient per ha (average 2011-2015)
Irrigated utilised agricultural area	1.0%	n.a.	% of UAA 2016
HNV farmland	90	41	% of agricultural land
Soil erosion	3.04	2.4	tonnes/ha/yr 2012
Average farm size	11.6	15.2	ha UAA/holding (2016)
% of agr. holdings < 5 ha	69.5	62.6	%/total no. of holdings

HNV = High Nature Value; LSU = livestock unit; UAA = utilised agricultural area (Source: S2BIOM, Benchmarking factsheets (<https://s2biom.wenr.wur.nl/web/guest/data-downloads>) updated with https://ec.europa.eu/agriculture/statistics/factsheets_en), additional Eurostat data (<https://ec.europa.eu/eurostat/web/agriculture/data/database>) and Ministry of Agriculture "Annual report on agriculture status in 2019")

The agricultural land per capita and agricultural employment in Croatia are slightly higher than the European average, although the ratio of agricultural land to total land area is similar. Croatia has slightly more high input farms (29%) than low input (25%); which is the reverse in Europe (29% vs 39%, respectively).

The Nitrogen (60 kg of nutrient per ha) and Phosphorus (5 kg of nutrient per ha) nutrient balances show relatively high losses as compared to the European average, which is likely related with relatively large differences between nutrient inputs and the nutrients that are removed by the crop with the harvest.

The share of agricultural land that is classified as High Nature Value farmland is extremely high which implies that Croatia still has large abundance of habitats and species with high nature conservation value in agricultural lands. These nature values depend for their conservation on a continuation of more traditional and low input farming systems.

Only 1% of the utilized agricultural area is irrigated, yet there is a high level of soil erosion due to wind and floods. There are slightly more farm holdings of <5 ha than the European average. In general, the soil quality is of good, and the farming conditions are relatively similar to the European averages.

Given the increasing challenges of agricultural production due to climate change, farmers need to think about how to maintain stable and sustainable agricultural production. Both current and new generations of farmers need to be educated to apply new practices, new technology and strike a balance between greater production and environmental protection. Education is key to spreading new knowledge and applying it. Also, negative agricultural practices in various aspects of agriculture can be mitigated through the proper education of all key stakeholders in the agricultural chain: from the primary producers to the end consumers.

Moreover, there is a need to connect agricultural production with food processing industry, which presents an important opportunity for Croatia, since food processing industry creates strong impacts on the whole economy, in terms of added value and new job openings. This is also important in terms of connecting farmers and agriculture sector with other sectors (especially technology development and innovation sectors), that will lead to regional and territorial development.

2.3. Crop production

When looking at the production of crops for existing food and feed uses, the Croatian production is in the lower position at the EU level with 3.8 million tonnes dry matter (d.m.) production (see *Figure 7*). The most important crops in Croatia are cereals and oil crops, e.g. sunflower and rape. Permanent crops cover an intermediate percentage age of the cropping area in comparison to the rest of the EU countries.

Total volume of gross agricultural production in 2018 increased by 5.0% compared to 2017. The growth in agricultural production in 2018 was affected by the growth in crop production, by 11.2%. In this type of production, most of the products with a larger share in crop production recorded a growth in production (e.g. maize by 37.7%, wheat by 8.2%, grapes by 30%, soya beans by 18.0%, etc.). Within gross agricultural production in 2018, crop production contributed with 59.1% and animal production with 40.9% (Croatian Bureau of Statistics, 2018b). In the period from 2013 to 2017, the harvested area and production of cereals decreased, while protein and oil crops showed a slight upward trend. According to the agricultural area utilized in the same period, maize is the most dominant crop in the Republic of Croatia, i.e. cereals. The productivity of crop production is relatively low, with average yields of basic crops below European levels. One of the key problems in crop production is insufficient adaptation to climate changes as well as market demand. For instance, irrigation, which, following frequent droughts on average every 3-5 years, results in significant crop damage and, depending on the intensity and duration of the drought, can reduce crop yields by 20-70%.

The underdevelopment of the water supply system on agricultural land is an additional factor supported by the fact that only 1.1% of the total utilized agricultural land is irrigated. Well-developed canal system was abandoned during the transition to the market economy. Most farmers do not have the opportunity to invest in irrigation infrastructure, and this risk is particularly evident during the summer months. Croatian agriculture is highly dependent on the weather, being the strongest reason of low agricultural output in crop production. The National Plan for Irrigation and Management of Agricultural Land and Water sets a target of 6% by 2020 (Ministry of Agriculture, 2013). In the light of climate changes, additional water consumption may have adverse effects on the ecological system. Good options for alleviation of water over-consumption is minimising the losses in the distribution system and developing highly efficient irrigation systems (i.e. drip or drop-by-drop irrigation systems). The other option would be to adapt cropping plans to novel climate conditions.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

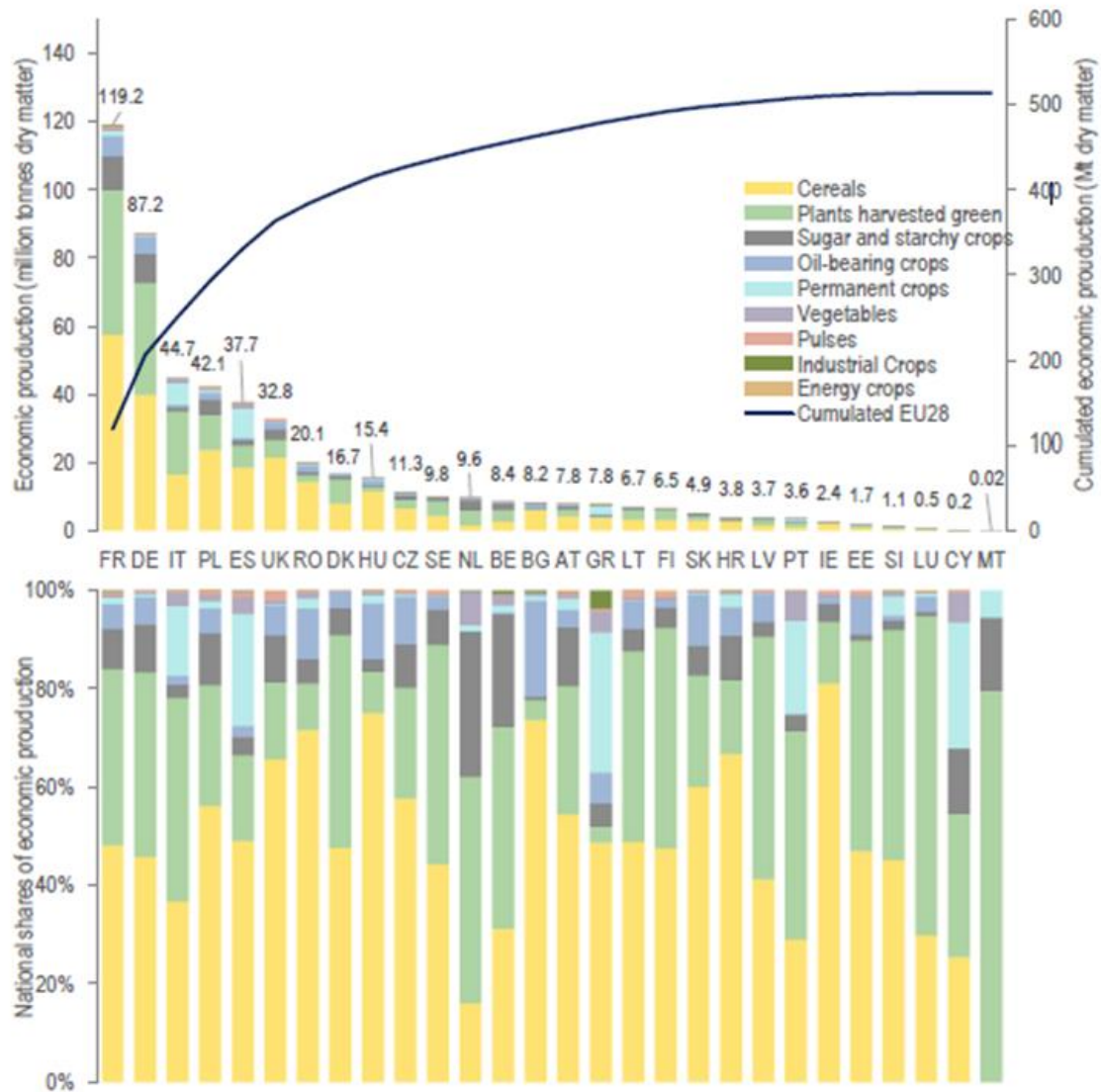


Figure 8 Economic production (top pane) from the main crop groups per member state, expressed in Mt of dry matter per year; and the shares at national level (bottom pane). Average values over the reference period 2006-2015. (Camia et al., 2018)

2.3.1. Cereals

In the period from 2010 to 2017, the total utilized agricultural area increased by 12% (from 1,333,835 ha to 1,496,663 ha) and cereal production decreased by 21% (from 584,663 ha to 461,483 ha). In the structure of cereal production, maize is predominant. In 2017, self-sufficiency in cereal production was 117.8%. In 2018, a total of 3,230,925 tonnes of grain was produced on a harvested area of 459,703 ha, with an average yield per hectare of 7 tonnes. The foreign trade of cereals generated a surplus. In 2018, cereals worth EUR 190.5 million were exported, while imports amounted to EUR 71.1 million resulting in a surplus of EUR 119.4 million.

Maize production in Croatia is directly influenced by global and climate trends. In the period from 2013 to 2017, maize is cultivated on an average of 260,819 ha, with the average year production over the five-year period of 1,868,920 tonnes. In 2018, 2,147,275 tonnes of maize were produced on 235,352 ha and the yield per hectare was 9.1 tonnes. Although Croatia's optimal geographical location for maize production with relatively fertile soils and a large selection of high-yielding hybrids, production differences can vary by more than 50% between years. The main reasons are insufficient rainfall during vegetation, uneven distribution of rainfall and extremely high temperatures in the phenological stages of flowering and fertilization. The lowest average yields were obtained in very dry years. In 2018, 516,694 tonnes of maize worth EUR 91.1 million were exported, while 41,309 tonnes of maize worth EUR 26.1 million were imported and a surplus of EUR 65 million was achieved.

It should be noted that the harvested areas refer to corn for the production of dry grain, while at the same time an average of 30,000 ha of silage maize is grown in Croatia (Iljkić et al., 2019; Zrakić et al., 2017). Production of silage maize in 2016 was carried out on 30,977 ha and a total of 1.3 mill. tonnes were produced. Due to the decreasing livestock number, maize silage growers opted for supplying biogas production. It has been estimated that some 700 Ktonnes of maize silage has been used for biogas production in 2018, harvested from 20,000 ha.

Wheat, in the period from 2013 to 2017, is cultivated on an average of 157,162 ha. In 2018, 135,708 ha were harvested, and 738,363 t of wheat was produced, and the yield was 5.4 tonnes per hectare. In the period of 2013 to 2017, 809,780 tonnes of wheat were produced annually on average, reducing production by 8.8% in 2018 compared to the five-year average. The impact of weather conditions on wheat yield is less compared to maize because it is a winter crop that is not so exposed to the effects of deficiency of precipitations and high temperatures. Wheat production shows a declining trend in utilized agricultural land (13.7% less in 2018 compared to the five-year average).

Barley, in the period of 2013 to 2017, also shows a declining trend in utilized agricultural land. In this five-year period, barley is in fourth place by utilized agricultural area, which was not the case earlier, while by production it is still in third place. Furthermore, barley was harvested on 50,818 ha with the production of an average of 218,795 tonnes. In 2018 barley was harvested on 50,988 ha which produced 227,520 t of barley, and the yield was 4.5 t per hectare. Due to the reduced harvested area, barley production in 2018 compared to the previous 2017 decreased by 12.6%. In 2018, 43,667 tonnes of barley worth EUR 7.7 million were exported, while 29,023 tonnes of barley worth EUR 6.9 million were imported, resulting in a surplus of EUR 871,368 (Ministry of agriculture, 2019).

Increase in the total volume of crop production in the overall structure of agricultural production after Croatia's accession to the European Union is a direct consequence of significant changes in the economic environment in which farmers currently find themselves. Given the positive production indicators, the domestic market is self-sufficient with cereals, especially wheat and maize, and since 2012 barley, except in years with extremely adverse climatic conditions. Croatia exports grain and creates positive net export values.

2.3.2. Oil crops

Compared to cereals, oilseeds, and especially soybeans and rapeseed, tend to grow in production areas. The most significant oilseeds in Croatia are soybean, sunflower and rapeseed. In the period from 2010 to 2017, in the total production of oilseeds, expressed in terms of quantity, soybean dominates (in the observed period soybeans make up 44.7% of total oilseed production), followed by sunflower (in the observed period sunflower accounts for 24.8% of total oilseed production) and rapeseed (in the observed period rapeseed makes 15.9% total oilseed production). In the same period, oil crops in the Republic of Croatia were on average annually produced on around 143,604 ha.

Soybean, in the period from 2010 to 2017, is cultivated on an average of 64,542 ha with the least harvested areas being recorded in 2014 (47,104 ha) and the highest in 2017 (85,133 ha). Due to increased sown areas, soybean is positioned as the third most important crop in Croatia, just after maize and wheat and ahead of barley. The increase in soybean harvesting areas can be observed from different points of view. Consumer preferences could represent one of the reasons, and another reason may be the Common Agricultural Policy, which allows the producer a higher production price. Furthermore, relatively safe purchase of soybean seeds and regular sowing times makes a soybeans appealing crop to grow. In the period from 2010 to 2017, average soybean production was 161,073 t, with the least production quantities being recorded in 2011 (96,718 t) and the highest in 2017 (244,075 t). The average yield in the same period was 2.5 t per ha.

Sunflower and rapeseed are, along with soybeans, most important oil crops in Croatia. Favourable weather conditions for the cultivation of sunflower are in eastern parts of Croatia, where it was harvested on the average on 34,695 ha with an average yield of 2.8 t per ha. Official records show significant differences in yield per hectare over a seven-year period which makes sunflower the most variable crop. Cultivation is strongly affected by weather conditions, although due to a well-developed root system, sunflower can give satisfactory yields even in dry years. One of the major disadvantages of sunflower cultivation is that it is susceptible to more diseases that occur more frequently in years with more precipitation.

Rapeseed is one more crop that shows an increasing trend in arable land. Although grown on an average of 24,032 ha (in the period from 2010 to 2017), in 2016 and 2017 the areas under this crop has doubled, with recent estimates for 2018 suggesting a record harvesting area under this crop of as much as 53,000 ha (Croatian Bureau of Statistics, 2018c). The values refer to rapeseed areas not intended for biodiesel production. Over a seven-year period, with the average production of 66.7 t per year, rapeseed is in sixth place by production, with large discrepancies between years. The most common reason for variations in the size of the sown area is in the sowing period, which is in Croatian conditions from 25th August to 10th September. If drought conditions are present in this period, many farmers are not keen on the cultivation of rapeseed.

The increase in crop production in the overall structure of agricultural production after Croatia's accession to the European Union is due to, among other things, significant changes in the economic environment. Changes in production over the past period are mainly a reflection of market needs for these products and to a lesser extent climate conditions and the prices of oilseeds themselves. The Republic of Croatia is self-sufficient with the production of oilseeds, especially sunflowers, soybeans and rapeseed. In 2015, self-sufficiency in the production of oilseeds was 355.8%. External trade in oilseeds generated a surplus. In 2016, EUR 95.7 million worth of oilseeds were exported, while imports of oilseeds amounted to EUR 12.7 million, resulting in a surplus of EUR 83.1 million. Oil crop residues are used for feed (protein cake), energy (husks), chemical compound for detergent, soups and cosmetics (technical fatty acid) and biogas substrate.

2.3.3. Permanent crop production

Permanent crops in Croatia are represented with orchards, olive groves and vineyards. In Croatia, diversified fruit production is possible due to climatic, pedological and hydrological potentials, but this does not mean that it is significantly represented in the total value of crop production output. In the period from 2010 to 2017, fruit production was carried out on average on 30,829 ha accounting for 3,6% of utilized agricultural land with an average production of 193,404 t per year with the least production being recorded in 2017 (121,434 t) and the highest in 2013 (263,441 t). Current fruit production is insufficient in relation to the needs of the population, tourism, the food industry, exports and employment opportunities. In 2016, fruit production accounted for most of the intensive production, which amounted to 151,256 tonnes on an area of 29,289 ha, while extensive production on family farms producing 4,032 tonnes of fruit was significantly smaller.

The most common fruit species produced in the Republic of Croatia during 2016 were mandarins, apples, plums and cherries. In 2015, self-sufficiency in fruit production amounted to only 58.8% of all domestic market needs (self-sufficiency was achieved only for cherry and cherry production with 162%, mandarin with 159.2% and apples with 107.3%). The degree of organization of producers in the fruit sector is low due to fragmented plots and low level of production technology. In addition, Croatia does not have sufficient storage facilities and cold storage and processing capacity and currently has three recognized producer organizations in the fruit and vegetable sector. In 2016, significantly higher quantities of fruit were imported than were exported from the Republic of Croatia. Fruits import amounted to EUR 172.9 million, while exports amounted to EUR 37.7 million, resulting in a negative foreign trade balance, or a deficit of EUR 135.2 million. However, this fact was caused by late spring frost, which caused almost 100% damage to all fruit crops and vineyards, resulting in higher import. Still, average yields on plantations are lower than those of EU countries due to outdated technology and frequent droughts. There is a need to invest in technical and technological modernization, to introduce new technologies for the production, storage and preparation of products for the market, and to promote the production and organization of the producer market, all with the common aim of ensuring greater productivity growth and job creation.

According to the Croatian Bureau of Statistics, in 2018, an 18,697 ha were under **olive groves**. The total production of olive oil was 28,418 t, and 36,573 hl of olive oil was produced in the same year. The processing of olive oil is gradually increasing, and Croatian olive oil is increasingly becoming an economically important potential in the agricultural production of Mediterranean Croatia, with significantly improved quality. Nevertheless, Croatia's supply of olive oil is insufficient for domestic consumption and considerable quantities are imported. In 2018, according to the Croatian Bureau of Statistics (CBS) data 4,101 tonnes of olive oil was imported, worth EUR 15.3 million, while exports of 289 tonnes of olive oil amounted to EUR 2,6 million in the same period, amounting to a deficit of EUR 12.7 million.

Agro-ecological conditions in the Republic of Croatia are favourable for the cultivation of **vineyards** and the production of grapes from which wines of different quality are produced. The most represented are wines with a protected designation of origin. According to CBS data, there was 20,512 ha of agricultural land under the vineyards in 2018. Grape production in 2018 amounted to 146,242 t. In 2018, the wine production recorded a negative foreign trade balance, i.e. a deficit of EUR 14.3 million.

Wheat, corn and barley, as the three most represented cereal crops, have been traditionally grown in Croatia for years. In the younger generations, these cultures are somewhat resilient, and newer generations are moving to other crops; permanent crops, vegetable crops, etc.

2.3.4. Livestock, related fodder production and use of pastures

In 2016, there was a slight decrease in the share of livestock in the total value of agricultural production, although a small recovery of the livestock stock was recorded at an intensity of 0.5 LU/ha. Currently, 135,026 active farm holdings are registered in the Register of Livestock Farms, with 147,283 owners.

The total number of **cattle** in 2018 was 414,125 and compared to the previous year it decreased by 8.1%, compared to the average of the five-year period from 2013 to 2017, the number of cattle decreased by 7.1%. The share of the Republic of Croatia in the number of European Union bovine animals is 0.5%. In comparison with the previous year 2017, in 2018 in the category of cattle under one year of age there was a slight decrease in the number of cattle by 0.8%. A decrease of 4.3% was observed in the category of slaughter calves, while in the category of other male calves, a decrease of 7.2% was observed and the number of other female calves increased by 8.4%. The number of cows in 2017 decreased by 2.6%, so the rate of decrease in the number of cows is lower than in the previous year.

Despite the decline in the price of **milk** in 2018, overall delivery at EU level did not change significantly. The total quantity of milk delivered to purchasers in the Republic of Croatia amounts to 453,458 t, which is 5.1% less than in 2017. In the period from 2013 to 2018, the number of milk suppliers decreases but the average quantity of milk delivered per supplier increases. In 2018, 6,139 suppliers participated in the delivery of milk to purchasers. Compared to the previous year 2017, the number of suppliers in 2017 decreased by 11.8% and compared to the average number of suppliers in the period from 2013 to 2017 decreased by 36.9%. The average annual delivery of milk per supplier in 2018 is 80,107 kg and compared to the previous year it is higher by 7.3%. Compared to the average amount of milk per supplier in the period from 2013 to 2017 it is increased by 34%.

Structural analysis of suppliers by volume class shows that producers delivering less than 6,000 kg of milk annually accounted for 18.8% of the total number of suppliers, delivering 0.8% of the total milk delivered. The largest quantity of milk delivered comes from 277 suppliers who deliver more than 200,000 kg of milk per year, accounting for only 4.5% of suppliers and delivering as much as 56.8% of the total milk delivered, or an average of 930.06 kg per supplier. At the same time, the data shows that there is a decrease in the number of manufacturers in all quantity categories. In 2018, milk was purchased by 34 dairies and 10 registered small family dairies that process milk produced on their own farm, with the top three milk purchasers buying 77.2% of the total quantities from 74.7% of suppliers. In the Republic of Croatia, the organization of milk producers is present through producer organizations that enable producers to associate and negotiate the price and terms of the purchase of milk through the contract system. By 2017, four producer organizations were active under the "milk package".

In 2016, live cattle exchanges made a deficit. 130,636 cattle worth EUR 73.1 million were imported while 43,824 cattle worth EUR 45.9 million were exported. Imports of live bovine animals account for the largest share of other cattle from 80 to 160 kg, and in the structure of exports of cattle for slaughter weighing more than 300 kg. When compared to 2017, the value of imports in 2018 increased by 1.3% while the value of exports increased by 75.8%.

In 2017 Croatia imported 18,209 tonnes of fresh or chilled beef and 4,345 tonnes of frozen beef in the total worth EUR 90.8 million, while exported 6,522 tonnes of fresh or chilled beef and 1,057 tonnes of frozen beef in the total worth EUR 32.0 million.

The total number of **pigs** in 2016 was 1,049,123 pigs, which is a decrease of 6.4% compared to 2017. Compared to the average number of pigs in the period 2013-2017, the number of pigs in 2018 decreased by 8.3%. The share of the Republic of Croatia in the number of pigs in the European Union is 0.7%. The trade in live pigs in 2016 generated a

surplus. A total of 485,759 pigs worth EUR 23 million were imported, while 282,065 pigs worth EUR 40.9 million were exported. In the structure of imports of live pigs, the most represented category is domestic pigs (except purebred breeding pigs) weighing up to 50 kg, accounting for 99% of the total number of imported pigs. In comparison with the previous year 2017, the value of imports decreased by 12.2% although 53,301 additional pigs were imported, compared to the previous year, while the value of exports increased by 1.6%. There was a deficit in the exchange of pork. In 2018, 60,915 tonnes of fresh or chilled pork and 26,614 tonnes of frozen pork with a total value of EUR 179.9 million were imported, while 6,236 tonnes of fresh or chilled pork and 1,205 tonnes of frozen pork with a total value of EUR 20.1 million were exported. In comparison with 2017, the value of pork imports increased by 9%, while the value of exports increased by 6.3%.

The structure of production, as well as the structure of imports and exports, indicates that, due to the lack of sows, insufficient numbers of piglets intended for fattening are produced, which is offset by imports of live animals of younger ages intended for fattening. Also, exports of live fattened pigs and imports of pork and processed products indicate that the slaughterhouse industry does not use domestic raw materials for processing and that primary producers obtain relatively better prices for fattened pigs by export.

Compared to 2015, the total number of **sheep** in 2018 decreased by 0.1% to 636,294 head. The share of the Republic of Croatia in the total number of sheep in the European Union is 0.7%. Of the total number of sheep in the Republic of Croatia, it is estimated that 80% are from original breeds, which are very modest in nutrition and care but also resistant to adverse climatic factors. In the coastal counties, Primorje-Gorski Kotar, Lika-Senj, Zadar, Šibenik-Knin and Split-Dalmatia, there are over 50% of the total recorded sheep, which confirms that sheep breeding is the main livestock branch in these areas.

An analysis of the size of the herd indicates that production on many sheep farms is based as an additional source of income for members of the holding and that only a small number of holdings are sheep being the sole source of income. Generally speaking, in the Republic of Croatia sheep are mostly raised for meat production, especially for the production of light- to medium-weight lamb carcasses, which are desirable for preparation on the spit. Recently, there has been an increased interest in raising sheep for milk production and processing milk on the family farm, especially in cheese. As a result, most of the sheep milk produced is used to feed lambs for slaughter, and only a portion of the remaining milk is used by producers to produce higher value-added sheep milk.

2.4. Biomass potentials from residues and unused lands

In terms of residual biomass production Croatia scores quite well, compared to other smaller EU countries, as Figure 8 shows. 4.8 million tonnes per year of residues are produced, of which the main sources are cereals and oil crops. Only 1 million tonnes are known to be harvested at this moment (according to the Sankey diagram in Figure 3). How much can be mobilised of these residual resources taking account of sustainability consideration of which the main is the conservation of organic carbon in the soil, will be discussed in next Section 2.4.1 in greater detail.

2.4.1. Lignocellulosic residual biomass potential from crops

As already became clear, Croatia has a relatively large cropping sector and therefore the residual biomass potential from crops are certainly of interest. By-products from arable crop production are mainly in a form of straw, stalk corn and corn cobs. They are used for traditional purposes (bedding) and lately, emerging agropellets for fuel and feed.

How many crop residues (e.g. straw) can be removed sustainably, depends on several factors. The maintenance of soil organic matter is an especially relevant function of straw-removal. Also, the nutrient balance should be maintained, but nutrients are often replenished, by mineral fertilizer application practices. The input of soil organic matter, however, is often only dependent on crop residues left behind. The amount of straw to be kept in the field is complicated to estimate as it depends strongly on the soil and climate characteristics and the long-term management practices. To give a good estimate of residual biomass potentials that can be sustainably removed we will present the results of a national assessment using average of time series data (2012-2016) as input and the methodology by Ćosić et al. (2011) and of the biomass potential assessments in the S2BIOM project (Dees et al., 2017⁸) (See Table 3) .

In Table 3 the primary residue potentials is presented of cereals and grain maize, which produces corn stover, which in the table includes corn husks and leaves and the cobs as assessed by Ćosić et al. (2011) and by S2BIOM. In the methodology from Ćosić et al. (2011) the total available quantities are reduced for soil protection against erosion and related loss of soil organic carbon and animal feed/bedding purposes. In S2BIOM the factors involved were the same, but the methodology of calculation was different (see Box 2.2). Furthermore, in S2BIOM a wider assessment was made of more crop residues (Dees et al., 2017) also at regional level (see also Table 2 3).

Table 3 Availability of primary residual biomass from cereals and grain maize (tonne d.m.) in Croatia

	Cereals straw		Maize stover (excl. cobs)	Maize stover (incl. cobs)	Corn cobs
	S2BIOM (assuming soil carbon conservation and subtracting straw use for animal bedding & feed)	Ćosić et al. (2011) using data 2012-2016 (assuming soil C conservation and use for animals)	S2BIOM (assuming soil C conservation and NO use for animals)	Ćosić et al. (2011) using data 2012-2016 (assuming soil C conservation and use for animals)	Ćosić et al. (2011) using data 2012-2016 (assuming soil C conservation and use for animals)
Total	548,496	1,000,000	1,201,316	350,000	340,000

⁸ D1.6 A spatial data base on sustainable biomass cost supply of lignocellulosic biomass in Europe - methods & data sources <https://www.s2biom.eu/en/publications-reports/s2biom.html>

The amount of cereal straw is quite significant in Croatia amounting to 1 million tonnes d.m., when assessed according to the Ćosić et al., and 550,000 tonnes d.m., when assessed in the S2BIOM approach. The difference is related to the application of a carbon balance model, taking account of diversity in carbon levels in the soils in Croatia, which leads to a larger diversity in sustainable removal rates over the country than the standard fixed sustainable removal rate applied in the Ćosić et al. methodology.

The maize stover availability is also significant but given the large difference between the S2BIOM estimate and the Ćosić et al. approach, one can conclude that a large part of the stover is already going to animal bedding and feed. Still, there is an unused potential of 350,000 tonnes d.m. In addition, a similar amount of biomass should also be available from the remaining cobs. Initiatives are already starting to make pellets from these primary residues.

Methodology of Ćosić et al. (2011) explained which was applied to average crop data 2012-2016:

Grain-straw ratio was 1.6 and 0.8 for straw and maize stover, respectively. The average of time series (2012-2016) was applied to reach the total available quantities. Further, restrictions were made for straw removal to prevent wind and water erosion and were set at a fixed level of 1.5 t/ha to be left in the field. The amount to be subtracted as competing use needed for livestock use was put at 0.75 t/head cattle. For estimating residues potential from corn, a technical potential of 30% is used and requirements for soil protection from wind and water erosion were estimated at 50% from all biomass of the corn stover.

Methodology of S2BIOM to calculate the crop residues potentials in Table 3 and Table 4

It identifies the part of the residues that can be removed from the field without adversely affecting the Soil O to demand for straw for animal bedding & feed. For corn stover, rice straw, and sunflower and rape stubl between the inputs of carbon to the soil and the carbon outputs. A negative balance, i.e. outputs are larg the long term. To calculate the soil carbon balance at regional level S2BIOM used the MITERRA-Europe mod & Jenkins, 1999) to calculate the soil carbon dynamics in a spatially detailed assessment.

When looking at the residual biomass potential per region in Table 4, one can conclude the most important arable crops delivering primary residues are from cereals and maize and sugar beet. Overall, the total quantities of available unused residues are relatively low also have a large spatial distribution. There are, however, clearly a couple of regions which have the largest concentration of sustainable removable arable crop residues which are Ličko-senjska županija, Zadarska županija, Splitsko-dalmatinska županija, Istarska županija, Osječko-baranjska županija and Sisačko-moslavačka županija. It is estimated that, except for a large part of the maize stover, these residues remain unused currently.

Table 4 Residual biomass potentials⁹ from arable crops 2020 in tonne d.m. (=S2BIOM UD1 potential)

County	Cereals straw	Oil seed rape straw	Maize stover	Sugar-beet leaves	Sunflower straw	Total
Primorsko-goranska županija	34,681	2,429	75,958	5,849	4,805	123,722
Ličko-senjska županija	52,156	3,653	114,232	8,797	7,225	186,063
Zadarska županija	35,229	2,467	77,158	5,942	4,880	125,677
Šibensko-kninska županija	28,654	2,007	62,759	4,833	3,970	102,223
Splitsko-dalmatinska županija	43,970	3,080	96,303	7,416	6,091	156,859
Istarska županija	27,255	1,909	59,695	4,597	3,776	97,232
Dubrovačko-neretvanska županija	17,094	1,197	37,440	2,883	2,368	60,983
Grad Zagreb	6,254	438	13,697	1,055	866	22,310
Zagrebačka županija	29,834	2,090	65,343	5,032	4,133	106,432
Krapinsko-zagorska županija	11,974	839	26,226	2,020	1,659	42,717
Varaždinska županija	12,294	861	26,926	2,074	1,703	43,858
Koprivničko-križevačka županija	17,036	1,193	37,312	2,873	2,360	60,775
Međimurska županija	7,073	495	15,492	1,193	980	25,234
Bjelovarsko-bilogorska županija	25,737	1,803	56,370	4,341	3,566	91,817
Virovitičko-podravska županija	19,713	1,381	43,176	3,325	2,731	70,326
Požeško-slavonska županija	17,767	1,244	38,914	2,997	2,461	63,383
Brodsko-posavska županija	19,752	1,383	43,261	3,331	2,736	70,465
Osječko-baranjska županija	39,473	2,765	86,454	6,658	5,468	140,817
Vukovarsko-srijemska županija	23,707	1,660	51,924	3,999	3,284	84,574
Karlovačka županija	35,300	2,472	77,315	5,954	4,890	125,932
Šišakmo-slavačka županija	43,540	3,049	95,361	7,344	6,032	155,325
Total	548,496	38,415	1,201,316	92,511	75,986	1,956,724

⁹ Source: S2BIOM project: Dees et al (2017) D1.6 A spatial data base on sustainable biomass cost supply of lignocellulosic biomass in Europe - methods & data sources <https://www.s2biom.eu/en/publications-reports/s2biom.html>

2.4.2. Residues from permanent (woody) crops

Current use of by-products from managing permanent crops is at very basic level. Pruning are used either for slow burning as a frost prevention or for heating, although most remain on field or are burned. Pruning potential for energy has been estimated at very wide range, from 0.4 GJ (Elbersen et al., 2016) to 4.21 PJ y⁻¹ (Bilandžija et al., 2012), strongly depending on the methodology This would relate to a range of 0.43 – 263 Ktonnes of permanent crop residues. A more detailed regional explicit potential taking account of sustainable removal rates assessed in Horizon 2020 project *up_running* (2017-2019). When considering pruning potential, 2 PJ y⁻¹ or ~ 100 kt of pruning can be used as a value to start planning (Dyjakon and Garcia-Galindo, 2019).

2.4.3. Dedicated crop potentials from unused lands

As a part of the EU, Croatia strives to increase the total share of renewables in overall energy production by using and developing technologies for exploiting various renewable energy sources such as the Sun, wind and biomass. Cultivating energy crops has multiple advantages such as: good biomass yield, increasing biodiversity, temporary animal habitat, regeneration of contaminated soil and other ecosystem services. At the same time, Croatia has large areas of agricultural land that are not being cultivated, which is considered as an unused potential. Also, the current economic situation in Croatia is not very good hence every option that could help create jobs and improve the economic situation should be considered.

Research conducted throughout S2BIOM project aimed to assess the potential for energy production from biomass produced from short rotation coppice (SRC) in Croatia. Since there were no energy plantations established at that moment in Croatia, three scenarios were developed to determine technical and energy potential of produced biomass. The energy potential was determined based on the category of ownership for different counties in Croatia. The case study for Croatia was done with 5 selected macro locations. Power plants up to 15 MW of installed capacity were considered. The internal rate of return (IRR) method was chosen to represent the technical and economic analysis of the selected locations for power plants. Projects with IRR higher than 12% were considered profitable. Research showed that only macro location Sisak was profitable with default parameters such as the investment cost, heat energy price, electricity price, etc. For each macro location the sensitivity analysis was done discussing how the change of important factors like the electricity price, transport cost, investment cost and fuel price could change the IRR. Generally, for all macro locations increase of the purchase price of electricity or decrease of the investment cost or fuel price only by 10% would make almost all the projects profitable. Transport cost had a very low influence on the IRR and it was shown that only 50% lower transport cost for some locations could help make projects profitable. The technical and energy potential of biomass calculated based on methodology developed in S2BIOM project are showed in *Table 5* and *Table 6*

Table 5 Technical potential of biomass

Scenario						
County:	S1 private (tonnes/year)	S1 state (tonnes/year)	S2 private (tonnes/year)	S2 state (tonnes /year)	S3 private (tonnes /year)	S3 state (tonnes /year)
Krapina-Zagorje	6,953.70	449.55	4,635.80	299.70	2,317.90	149.85
Varaždin	5,729.10	3,938.18	3,819.40	2,625.45	1,909.70	1,312.73
Međimurje	11,349.00	6,641.27	7,566.00	4,427.51	3,783.00	1,213.76
Koprivnica-Križevci	3,849.30	9,997.10	2,566.20	6,664.74	1,283.10	3,332.37
Osijek-Baranja	20,732.40	14,924.17	13,821.60	9,949.45	6,910.80	4,974.72
Vukovar-Srijem	10,381.80	17,338.19	6,912.20	11,558.79	3,460.60	5,779.40
Virovitica-Podravina	20,361.90	27,374.72	13,574.60	18,249.82	6,787.30	9,124.91
Zagreb	34,671.00	31,160.77	23,114.00	20,773.84	11,557.00	10,386.92
Bjelovar-Bilogora	60,356.40	38,902.27	40,237.60	25,934.84	20,118.80	12,967.4
Požega-Slavonia	50,212.50	60,026.27	33,475.00	40,017.51	16,737.50	20,008.76
Brod-Posavina	28,571.40	76,790.10	19,047.60	51,193.40	9,523.80	25,596.70
Karlovac	320,810.10	127,794.58	213,873.40	85,196.38	106,936.70	42,598.19
Sisak-Moslavina	223,906.80	131,559.32	149,271.20	87,706.22	74,635.60	43,853.11
Total	797,885.40	546,896.49	531,914.40	364,597.65	265,961.80	181,298.82

Table 6 Overall energy potential

Scenario:	S1 (TJ/year)	S2 (TJ/year)	S3 (TJ/year)
Krapina-Zagorje	90.47	60.31	30.16
Varaždin	118.13	78.76	39.38
Međimurje	219.84	146.56	73.28
Koprivnica-Križevci	169.20	112.80	56.40
Osijek-Baranja	435.72	290.48	145.24
Vukovar-Srijem	338.74	225.83	112.91
Virovitica-Podravina	583.34	388.89	194.45
Zagreb	804.46	536.31	268.15
Bjelovar-Bilogora	1,212.94	808.63	404.31
Požega-Slavonia	1,347.12	898.08	449.04
Brod-Posavina	1,287.52	858.35	429.17
Karlovac	5,481.95	3,654.63	1,827.32
Sisak-Moslavina	4,343.80	2,895.86	1,447.93
Total	24,703.63	2,895.86	1,447.93

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

2.4.4. Residual biomass potentials from livestock

The manure potential for biogas in Croatia assessed by the JRC (Scarlat et al. 2018) is based on 4.8 Mt of collectable manure with 5.43 PJ biogas potential or 104 MW. Yet, anaerobic digestion (AD) rarely occurs as mono-digestion and manure represents a co-substrate with lesser energy content. Biogas (and biomethane) potential has been estimated from 5.83 to 11.5 PJ y⁻¹ with the prospects to increase by including waste, by-products and residues from food processing streams suitable for AD (Kulišić et al., 2018).

In 2016-2019, within Horizon 2020 project BiogasAction, the future biogas market for Croatia has been outlined. The table below (Table 7) refers to the manure related potential and replication rate as well as the productivity.

Table 7 Biogas potential in Croatia by different beneficiaries (source: Horizon 2020 Biogas Action, 2019)

Size of the plant	<30 kW		<500 kW		1,000 kW
Potential users	~11,400		~2,100		40
Sector	cattle&pig	poultry	cattle&pig	poultry	industry
Replication potential	4,900	6,500	1,250	800	40
Biogas	541	715	982	644	135
Electricity	1,028	1,358	2,160	1,416	280
Heat	1,028	1,358	2,160	1,416	280

In 2016-2019, within Horizon 2020 project BiogasAction, the future biogas market for Croatia has been outlined. The Table 7 refers to the manure related potential and replication rate as well as the productivity. Replication rate reflects the number of potential beneficiaries for each category. Depending on the desired outcome of the concerted policy, with the 85% less the investment size and sacrifice of 25% less production of renewable energy, ~5 time more beneficiaries could be addressed in the micro (<30 kW) biogas plants than in small biogas plants category (<500 kW). That decision would not have merit in renewable energy production but in freshwater protection from excess nitrogen leaching and livestock farmers empowerment. On the other hand, true biogas plants with economics of scale (1 MW) have only 40 beneficiaries to be replicated with Table 9. At this point, only one biogas plant processes abattoir waste as an AD substrate.

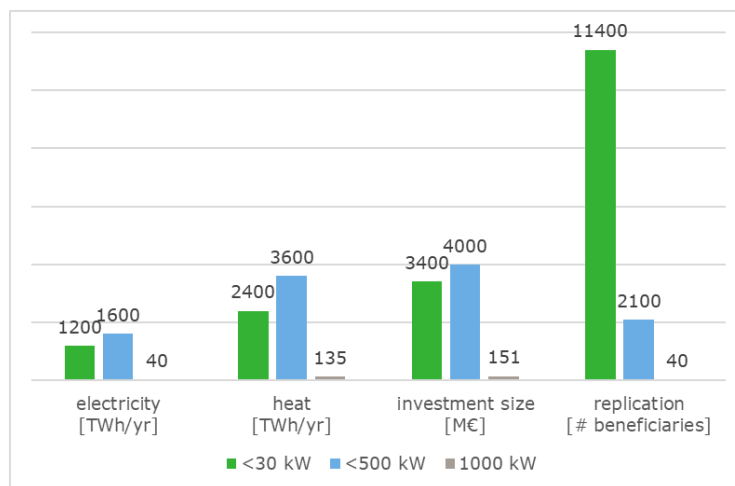


Figure 9 Outlines of the potential future biogas market in Croatia (Kulisic et al., 2018)

2.5. Agricultural processing industries

The agri-food sector in the Republic of Croatia has a long tradition and is deeply rooted in rural space, history and development of the country. Due to its preserved nature and environment, Croatia has an advantage over other developed countries and can produce a variety of high-quality food that is safe for consumer health. The food and beverage sector with approximately 55,000 employees accounted for 21% of the manufacturing industry's total employment in January 2019. According to the Labour Force Survey (CBS), which also takes into account informal employment, in the last quarter of 2017, the number of employees in Croatia was 1,639,000. Of these, 116,000 are related to agricultural activities, which is 7% of the total employed. The entire food production chain employs 10% of all employees in Croatia. Important is the existence of all-natural resources that can enable competitive, healthy and safe food production with great potential for raising productivity. Also, as a small and open country, Croatia should not neglect the importance of producing its own food as a long-term strategic security component. Croatian agriculture needs a generally accepted long-term food production strategy that will cover multiple EU programming periods in order to ensure continuity of growth and make the necessary changes in the long run.

2.5.1. Main agri-food processing industries

Food and beverage production are an important activity for every country. In the Republic of Croatia, the most profitable activities in this sector are cigarette production and tobacco processing, fish processing, beer production, milk processing, tea and coffee processing, and soft drink production. There are about 10 larger agricultural processing industries in Croatia. The largest ones are in the meat and dairy sectors. These are also the industries that have attracted most foreign investment and operate highly successful companies.

Important are the export products of the food, beverage and tobacco industries: sugar, cigarettes, Vegeta (food spice), beer, baby food products, salted anchovies etc. Most imported are oilcakes, cigarettes, sugar, mineral water, frozen pork.

The most important export destinations are the agricultural and food products of the markets of neighbouring countries Bosnia and Herzegovina, Italy, Slovenia and Serbia, while the most imported products originate from Germany, Italy, the Netherlands, Brazil and Hungary.

Croatia can offer recognizable products of high quality and originality to the world market. Currently, there are several food products bearing the geographical indication in Croatia: Dalmatian, Drniš and Krk prosciutto, Baranja kulen, Lika potatoes, Zagorje turkey meat and Poljica pie. The designation of origin is: prosciutto from island of Krk, kulen from Baranja, potato from Lika, prosciutto from Drniš, prosciutto from Dalmatia, Poljički soparnik/zeljanik/uljenjak, turkey from Zagorje, kulen from Slavonia, Međimursko "meso 'z tiblice", lamb from Lika, cheese škirpavac from Lika, štrukli from Zagorje, pumpkin seed oil from Varaždin, carob from Komiža, "mlinci" from Zagorje, "kvargl" from Bjelovar, "greblica" from Samobor, "klipić" from Varaždin, sausage from Slavonia, "varenik" from Brač, and bacon and tenderloin from Dalmatia¹⁰.

¹⁰<https://poljoprivreda.gov.hr/istaknute-teme/hrana-111/oznake-kvalitete/zoi-zozp-zts-poljoprivrednih-i-prehrambenih-proizvoda/228>

2.5.2. Side-products from agri-food processing

Residues from fruit processing (pits, pulp, water) represent an excellent opportunity to improve cost efficiency of agri-food processing companies. This is particularly urgent for fruit processing companies. While fruit growing agrotechniques are outdated, food processing industry is able to keep up the pace with the technological development. Generating yield from waste streams just started to be considered as a good opportunity to improve competitiveness. It is likely that hesitation lies in the necessity to step out from the current marketplace and food processing as core business.

Wine producers have considered pelletizing grape pomace for either feed or fuel but without significant market uptake. Pomace is usually processed to hard spirit, similar to Italian grappa. There is room to improve competitiveness through increasing the use of by-products in the wine-making process in Croatia.

The use of olive oil residues has been considered in numerous projects but with little success. Recently, a small olive cake pelletizing facility (6,000 t/year) in Istria started producing solid biofuels for the market. The challenge in utilising olive processing waste is their fluctuation over the time: i.e. yield in 2007 (58 hl) and yield in 2014 (11 hl) and high seasonality.

Table 8 Biomass potentials from agrifood processing industries 2020 in Tonnes d.m.

	Olive stones	Pressed grapes dregs	Cereal bran	Total
Primorsko-goranska županija	257	338	6,979	7,573
Ličko-senjska županija	386	508	10,495	11,389
Zadarska županija	261	343	7,089	7,693
Šibensko-kninska županija	212	279	5,766	6,257
Splitsko-dalmatinska županija	326	428	8,848	9,601
Istarska županija	202	265	5,484	5,952
Dubrovačko-neretvanska županija	127	166	3,440	3,733
Grad Zagreb	46	61	5,343	5,450
Zagrebačka županija	221	290	6,003	6,515
Krapinsko-zagorska županija	89	117	2,409	2,615
Varaždinska županija	91	120	2,474	2,685
Koprivničko-križevačka županija	126	166	3,428	3,720
Međimurska županija	52	69	1,423	1,545
Bjelovarsko-bilogorska županija	191	251	5,179	5,620
Virovitičko-podravska županija	146	192	3,967	4,305
Požeško-slavonska županija	132	173	3,575	3,880
Brodsko-posavska županija	146	192	3,975	4,313
Osječko-baranjska županija	292	384	7,943	8,619
Vukovarsko-srijemska županija	176	231	4,770	5,177
Karlovačka županija	261	344	7,103	7,708
Sisačko-moslavačka županija	322	424	8,761	9,507
Total	4,062	5,340	114,454	123,856

2.6. Cost of main biomass sources

Since for most agricultural residues no commodity market has yet been developed, it is very difficult to provide figures on prices. Instead cost estimates can be presented building on the S2BOM methodology and assessment. The cost refers to Roadside cost and these cover all biomass production collection and pre-treatment cost up to the road where the biomass is located. The roadside cost is a fraction of the total 'at-gate-cost.'

Table 9 Roadside cost levels (€/tonne d.m.) for agricultural biomass sources based on S2BIOM cost calculations

Roadside cost for agricultural biomass	Average (€ tonne d.m.) (2020 cost level)
Rice straw	24
Cereals straw	19
Oil seed rape straw	16
Maize stover	15
Sugarbeet leaves	40
Sunflower straw	18
Residues from vineyards	197
Residues from fruit tree plantations (apples, pears and soft fruit)	72
Residues from olives tree plantations	106
Residues from citrus tree plantations	77
SRC unused lands	28
Dedicated crops on unused lands	28

2.7. Summary and conclusions in relation to SWOT elements

Biomass production, harvesting and collection in Croatia is a challenge for different reasons. One of these is that biomass is produced dispersed (a low density per area) and is almost by definition bulky, low in energy density and generally contains considerable amounts of water. The idea of bio-hubs as regional facilities to collect, transport and pre-treat biomass in the areas with the highest biomass concentration did not come to life. One exception is Istria, where local farmers are in the process of setting up a hub.

Biomass from the agricultural sector in Croatia has a large potential for future development, but there are also several threats to this development. A SWOT analysis is presented in the following *Table 10* to show the Strengths, Weaknesses, Opportunities and Threats of this sector in Croatia.

Table 10 SWOT analysis for agriculture sector

<p>Strengths</p> <p>Unused potential available from primary residues, secondary residues and unused lands Roadside cost relatively low and good road connectivity within the country Still many underutilised biomass resources</p> <p>Non-utilised arable land Rural Development Program Cost of biomass resources are relatively low in comparison to many regions in the EU</p>	<p>Weaknesses</p> <p>The spatial concentration of biomass is low, makes collection cost relatively high Absolute amounts of agricultural biomass are not very large as the average agricultural land is small, and yields are relatively low The facilities to collect, transport and pre-treat are not in the areas with the highest biomass concentration. Ownership of land unclear and unused lands are very dispersed, so it presents a challenge to mobilise unused land resources Support needed to make investments Market demand for unused biomass not developed Small average size of fields Lack of logistics centres to establish a stable biomass supply</p>
<p>Opportunities</p> <p>Still many biomass resources that can be mobilised Because of harbours (coastal and inland), local biomass resources can be combined with imported resources to strengthen security of supply Unused land resource is significant, so opportunities to produce low-ILUC biomass on abandoned lands Expansion of family farms (both in continental and coastal area) into tourism sector (and diversification to other potential sectors) to generate additional income, entrance to new market - ecotourism Production of healthy food for a European market Europe is a trend the Croatian market can connect to.</p>	<p>Threats</p> <p>The risk for loss of HNV farmland when demand for biomass takes off Lack of rural population to produce and collect the biomass in the long term No market for high added value biomass, uses only low-quality chains for heat/electricity Impact on the environment – soil erosion and leaching Favourable work conditions outside of Croatia – increasing trend of labour outflow Raising competitiveness and agricultural development in the EU market could pose a problem for Croatian farmers and their future placement of value-added products Large land purchases for financial investment and industrial agricultural production, without stimulating local communities and creating jobs - Land-grabbing</p>

3. BIOMASS SUPPLY: FORESTRY

3.1. Introduction

Total area of forests and forest land in Croatia amounts to 2,759,039 ha (49% of total land area of Croatia). Out of that, 2,097,318 ha (76%) are state-owned, whereas 661,721 ha are privately owned (24%). On the other hand, forests (forested area) within the forest management area covers the total of 2,493 kha (General FMAP 2017, Ministry of Agriculture) or 44.0% of the Croatian land territory (5,659 kha, Croatian Bureau of Statistics, 2018). From the total forested land 74% or 1,841 kha is state owned, while 26% or 652 kha is privately owned (Table 11). Vast majority of state-owned forests (2,018,987 ha or 97%) are managed by a state company Hrvatske šume (Croatian Forests Ltd.) and to a lesser extent (<3%) by other Legal bodies founded and owned by the state such as national parks, Faculty of Forestry, Ministry of Defence, "Croatian Waters" etc. The private forests are managed by the private forest owners in accordance with valid forest management plans and with a support of Ministry of Agriculture. Forests in Croatia have predominantly natural structure (95%) and are characterised by diversity and productivity differently distributed within the country, ranging from very productive oak and beech forests in the eastern and central part of the country to degraded macchia and bush-wood forests in the south. From total forest land 79% of area are deciduous forests, 16% coniferous and 5% degraded forests in form of shrubs (Strategy of spatial development (OG No. 106/2017). Forest cover according to the CORINE land cover is shown in *Figure 10*.

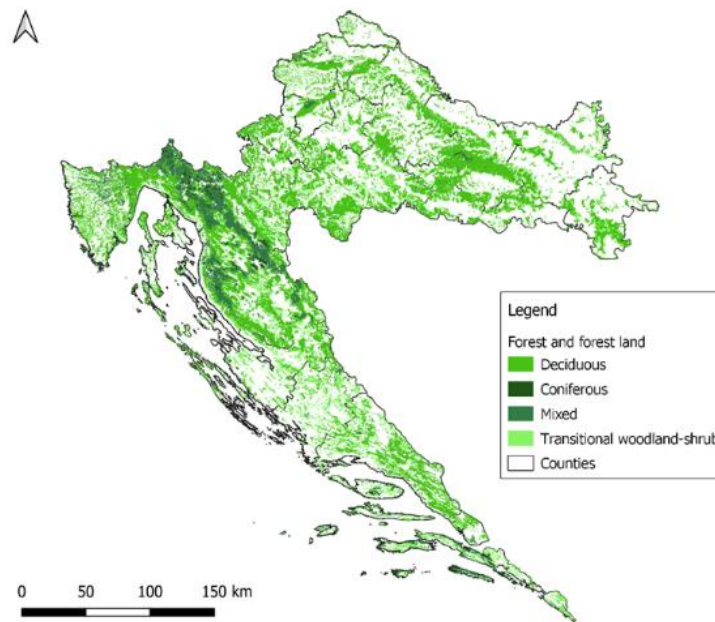


Figure 10 Forest cover in Croatia (source: EHP based on CORINE 2018)

The distribution of woodland in Croatia (*Figure 11*) provides an image on source distribution within different Croatian counties¹¹.

¹¹ <http://www.wisdomprojects.net/global/csdetail.asp?id=15>

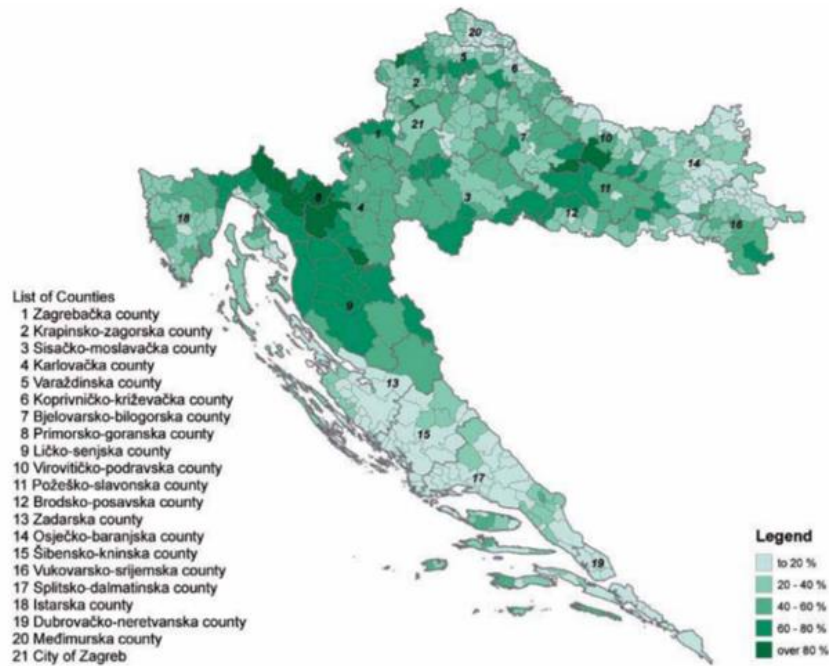


Figure 11 Share of woodland in municipalities/towns (Source: Wisdom)

Except by the ownership, forests are classified according to their purpose as well. The Forest Law states that according to their purpose, forests can be Productive, Protective and a Special purpose forests. The Productive forests are used for the production of forest products, next to the preservation and improvement of their welfare functions, while Protective serve for the protection of soil, waters, settlements etc. Forests with special purpose are within protected nature areas (strict reserves, national parks, nature parks, nature monuments, important landscapes, park forests), forests and parts of forests registered for production of forest seed (seed stands), forests for scientific research, forests for defence of the state.

Accordingly, and based on experts opinion, only the Productive forests have a real potential for woody biomass, while Protective forests (especially those on steep slopes) and Special purpose forests have another primarily function where eventually woody assortments are 'by-products', and the commercial fellings are prohibited in most of those forest categories. Hence, further elaboration regarding potential biomass supply from forests should/ will be based on Productive forests data.

Table 11 Structure of forests & forest land in Croatia by ownership and purpose (Source: General FMAP, 2017)

Ownership	Purpose of forest (land)	Forest (ha)	Land under the forest management			Total (Forest + land under forest management)
			Unstocked productive	Unstocked unproductive	Unfertile	
			ha			
State owned	Productive forests	919,838	36,534	10,643	15,371	982,387
	Protective forests	528,783	99,420	8,343	14,085	650,631
	Forests with special purpose	391,995	55,228	4,685	12,393	464,300
	Sum	1,840,616	191,182	23,671	41,849	2,097,318
Private	Productive forests	433,973	7,896	1,197	357	443,423
	Protective forests	181,355	29	61	20	181,464
	Forests with special purpose	36,733	39	28	34	36,833
	Sum	652,060	7,964	1,285	411	661,720
State + private	Total	2,492,676	199,146	24,955	42,260	2,759,039

The structure and area of forests and land under forest management has been changing due to inclusion or exclusion of areas into forest management (according to Law on Agricultural Land (OG No. 20/2018, 115/2018), article 3; Forest Law (OG No. 68/2018, 115/2018, 98/2019) article 51 and 52), but in general, total forest area has increased since 2006 for 70.35 kha or 2.6 % (General FMAP, 2017), mostly due to significant increase in private forests area, while state forests area has suffered a slight decrease (around 10 kha).

Forests and forestland in Croatia are governed according to the Forest Law (OG No. 68/2018, 115/2018, 98/2019 and Ordinance on Forest Management (OG No. 97/2018, 101/2018), and managed based on the 10-year General Forest Management Area Plan (FMAP), appointing activities that will be performed in the forests and forestland within the complete Croatian forest management area, concerning both state and private forests (General FMAP, 2017). The diversity in the forest management between state forests (with 250 years old forestry tradition and FSC certificate since 2002) managed by company Croatian Forests Ltd. and other state and private forests is at least significant, which can be seen in increasing forest productivity. During the last management period (2006-2015) the management plans have been made for all forest land managed by Croatian forests Ltd., whereas plans were made for only 27% of state forestland managed by other legal bodies and for 66% of forestland managed by private forest owners, while in 2021 management plans for all private forests have been made at least once. However, the latter represents a significant advancement compared to period prior to 2006, when only 6% of private forests had management plans. The main factors inhibiting greater management of private forests are small size of forest parcels (average size around 0.43ha) and fragmented ownership of same forests by several owners (Strategy of spatial development (OG No. 106/2017).

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Within the forest growing stock, the dominant origin of forests¹² are seed forests present at 56% of forest area. However, significant shares of forests area constitute of degraded forms such as shrubs (18%) and coppices (14%) (Figure 12).



Figure 12 Forest growing stock origin in forested areas (ha) (Source: General FMAP, 2017)

According to the data shown in Figure 13 it is evident that Productive forests regardless ownership, take only 54% of total forestland, but contain 72% of the forest growing stock, which indicates their high productivity. Protective forests occupy 28.5% of forestland but contribute with only 6% to forest growing stock with 108 m³/ha.

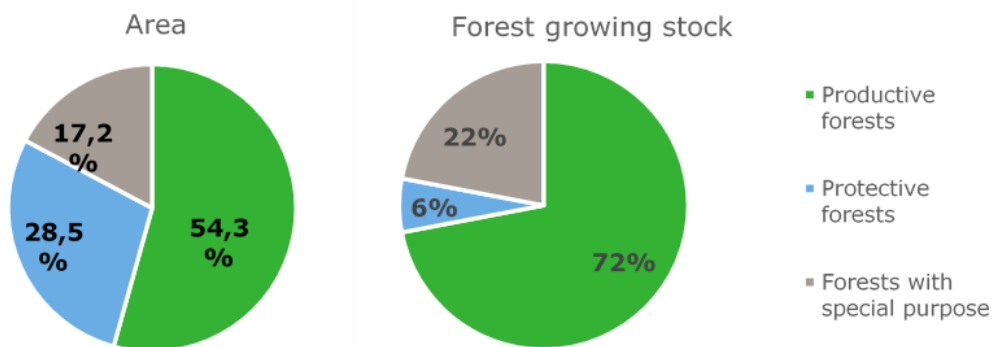


Figure 13 Comparison of forestland area and forest growing stock in different forest categories by purpose

The main characteristics of the forestry sector compared to EU forestry sector are shown in Table 12.

¹² Seed forests – stands formed by trees originated from seed or seedling; coppices – stands formed by threes originated from stump or roots; cultures- artificial stands developed without application of agrotechnical measures; degraded stands (shrubs, maquis, thicket, garrigue) - degraded stands formed by different trees forms and shrubs (Regulation on forest management (OG No. 97/18, 101/18)

Table 12 Overview of main characteristics of forestry sector in Croatia

Category	Croatia*	EU average	Unit
Forest area	0.67	0.650	ha/capita
Forest increment**	5.87	5.47	m ³ /ha
	1.74	2.80	m ³ /capita (2010)

* based on population and forest area for 2018

** excludes trees in first age class

Regarding Productive forests, the General FMAP 2016-2025 determines total growing stock of about 303 mil. m³ in 2016 (for comparison 418 mil. m³ for forests of all categories) calculated based on the measured diameters at breast height and height of living trees above the taxation level (10 cm in breast height diameter). The average annual increment in 2016 for all forests in Croatia is 5.87 m³/ha. There is significant difference in average annual increment between private and state forests. Annual increment in state-owned Productive forest is 7.01 m³/ha, whereas annual increment in privately-owned Productive forests is 4.94 m³/ha in 2016. Lower increment in private forests is a historical result of a lack of adequate management in (not all) private forests. Comparing 2006, in 2016 the total growing stock of all forests increased for 5% (20.6 million m³), while annual increment decreased for 4%, mostly resulting from decrease of periodic increment in state forests (465,000 m³).

Out of total growing stock 80% is under state-owned forest (75% by Croatian Forests Ltd. and 5% forests owned by other legal bodies) and ten most common tree species: common beech (37% of total growing stock), pedunculate oak (12%), sessile oak (9%), common hornbeam (8%), European silver fir (8%), narrow-leaved ash (3%), spruce (2%), black locust (2%), black alder (2%) and turkey oak (2%). The average growing stock in Productive forests is 258 m³/ha. However, the growing stock in state Productive forests is determined to 293 m³/ha while the stock within private Productive forests is determined to 186 m³/ha (General FMAP, 2017). The growing stock is not measured for the first age class of even-aged forest, and in case of maquies and shrub forests estimation was performed using the expert judgement on increment in these forests.

The growing stock can be disturbed by natural calamities and human caused disasters, which have occurred lately in Croatia. Forest fires predominantly appear in southern parts of the country and do not affect the most productive forests. However, forest fires do affect Protective forests and forests with special purpose and their ecological services. With exception of 2017, when total forestland area affected by fires was 41,174 ha, the yearly affected area by fires within the last 10 years was below 10,000 ha (Figure 14).

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

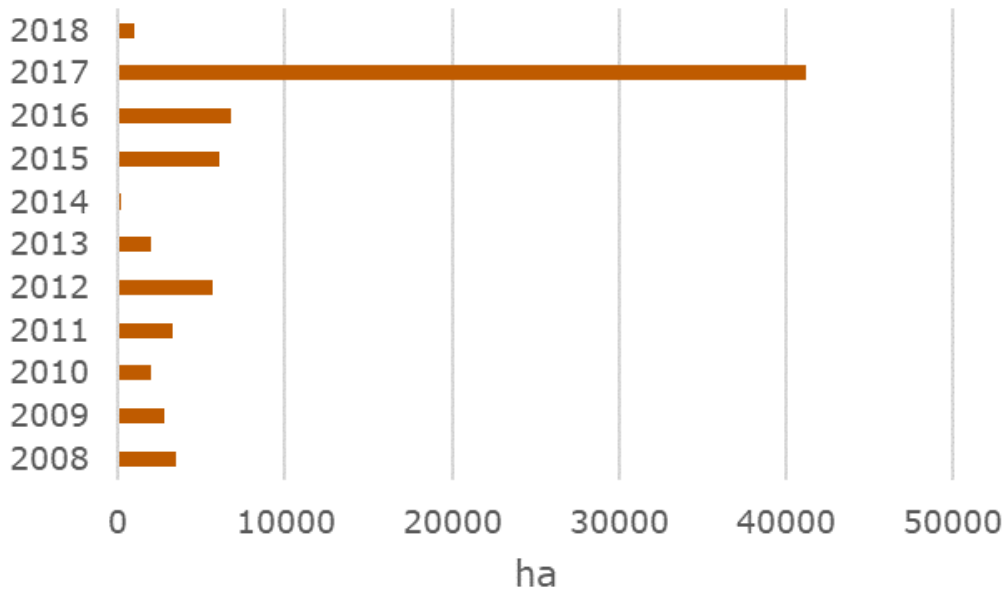


Figure 14 Area of forestland affected by forest fires (Croatian bureau of Statistics, 2018a)

On the other hand, high productive forests are often affected by storms and infestations which results in higher annual cut than expected in affected areas. In 2018, from total gross cut of wood made in state owned forests managed by Croatian forests 1.6 million m³ come from dry wood, damaged wood by wind, snow, ice and illegal cutting (Croatian Forests, 2019).

Around 34,000 ha of forestland (~1%) is under mined areas which means that is temporary out of the management and silvicultural works. The removal of mines is expected in the future.

3.2. Primary biomass resources from forestry, current and planned harvest levels and uses

Croatia has a relatively large forest potential for the small size country it is. This results in a large primary and secondary forestry potential. Forests are considered as one of the most important resources for Croatian economy, both as energy source and feedstock for wood processing industry (Table 14). In the previous General FMAP period (2006-2015) the overall forest cut (felling) was achieved at 60% of total area proscribed for cut and accounted for 86% of proscribed cut volume in all forests. The difference between the planned and achieved cut is shown in Table 13, as well as proscribed harvest for current General FMAP encompassing the period from 2016-2025.

Table 13 Planned and achieved cut in 2006-2015 and proscribed harvest for 2016-2025 (General FMAP, 2017)

FMAP 2006 -2015	Prescribed harvest	Achieved cut	% achieved	Prescribed harvest in 2016-2025 (m ³)	Prescribed harvest in 2016-2025 (tonnes d.m.)
	m ³				
Croatian forests Ltd.	57,935,018	53,639,369	93	64,196,393	36,881,791
Other legal bodies	661,366	128,463	19	525,372	301,834
Private forest owners*	7,047,369	2,392,543	34	15,649,957	8,991,135
Total period	65,643,753	56,160,375	86	80,371,722	46,174,760
Total annually	6,564,375	5,616,038	/	8,037,172	4,617,476

*The numbers regarding private owners includes wood assortments derived from management units for which management plans have not been made at the time. This number should be taken with caution due to reliability and availability of data for this estimation since for some years data were not available.

According to the Forest Management Area plan for period 2016-2025 the Prescribed harvest (felling) in this period is 80,371,722 m³ on total area of 1,288,821 ha (Table 13). Regarding previous management period 2006-2015, this represents a total increase in cut for 14,727,969 m³, followed by a decrease in total area available for cut for 12,988 ha, which implies higher cut on smaller area. This is primarily a result of increased cut both in state and private forests, and a decrease in area for cut in state forests (61,560 ha) and increase of area for cut in private forests (48,579 ha).

The structure of forest assortments production in 2018 is shown in Table 14. From the total cut in 2018, 2.18 mil. m³ was fuel wood and 3.21 mil. m³ industrial wood. From the Table 13 it is evident that the total cut (felling) in 2016-2018 was lower than the average cut in the previous management period and a proscribed harvest for current period.

Table 14 The structure of forest wood assortments production in 2016- 2018 (HR bureau of Statistics, 2018a)

Forest assortment production	2016	2017	2018
	m ³		
Fuel wood (including charcoal)	1,768,000	1,858,000	2,176,000
Industrial roundwood			
Sawlogs and veneer logs	2,402,000	2,392,000	2,675,000
Pulpwood	988,000	1,052,000	533,000
Other industrial roundwood	7,000	5,000	6,000
TOTAL wood (m³)	5,165,000	5,307,000	5,390,000
TOTAL wood (Tonne d.m.)	2,967,370	3,048,951	3,096,636

Croatian Forests Ltd. are by far the largest primary biomass producer and the largest woodchip producer at the domestic market (capacity of around 850,000 mil. m³). The contracts for woodchip supply were assigned through contracts in 2015 for 640,000 tonnes and additional 120,000 tonnes in 2016. The existing contracts were revised in 2019, and biomass was allocated from cogenerations that have not fulfilled the requirements to the new subjects selected through the public tender. The interest in biomass was much higher than quantities available (265,000 t of woodchips or 265,000 m³ of fuel wood) and allocated through the public tender, which indicated a need for more biomass among energy producers. Currently there are 33 woody biomass power plants in operation with total installed capacity of 70.714 MW. Additional 18 plants with 39.394 MW installed capacity have contracts for power purchase but are still not operational (HROTE, data from August 2019). The quota for biomass cogeneration is set on 120 MW, but the interest is much higher indicated by exceeded application for additional 51 MW. Along Croatian Forests Ltd. as main biomass producer, there are several additional smaller producers of woodchips.

The prescribed harvest in state-owned forests in 2018 within the different management unit is shown in *Figure 15*. On geographical scale, the largest fellings/cuttings can be expected in areas with the largest primary biomass production, and these are areas in continental and mountainous parts of Croatia. There, the residues can be easier collected due to already available machinery and established logistic chains. The felling in coastal regions (Forest administration (FA) Split and Buzet) is very small compared to continental FAs. The reason for the low felling rate is that coastal forests do not have large economic values, predominantly due to their structure (high share of degraded forms), but also technical limitation such as relief.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

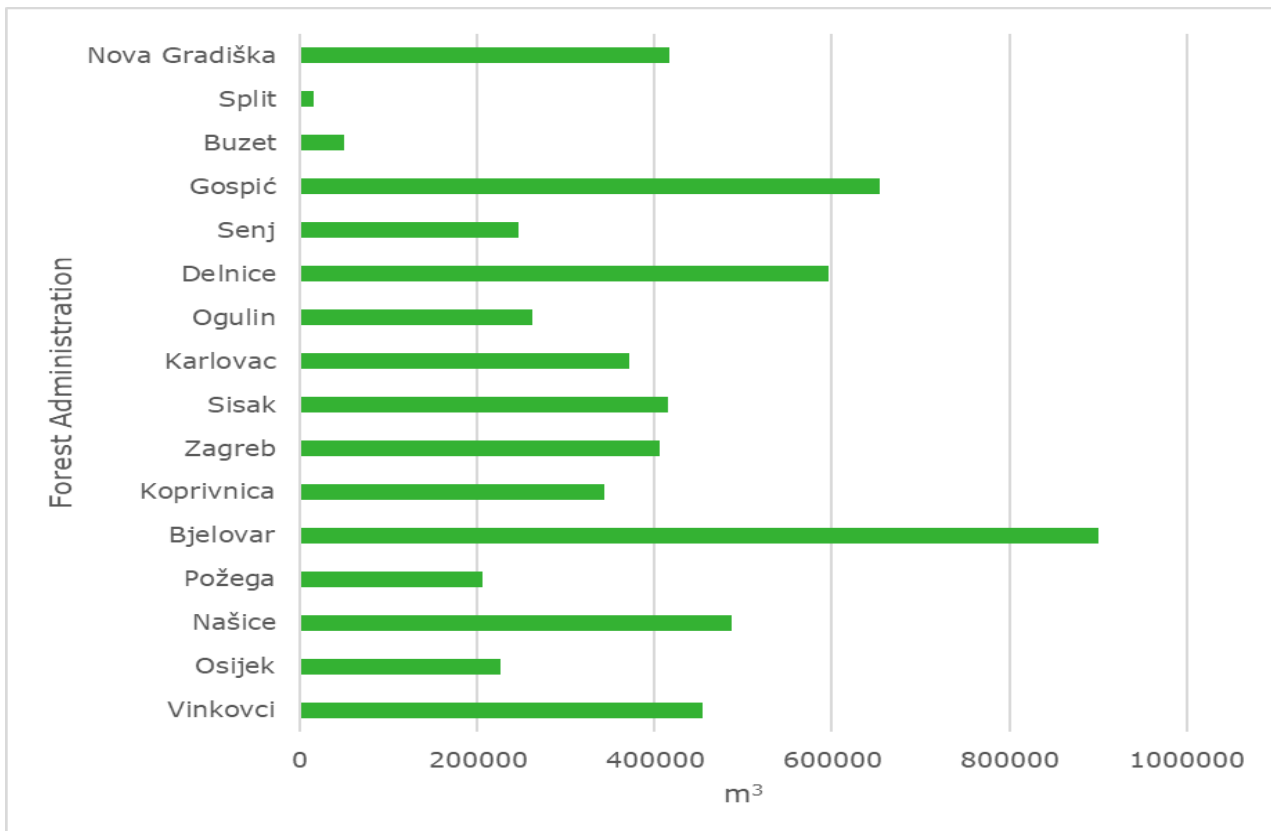


Figure 15 Prescribed harvest (felling) in 2018 in state-owned forests managed by Croatian Forests Ltd. (75% of total growing stock of all forests)

The data on fuel wood production from Croatian Bureau of Statistics shown in Table 14, are significantly different from data provided in Energy in Croatia 2018 (EIHP, 2019), which indicated production of 5.98 mil. m³ of fuel wood, an amount that is double from the one reported by statistics. This indicates a general problem of reliability of solid information, what can significantly impact estimation of available potentials. Regardless the amounts, biomass as a fuel is especially important for households that make 87% of energy consumption from biomass, with only 1% of modern biomass share (pellets, briquets) (EIHP, 2019).

In Table 13 an overview was given of the total harvested volume of forest biomass and the prescribed cuts over 2016-2025. From Table 14 it is evident that the average yearly harvest of primary forest biomass was at 5.3 mil. m³ which is around 3 mil. tonnes of dry mass. The prescribed harvest in 2016-2025 foresees a clear increase in this harvest which amounts to 46 mil. tonnes d.m. in 10 years which equals a yearly harvest of 4.6 million tonnes d.m. When this is to be compared with prescribed harvest to what is estimated to be available as harvestable potentials in the S2BIOM biomass assessments for forests, one can conclude that the current average yearly harvest as reported by the Croatian Bureau of Statistics (Table 14) is in line with the 2020 potential of 3.3 mil. tonnes d.m. in S2BIOM. This means that the exploitation of forest biomass from forests in Croatia is relatively in line with what can also be potentially harvested from the forest.

The prescribed harvest figures in Table 13 of 46 mil. tonnes of forest biomass in 10 years (2016-2025) show that a further mobilisation of biomass in Croatia's forests is clearly intended. For the mobilisation of this forest biomass the growth in forest harvest should particularly come from the private forest owners. The EFI-GTM harvest levels expressed as

proportion of the increment in Table 15 confirm that there is certainly room in Croatia for mobilising additional forest biomass.

According to the General FMAP 2016-2025, in the previous forest management period (2006 -2014, + planned in 2015) 92% of the prescribed harvest in state owned forests was achieved, while only 34% in private forests. This indicates that a certain potential in the private forests remained unutilised. The underlying reason for such underperformance in private forests is that forests are often inherited by people who do not rely on forestry as income nor manage their forests actively. However, there is also a harvest in private forests which is not registered in the system. Due to unregistered harvest it can be assumed that the percentage of achieved harvest in private forests is higher, but it is not possible to provide an exact number.

The prescribed harvest for 2016-2025 period increased for 14.74 mil. m³ compared to prescribed harvest in previous management period and it is around 24 mil. m³ higher than achieved harvest in previous period. This signals the potential availability of additional biomass according to the prescribed harvest for current period. The increase in the harvest is expected to come from both private and state forests (Table 13).

The biomass availability for production of energy was estimated for the *Energy Development Strategy for the Republic of Croatia for 2030 with a view to 2050* and the numbers are shown in Table 15. The estimation is based on current General FMAP, available other documents and expert estimations. The table provides total available biomass from primary forestry for energy or other purposes without consideration of current use and potential for biomass mobilisation. The availability for all categories but Forest residues is copied from the FMAP for both private and state-owned forests.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Table 15 2010, 2020 and 2030 EFI-GTM harvest levels expressed as % of yearly average biomass increment level in forests. (Elbersen et al., 2016; Biomass Policies project)

% Harvest & residues potential/Increment				
	Country	2010	2020	2030
AT	Austria	60%	53%	59%
BE	Belgium	55%	55%	53%
BG	Bulgaria	22%	18%	18%
HR	Croatia	72%	67%	64%
CZ	Czech republic	69%	75%	72%
DK	Denmark	24%	17%	17%
EE	Estonia	56%	68%	68%
FI	Finland	59%	57%	53%
FR	France	29%	26%	35%
DE	Germany	43%	47%	50%
EL	Greece	35%	46%	48%
HU	Hungary	23%	33%	30%
IE	Ireland	36%	40%	47%
IT	Italy	8%	10%	13%
LV	Latvia	44%	42%	55%
LT	Lithuania	49%	49%	53%
LU	Luxembourg	44%	48%	63%
NL	Netherlands	36%	31%	33%
PL	Poland	47%	56%	53%
PT	Portugal	58%	56%	63%
RO	Romania	26%	36%	35%
SK	Slovakia	95%	81%	82%
SI	Slovenia	21%	31%	45%
ES	Spain	41%	39%	35%
SE	Sweden	69%	62%	62%
UK	United Kingdom	45%	47%	49%

Table 16 Availability of biomass for energy from primary forestry (EIHP, 2019)

Available biomass for energy*	Amount (m ³)	Amount (tonnes)
Industrial roundwood	887,216	509,719
Fuel wood	2,653,845	1,524,674
Wood residues	1,135,792	652,530
Forest residues <7 cm in diameter with bark, measured on thicker end	224,237	128,828
Total	4,901,090	2,815,750

* (Current use is not excluded from numbers. Dead wood and other biomass from maintenance are not included.)

Strategy for wood processing and furniture production development (2017) indicates that some other sources estimate availability of 0.75 mil. m³ of forest coproducts and 2 mil. m³ of fuelwood annually for energy and industrial production. The Strategy also indicates the total stock of around 33 mil. m³ of dead wood in forests. However, the dead wood is important for biodiversity conservation and certain amounts should be left in the forest.

Currently, most of the produced primary biomass has been allocated to various established pathways. The additional biomass from current production can arise either from greater efficiency in current pathways (transition to higher efficiency technologies that would minimise the need for fuel wood among households) or by mobilisation of unused or additional biomass (termination of contracts for feedstock supply due to non-compliance with the contractual commitments and redirection to other customers, utilisation of harvesting residues -wood under 7 cm in diameter, utilisation of wood from maintenance of forest infrastructure. Additional harvest, and therefore quantities of biomass, are expected from both state and private forests through increased annual prescribed harvest defined within the valid General Forest Management Area Plan. The available potential from the increased cut will greatly depend on the primary biomass needs for the wood processing industry.

3.3. Secondary biomass resources from forestry: wood processing industries

Secondary forestry residues from sawmills and wood processing industries build on the potentials assessed in EUWood and S2BIOM in combination with some up-dated data from national sources.

Wood processing and furniture production is an important segment of Croatian economy. It represents 6.14% of industrial production, contribution 3.6% to the GDP. There are ~40 sawmills with maximal capacity of stemwood processing 1.1 mil. m³/annually (Ministry of Environment and Energy, 2019).

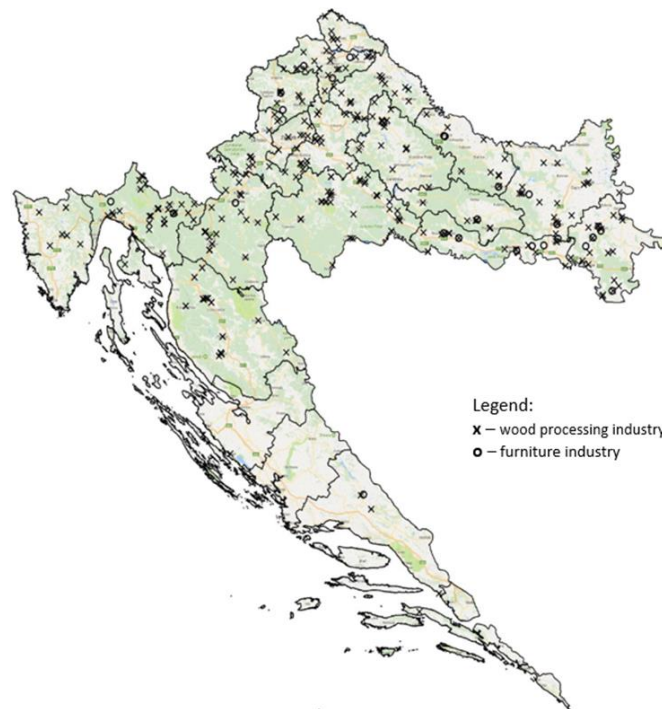


Figure 16 Distribution of wood processing subjects and furniture industry (Source: Strategy for wood processing and furniture production development, with action plan 2017-2020)

Most important wood products include furniture (tables, chairs, beds, ...), furniture elements, flooring, dredged boards etc. There are more than 3,500 companies related to wood industry. It is evident that Croatia has well developed wood processing and furniture industry, mostly located in areas with better access to wood supply such as continental Croatia. The structure of industrial products from forestry achieved in year 2018 is shown in Table 17.

Table 17 Structure of industrial products from forestry (Croatian Bureau of Statistics, 2018a)

Industrial product	Amount
Charcoal	10,000 (t)
Wood chips, particles and residues	587,400 (m ³)
Wood pellets	305,900 (t)
Other agglomerats	56,200 (t)
Sawnwood	1,459,700 (m ³)
Wood based panels	183,000 (m ³)
Pulp wood	38,800 (t)
Paper and paperboard	333,200 (t)

The amount of residues that result out of the wood processing industry is estimated by EIHP for development of Energy Development Strategy for the Republic of Croatia for 2030 with a view to 2050 and indicated in Table 18

Table 18 Availability of secondary biomass from forestry (Ministry of Environment and Energy, 2019)

Secondary biomass	Amount
Residues from wood processing industry	1,291,854 m ³
Sawmill residues with bark	293,261 m ³
Other sources*	300,000 t

* Wood waste from construction sites, wood residues from landscaping etc.

From the table it is seen that larger amounts of residues from wood industry are potentially available for biobased industries. However, many wood processing industries nowadays have adjacent cogeneration plants in which they utilise residues from their processes (e.g. sawdust). This has proved to be most convenient way to manage waste wood and to secure cheaper heat and power for industrial processes. The exact quantity of waste wood is unknown due to incomplete reporting to the Ministry of Environment and Energy by all wood processing companies. In 2017 some 97,906 t of non-hazardous wood waste from furniture industry, wood processing, paper and cellulose production (Category 03) was registered in the Registry of environment polluters. The structure and quantities of the waste in the Registry, related to wood only, is shown in Table 19.

Table 19 Reported amounts of wood industry processing residues in 2017

Code	Type	Amount reported (t)
03 01 01	Bark and cork residues from furniture production	9,294
03 01 05	Sawdust, slabs, shavings, peeler cores, offcuts	63,466
03 01 99	Other	20
03 03 01	Bark and other residues from cellulose and paper production	42

The above listed categories make 72,822 t of waste wood. From these reported amounts, the use as a fuel and energy production is reported for 34,208 t, while other amounts are either composted, disposed or mixed with other materials.

Due to the size of the wood processing industry significant amounts of secondary biomass can be expected. The general conclusion is that available data are uncomplete and inconsistent to make an adequate estimation of potential from wood processing industry, mostly because current level at which residues are used is unknown.

In the future, the expected increase in the annual cut should also create larger quantities of wood intended for processing and consequentially larger amounts of secondary residues from wood processing industry.

3.4. Forest biomass mobilisation options

Primary forest potential estimated through S2Biom project is around 61 PJ, while potential calculated by EIHP's experts' range between 35.5 – 68.42 PJ/annually or even 100 PJ if mobilisation measures are applied. The potential is based on Forest management plans and various estimations of potential from wood processing industry. However, certain amounts of potential are not registered in the statistic system. This refers primarily to the uncertainty of fuel wood extracted from forests, and residues from wood industry. A detailed survey among industry is needed to establish quantities of wood residues produced and their pathways.

The amounts and pathways of biomass from maintenance of transmission lines, paths for fire protection, maintenance of roads and other infrastructure are not recorded within these numbers. This potentially represents a significant source of biomass that should be further explored.

Out of the total amount of industrial wood and fuelwood harvested almost 50% was allocated for households while remaining 50% was allocated for other energy purposes (cogeneration of electricity and heat, pellet, briquette and charcoal production), industry (paper, plywood, furniture...) and export. Since the amount of industrial roundwood and fuelwood is limited, there is obviously a competition for the same feedstock between energy and industry (wood processing), and within the energy sector itself (solid biofuels, electricity production). The data on fuel wood produced is significantly different between sources.

Croatian Forests Ltd. is and will remain the main biomass supplier for the market, due to established procedures and quantity of biomass. Based on the FMP they establish the amounts and set the price for biomass that can be supplied. However, wood from forestry in state forests has its own pathways already established, most of it is already contracted. New bioenergy developments will have to rely more on biomass from private forests and wood processing industry, or amount coming from increased annual cut.

In regard to the private forests, there are some major problems for the utilisation of growing stock from private forest, such as fragmentation and small parcel size with often several owners. The owners are often elderly people, or they live far from the property and are not aware of the existing biomass market for energy production. Inconsistent forest management in most of private forests has resulted in growing stock per hectare more than two-times lower than in the state-owned forests. To achieve better management, education and information of private forest owners is needed. Although mobilisation of this resource is planned, it is not possible to predict to which extent and when it would happen. Some estimates indicate potential of 200,000 tonnes annually.

The General FMAP 2016-2025 predicts an increase in the allowed annual felling rate, compared to the previous management period. The harvesting is still significantly below annual increment. Part of this "newly" available biomass can be directed in biobased industries or energy production.

Wood industry is also a significant source of wood residues that can be used for energy production or other purposes. The availability will depend on production of main products and the pathways the wood residues take (e.g. feedstock for other material products). Wood residues from wood processing industry are for the most part already being used by the industry for own energy production needs or sold on the market.

Forest harvesting residues can also be collected. However, further assessments are needed to establish their location and the available amounts which can be recovered at acceptable costs and without harmful environmental effects.

3.5. Summary and conclusions in relation to SWOT elements

In Croatia, forestry and wood processing sectors have a long tradition and are well developed. There are 336 companies licenced for forest works and fellings with different allowed annual quantities, but in the total amount of 5.04 mil. m³ annually, excluding Croatian forests. This indicates the existence of knowledge, machinery, people. In 2002 Croatian Forest Ltd. acquired FSC (Forest Stewardship council) certificate that is renewed every five years. The certificate indicates that the company is managing the forests according to strict ecological, social and economic standards. Furthermore, and over 150 wood processing firms have 150 FSC COC. The use of traditional biomass (fire logs) in inefficient stoves is extensive. Transition to modern biomass such as pellets would mean greater efficiency in feedstock transformation. Additional harvest of 2.4 mil m³ annually in comparison to achieved cut in the previous period is allowed. The fact that the planned cut has not been realised in the last management period and has been increased in current management period leaves space for biomass use. Statistical data are sometimes weak or contradictory. This is especially valid in the case of fuelwood and wood residues from wood processing industry. Private forests were not so far an important source of biomass, but this is expected to change in future, especially with support from EU funds for rural development. The competition for industrial roundwood between different sectors and within sectors is significant. Therefore, the attention should be directed towards projects with the best efficiency. Forest biomass potential is significant and further additional mobilisation plans are already well on their way. The State forest sector manages a large forest area, which makes it easier to contract and collect efficiently.

In future, it is necessary to improve infrastructure to mobilise biomass in areas that are more remote and establish a group of private forest owners to manage their land more successfully. Furthermore, restrictions on the type of biomass that can be utilised to avoid competition with other uses to allow currently established flows to operate should be set. A SWOT analysis is presented in the following *Table 20* to show the Strengths, Weaknesses, Opportunities and Threats of this sector in Croatia.

Table 20 SWOT analysis for forestry sector

<p>Strengths</p> <p>A long sectoral tradition in forestry and wood processing industry</p> <p>Tradition of sustainable management of forests - FSC</p> <p>150 wood processing companies have FSC COCs</p> <p>Skilled and qualified workforce as result of long tradition</p> <p>Large state-owned forest</p> <p>Knowledge of cascading use of wood</p> <p>Significant additional mobilisation of primary forest resources possible and also already planned</p> <p>Forest processing industry is growing and leads to more secondary forestry residues</p>	<p>Weaknesses</p> <p>Short and vertical value chain</p> <p>Lack of national statistics on biomass flow balance (information to improve planning of forest biomass exploitation)</p> <p>Lack of industry for glued boards and chipboard, pulp, paper...</p> <p>Inconsistent potential statistics</p> <p>High percentage of firewood in energy balance</p> <p>Lack of bio-hubs for storage, pre-treatment and processing</p> <p>Poor management of private forests</p>
<p>Opportunities</p> <p>Mobilisation of unused biomass</p> <p>Development of new bio-based products on lignocellulosic base</p> <p>Private forest owners</p> <p>Biomass production for low ILUC biofuels</p>	<p>Threats</p> <p>Climate changes in terms of</p> <ul style="list-style-type: none"> - increasing numbers of forest fires - drought - prolonged vegetation season - mild winters suitable for diseases and pests - infestations with insects and diseases atypical for this geographical and climatic area etc. <p>Energy poverty</p>

4. BIOMASS SUPPLY: WASTE

4.1. Introduction

In Croatia, waste management is currently one of the largest challenges in the environmental sector and certainly one of the most demanding areas in terms of adjustment to the standards of the European Union. Solving these issues and orientation toward integral and modern waste management are one the requirements a sustainable waste management system and implementation of Circular Economy and Bioeconomy principles. The issues that the country needs to address are following: stop the increase in solid waste, improvement of recycling programs, improvement of data availability concerning flows and quantities of waste (segments) and improvement of organization of disposal sites and management of waste particularly waste separation.

Currently, municipal waste management in Croatia is undergoing a radical transformation from decentralized disposal of non-treated waste on numerous local sub-standard landfills within counties to centralized waste management and Waste Management Centres (WMC) serving the needs of one county or, in some cases, of several counties. The WMC concept has been adopted by the Croatian Government in its National Waste Management Plan (Government of Republic of Croatia, 2017).

Croatian strategic documents related to waste management are *Waste Management Plan for Republic of Croatia for period 2017-2022* (OG No. 3/2017) and *Waste Management Strategy for Republic of Croatia* (OG No. 178/04 – a part of Environment protection strategy), which are aligned with European legislation and strategies. The purpose of these documents is creation of a framework within which Croatia can reduce its waste amounts and manage these amounts in a sustainable manner, within principles of Circular Economy and Bioeconomy.

Within mentioned documents, significant number of regulations, ordinances and statutes are mentioned, that define the following:

- Basic goals and measures for waste management;
- Measures for hazardous waste management;
- Guidelines for waste recovery and treatment.

Moreover, Croatian Waste Management Strategy prescribes the maximum allowed mass of biodegradable waste that can annually be landfilled in Croatia, compared to mass of biodegradable municipal waste produced in 1997 and it is following:

- 75%, i.e. 567,131 tonnes by 31st December 2013
- 50%, i.e. 378,088 tonnes by 31st December 2016
- 35%, i.e. 264,661 tonnes by 31st December 2020.

Figure 17 shows the current status and progress of Croatia in terms of biodegradable waste management, and it can be seen that there is still much room for improvement in this sector.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

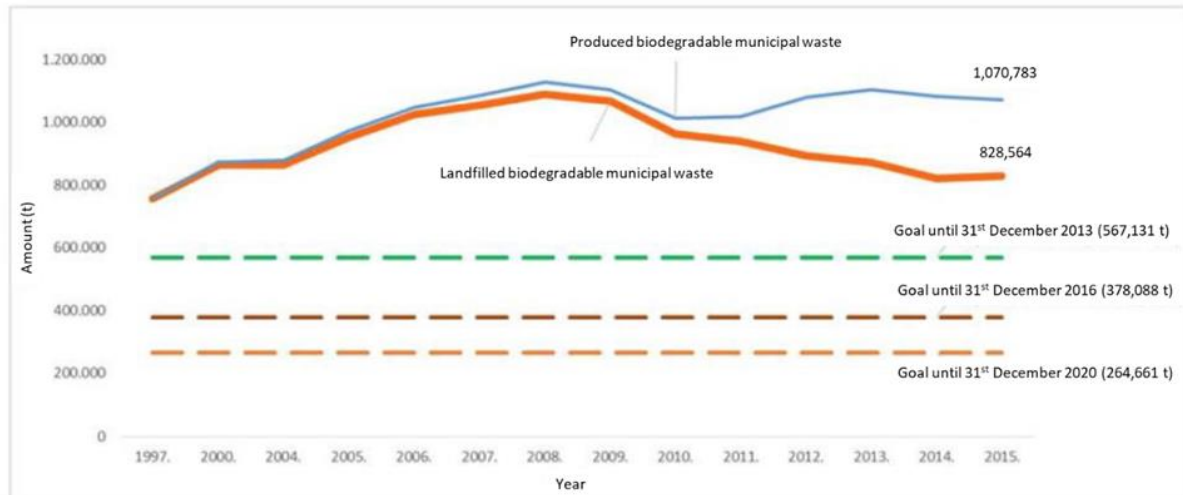


Figure 17 Produced and landfilled biodegradable municipal waste in period from 1997 to 2015, in relation to prescribed goals (Government of Republic of Croatia, 2017)

In order to reduce the amounts of biodegradable waste that is landfilled, separate collection of biodegradable municipal waste is legally defined, with goal of its material and/or energy recovery through composting, digestion (aerobic, anaerobic)¹³.

Moreover, to implement the Circular Economy and Bioeconomy strategies, Croatia needs to define waste streams that are available for energy and material recovery, which could be returned to the production cycle.

¹³ Law on sustainable waste management for Republic of Croatia, OG No. 94/2013

4.2. Waste from biological resources

According to data from Croatian Agency for Environment and Nature (CAEN), *Table 21* presents the amounts of waste in period 2010-2017. As it can be seen, the amounts of total municipal waste produced in Croatia vary around 1.6 million tonnes each year. Following on Croatia's entering EU in 2013, the living standard started improving and the amounts of waste started to grow. Moreover, Croatian legislation framework was aligned with the EU waste framework, accepting the goals for waste management – the most important ones: increasing the share of separately collected waste up to 50% and reducing the share of biodegradable waste on landfills (*Figure 17*).

Table 21 Amount of total municipal waste generated in period 2010-2017¹⁴

Year	Amount of total produced waste [t]
2010	1,629,915
2011	1,645,295
2012	1,670,005
2013	1,720,758
2014	1,637,371
2015	1,653,918
2016	1,679,765
2017	1,716,444

In order to satisfy the goals set for Croatia by the EU, the share of separately collected biodegradable waste types and biodegradable waste that should be energy and/or materially recovered will increase (e.g. collected biowaste should be above 40% by 2022). Total waste generation per category for the period 2010-2017 is presented in *Table 22*. These amounts are related to biodegradable non-hazardous waste categories that could be considered for waste management within the principles of Bioeconomy. It should be mentioned that in period 2010-2013, biodegradable waste was considered only as a share of municipal waste – from 2014 a new *Methodology for determining composition and amounts of municipal, i.e. mixed municipal waste* by CAEN was introduced, where biodegradable waste was separated in specific waste categories (*Figure 18*).

Moreover, it should be noted that biodegradable waste in Croatia includes the following waste types: paper, cardboard, biowaste, textile and wood, etc. Since most of the aforementioned waste types are recyclable, which are planned to be treated in WMCs, the remaining waste type for energy and material recovery is biowaste.

¹⁴ CAEN, *Reports on municipal waste (2010-2017)*

Table 22 Municipal biodegradable waste amounts produced in Croatia in period 2010-2017¹⁵

Year	Amount of total produced waste [t]	Amount of landfilled waste [t]
2010	1,012,651	963,889
2011	1,017,519	937,375
2012	1,078,295	892,049
2013	1,103,593	870,434
2014	1,083,596	819,757
2015	1,070,783	828,564
2016	1,072,439	831,977
2017	1,091,066	801,238

Biowaste in Croatia is defined as biologically degradable waste from gardens and parks, food and kitchen waste from households, restaurants and retail and similar waste from production of food products. As waste management in Croatia is already oriented toward recycling of materials such as paper, cardboards, metals, etc., biowaste could be considered as a feedstock for Bioeconomy.

Assessed amounts of produced biowaste from municipal waste do not differ greatly from 2012, and amount in average around 530,000 tonnes annually. The share of biowaste in mixed municipal waste is around 37.06%¹⁶. From this amount, around 13% is collected separately (71,046 t in 2017 (CAEN, 2017) and forwarded to recovery (composting, anaerobic digestion), while the rest ends up in landfills at this moment (around 450,000 t).

The S2BIOM figures on the biodegradable waste potential for 2020 are in the same line and estimate a total of 493 Ktonnes d.m. biowaste which is not far off the 530 Ktonnes mentioned above based on the 2012 and figure for the following years. The difference in total is probably related to the fact that S2BIOM figures were based on population numbers for 2020. In S2BIOM it is estimated that 290 Ktonnes of the biodegradable waste is already separately collected, while the remaining 40% remains in the mixed waste stream and requires separation after collection. As it can be seen from national data and reports, this number is not achieved.

¹⁵ CAEN, Reports on municipal waste (2010-2017)

¹⁶ Share of 37.06% is determined based on the defined composition of mixed municipal waste in Croatia, taking into account the following components: garden waste (5.68%), kitchen waste (30.93%), animal skin/bones (0.45%). Since wood component's origin is not known, it was not considered during the composition determining of biowaste share in mixed municipal waste.

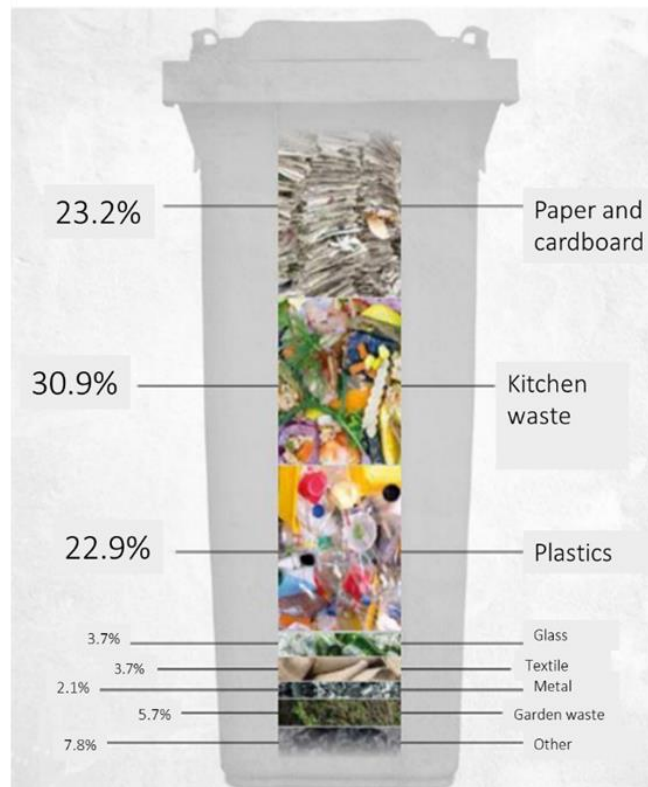


Figure 18 Estimated composition of mixed municipal waste in the Republic of Croatia in 2015

There is another separate biodegradable waste flow of 70 Ktonnes d.m. of post-consumer wood. This biomass potential has so far not been included in the above totals and is an attractive source to further recycle in biomaterials, especially where it relates to the non-hazardous fraction. The larger fraction of hazardous post-consumer wood could at least go to energy generation. Current uses of this biowaste resource are:

- Energy recovery
- Recovery other than energy recovery – Backfilling

Table 23 Biodegradable waste potentials for Croatia (Ktonnes d.m.) as assessed in S2BIOM

Ktonnes d.m. 2020 Base potential		Biowaste unseparately collected	Biowaste separately collected	Total	Hazardous post consumer wood	Non hazardous post consumer wood	Total
Name	R_code	5111	5112		5211	5212	
Primorsko-goranska županija	HR031	20	14	34	2	3	5
Ličko-senjska županija	HR032	3	2	6	0	1	1
Zadarska županija	HR033	12	8	20	1	2	3
Šibensko-kninska županija	HR034	7	5	12	1	1	2
Splitsko-dalmatinska županija	HR035	31	22	52	3	5	7
Istarska županija	HR036	14	10	24	1	2	3
Dubrovačko-neretvanska županija	HR037	8	6	14	1	1	2
Grad Zagreb	HR041	54	38	91	4	9	13
Zagrebačka županija	HR042	22	15	37	2	3	5
Krapinsko-zagorska županija	HR043	9	6	15	1	1	2
Varaždinska županija	HR044	12	8	20	1	2	3
Koprivničko-križevačka županija	HR045	8	5	13	1	1	2
Međimurska županija	HR046	8	5	13	1	1	2
Bjelovarsko-bilogorska županija	HR047	8	6	14	1	1	2
Virovitičko-podravska županija	HR048	6	4	10	0	1	1
Požeško-slavonska županija	HR049	5	4	9	0	1	1
Brodsko-posavska županija	HR04A	11	8	18	1	2	3
Osječko-baranjska županija	HR04B	21	14	35	2	3	5
Vukovarsko-srijemska županija	HR04C	12	8	21	1	2	3
Karlovačka županija	HR04D	9	6	15	1	1	2
Sisačko-moslavačka županija	HR04E	12	8	20	1	2	3
Total		290	204	493	24	47	70

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Additional feedstock that can be used within Bioeconomy is sewage sludge from wastewater treatment plants (WWTP). The amount of produced sewage sludge in Croatia is around 35,000-40,000 tonnes per year (around 20,452 tonnes of dry sludge matter) (Government of Republic of Croatia, 2017). Of that amount, around 50% of the sludge is produced by and located at the site of the Central Device for Wastewater Purification of the City of Zagreb. It is additionally estimated that, on a national level, around 1,100-2,000 tonnes of sludge are used for agricultural purposes and 110-200 are composted annually¹⁷. The remaining sludge is mostly landfilled. Although this potential for bioeconomy feedstock is relatively small, the amounts of sewage sludge will grow in the future with construction of WWTPs with higher wastewater treatment levels (Figure 19). If all future and planned WWTPs in Croatia would operate under full load, they would generate between 95,000 and 101,000 tonnes of sewage sludge dry matter per year (considering the production of 30 kg dry matter/person equivalent per year (Karagiannidis et al., 2011; data from WWTP Zagreb), which is a significant increase compared to current state. However, currently an adequate management system for residual sludge from WWTPs is not established yet, primarily meaning the necessary infrastructure for treatment.

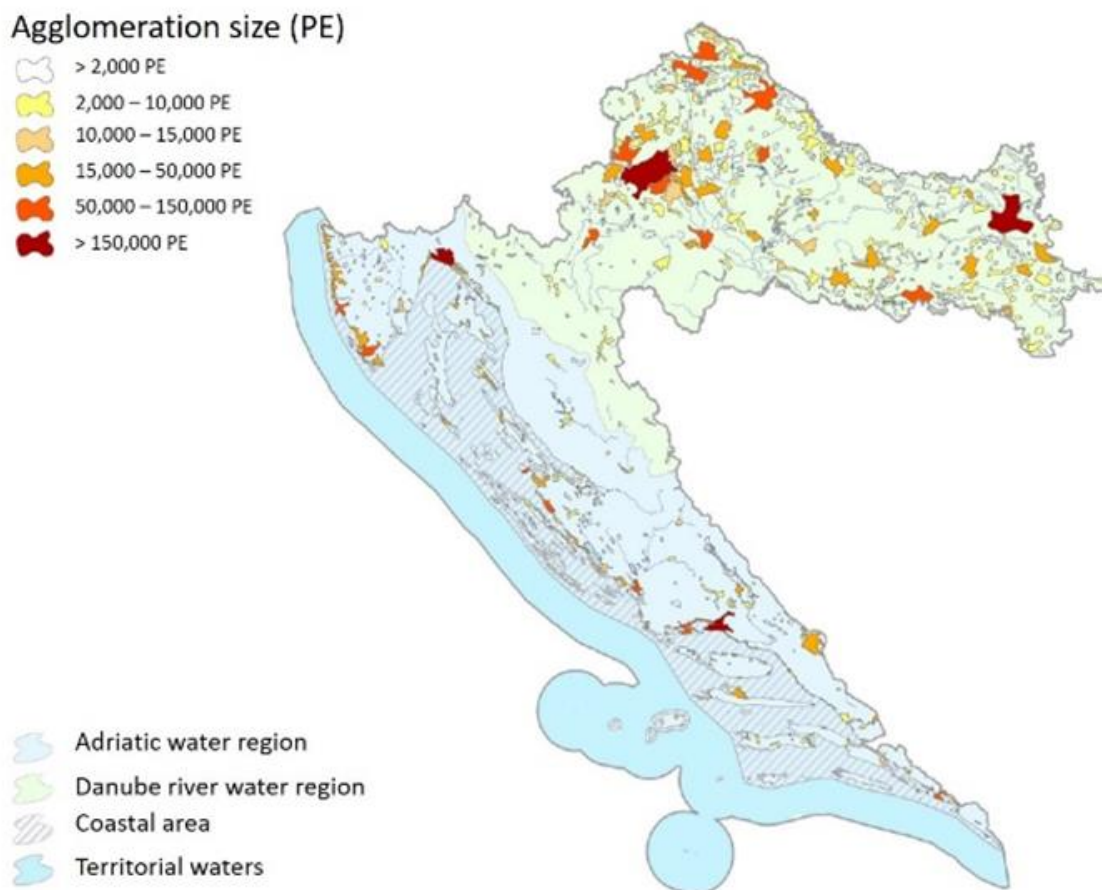


Figure 19 Spatial arrangement of agglomerations in Croatia (Đurđević et al., 2019)

¹⁷ CAEN, Management of sewage sludge from WWTPs when sludge is used in agriculture, 2010-2017

Waste cooking oil is collected in household and service sector, which is delivered to authorized companies that are recovering this type of waste. According to data from Environmental Protection and Energy Efficiency Fund (Government of Republic of Croatia, 2017), around 86,500 l (760 tonnes) of waste cooking oil is collected annually, from which 98% is recovered.

Regarding industrial waste, Croatia implements a "polluter pays" principle, which determines that the producer of waste must manage its waste accordingly and properly. Waste amounts produced in the industry sector are defined in the *Polluter Register* (created in 2011), which includes hazardous and non-hazardous waste categories. *Table 24* shows the amounts of industrial waste produced in period 2010-2017.

Table 24 Industrial waste amounts produced in Croatia in period 2012-2017¹⁸

Year	Non-hazardous waste produced [t]
2012	1,309,770.57
2013	1,377,847.86
2014	1,523,538.24
2015	1,844,367.98
2016	2,007,816.38
2017	1,780,089

¹⁸ Polluter Registers for period 2012-2017

4.3. Current waste treatment and unused potential estimates

4.3.1. Existing waste treatment facilities

According to the Waste Management Plan for Croatia, facilities for waste management are facilities for waste collection (recycling yards), facilities for waste treatment (incineration, AD plant, composting facilities, energy recovery) and WMCs.

Aerobic biological treatment of bio-waste by composting is conducted in 11 composting plants of a total capacity of around 103,397 t/year, of which, in 2016, 7 had a valid waste management permit.

In 2016, of the total 11 biogas facilities, 6 biogas facilities possessed the permit for anaerobic biological treatment of bio-waste, totalling a capacity of 234,800 t/year. An overview of locations of composting plants and biogas facilities in Croatia in 2016 is given in *Figure 20*, and an overview of the existing composting plant capacities in *Table 25*.

Currently the biodegradable treatment installations for compost mostly have one outlet and that is compost. But for investments in further installations and existing ones it would be good to create treatment chains that first win the energy in an anaerobic digestion installation and then use the digestate for compost generation. This combined treatment is attractive as it is more resource efficient particularly when options are also created to use the generated heat locally.

Table 25 Composting plants and their capacities in Croatia in period 2012-2017

Object location		Capacity [t]
Buzet*		7
Čakovec		10,000
Imbriovec		6,990
Kloštar Ivanić		27,300
Koprivnica		1,900
Krk		6,000
Perušić		1,200
Prelog		3,000
Zagreb	Jakuševac*	27,000
	Markuševac	10,000
	Jankomir	10,000
Total		103,397

*composting facility not active or does not have a valid permit

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

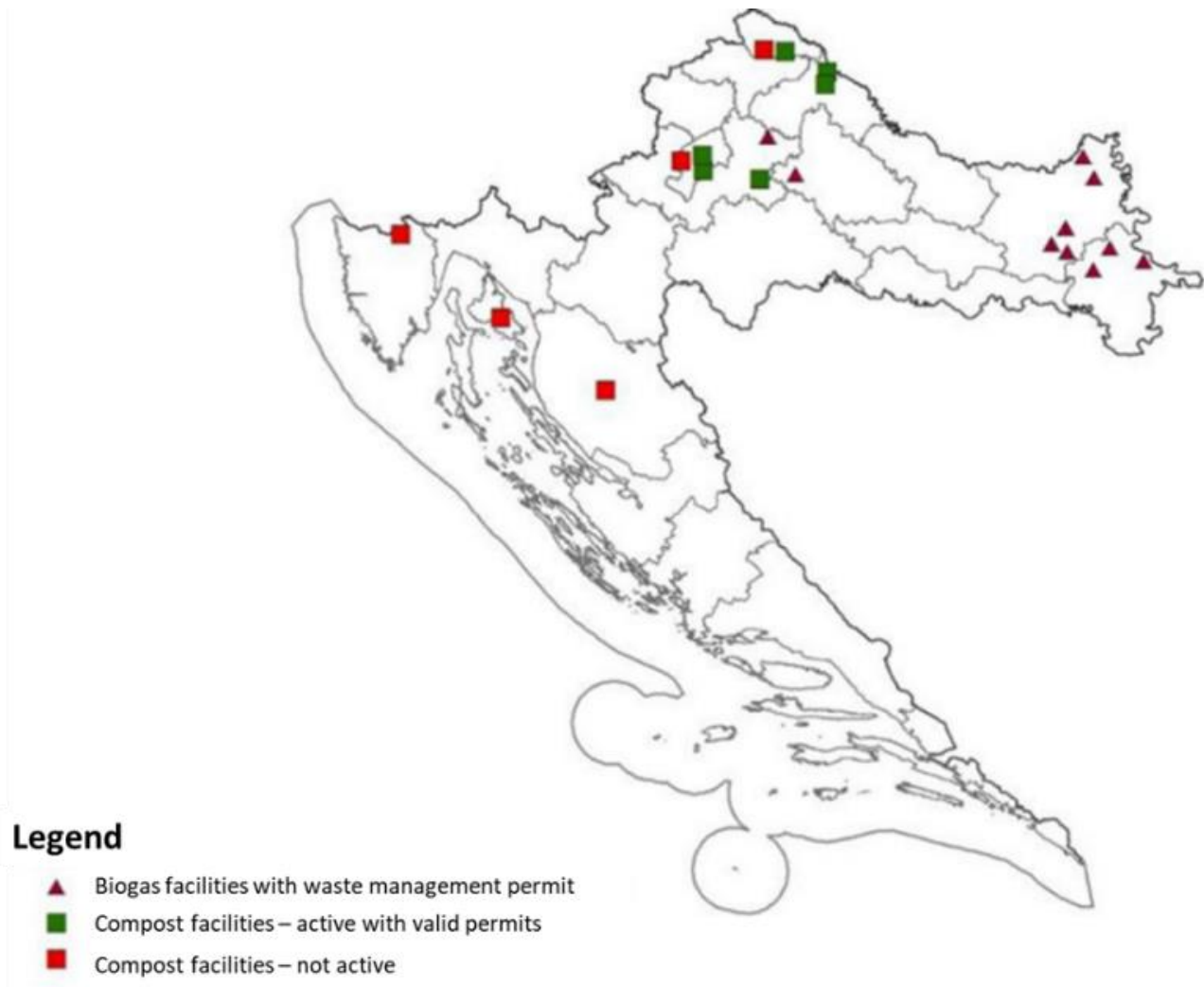


Figure 20 An overview of composting and biogas facilities in Croatia, 2016 (Govt of Republic of Croatia, 2017)

The Waste Management Plan of Croatia foresees the construction of 13 WMCs for treatment of mixed municipal waste and other waste that was not previously recyclable (Figure 21). These plants are planned with the concept of mechanical-biological treatment technology (MBT), which contribute to the achievement of goals regarding the decrease of biodegradable waste landfilling and total quantities of landfilled waste, but it is not sufficient in regard to achieving the municipal waste recycling goals.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

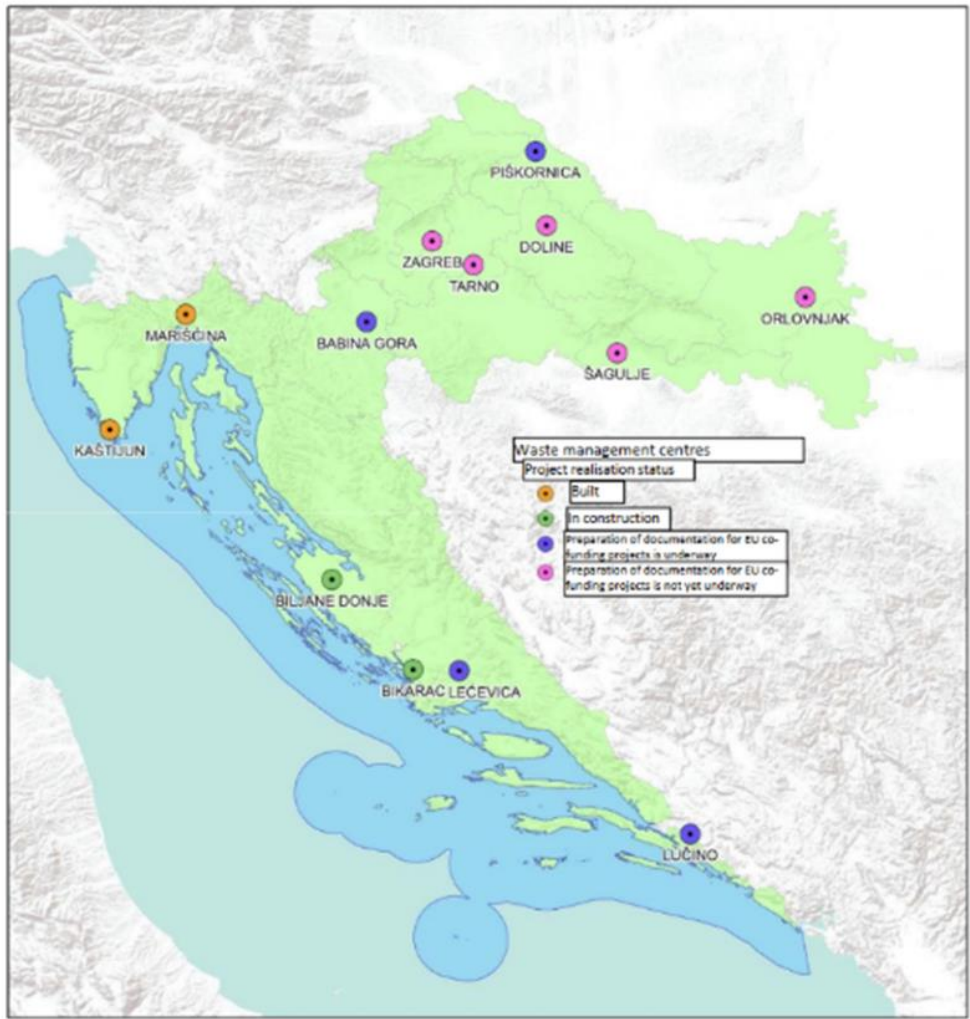


Figure 21 Position and capacity of planned WMCs according to the Waste Management Plan, according to the current status of realisation (Government of Republic of Croatia, 2017)

Taking into consideration the mentioned portion and quantities of landfilled mixed municipal waste, we come to the conclusion that landfills in the Croatia annually receive almost 500,000 tonnes of biowaste (mostly biodegradable waste from gardens and parks on public surfaces), of which around 380,000 tonnes are estimated to be food waste (Table 26). On average, around 11% of total produced biowaste is separately collected, i.e. 60,000 tonnes, of which only a half is directed to recovery (composting, anaerobic digestion). Separate collection of biowaste in 2015 was conducted in 96 local self-governing units (17%), where quantities of separately collected biowaste from households are negligible.

Regarding industrial waste, the producer of waste has to manage it according to the regulatory framework. The amounts of produced and treated waste (industrial and municipal) are recorded in the *Polluter Register*, where waste management is presented per waste categories (industrial and municipal; hazardous and non-hazardous) and waste treatment. *Table 26* shows the waste amounts treated (landfill, storage, preparation for reuse, energy/material recovery, etc.) in Croatia in the period 2010-2017.

Table 26 Waste amounts of treated waste (municipal and industrial) in Croatia for period 2010-2017¹⁹

Year	Non-hazardous waste produced [t]
2012	3,208,209.72
2013	3,445,549.11
2014	3,416,840.51
2015	3,723,968.58
2016	3,861,815.82
2017	3,918,487.00

4.3.2. Estimates of waste potential

In order to calculate this potential, the following approach was implemented:

1. First the total waste generation per category of waste was considered
2. Then the waste treatment categories were identified per type of waste.
3. Considering that waste treatment options mentioned in documents related to waste management in Croatia include landfilling, storage, etc., these waste treatment categories are considered as potentials for waste utilization. So, the part already going to energy is also perceived to be available as part of the potential.

Table 26 shows that amounts of waste managed and treated surpass the amounts of municipal and industrial waste produced (additional waste is imported). These amounts include the waste that is landfilled, energy recovered, stored, etc. Therefore, the waste amounts mentioned for these purposes could be considered as a potential for energy and/or material recovery, instead of wasting their potential in landfills (without energy recovery).

In terms of municipal biodegradable waste, *Figure 22* shows the amounts of biodegradable municipal waste that remain unused and that has the potential for energy and/or material recovery within the Bioeconomy principles.

¹⁹ *Polluter Registers for period 2010-2017*

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

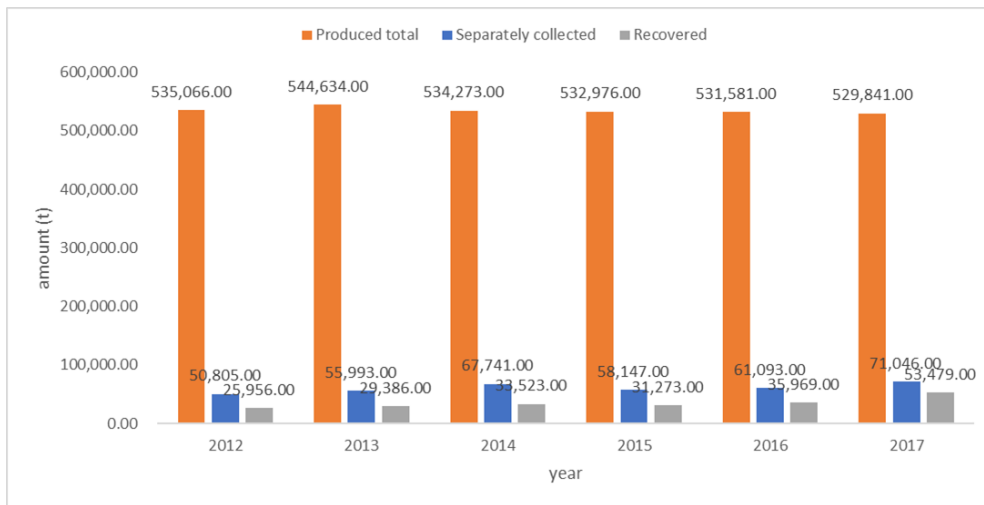


Figure 22 Quantities of produced, separately collected and recovered biowaste from municipal waste in Republic of Croatia, in the period from 2012 to 2015 (Government of Republic of Croatia, 2017)

Total treated waste, considering treatment determined within *Polluter Register*, has the potential of unused waste in terms of landfilled waste that could be energy and/or materially recovered. The amounts that have the highest potential are presented in Table 27.

Table 27 Waste amounts with potential for energy and/or material recovery (municipal&industrial) 2010-2017²⁰

Year	Non-hazardous waste produced [t]
2012	1,938,822
2013	1,832,906
2014	1,687,761
2015	1,773,566
2016	1,764,643
2017	1,649,989

²⁰ Polluter Registers for period 2010-2017

4.4. Summary and conclusions in relation to SWOT elements

Although waste management sector in Croatia improves each year (amounts sent to landfills decrease and reuse and recovery of waste increase), the progress is very slow. Moreover, raw materials are lost with lack of energy and material recovery systems. Generated waste per year amounts to cca 3.5 million tonnes of combined municipal and industrial waste (Table 26). This waste is treated in various ways, but the largest share is still going to landfill. Biodegradable waste is treated in three ways: Landfilling; Anaerobic digestion (biogas facilities – energy recovery); Composting (composting facilities – material recovery).

Based on the aforementioned data, it can be seen that one of the strengths of waste management for the purpose utilization within Bioeconomy is the amount of waste generated, i.e. landfilled – therefore, usable for utilization. Moreover, the Croatian legislation and strategic framework are aligned with the EU legislation framework, which opens the possibilities of easier implementation of Circular Economy and Bioeconomy principles.

However, one of the weaknesses is the implementation of this legislation framework. Due to lack of knowledge on Bioeconomy principles and its possibilities, a significant amount of waste that could be energy/materially recovered ends up in landfills and unused. Moreover, the public awareness on waste management is very poor. Although there have been some projects related to increase of knowledge and awareness of citizens on waste management, the whole system is still in early phases in Croatia.

Following on all the above-mentioned data and information, there are a lot of opportunities for Bioeconomy principles implementation in Croatian waste management system. Biodegradable waste amounts, currently landfilled, could be utilised for energy and/or material recovery. Moreover, the concept of "Waste Market" should be implemented during this Waste Management Plan's period and the action plan on Bioeconomy oriented to support waste utilization in form of energy and material recovery. This will define the principles of financing and specific legislation (e.g. *Ordinance on by-products and end-of-waste status*) on waste management, which is currently missing or not developed enough. Additionally, the infrastructure construction is in implementation process, which means that there will be room for utilization of residual waste for energy and/or material recovery (within existing or new waste treatment facilities). Since investment for waste management infrastructure is mainly co-financed by the EU funds, there is an opportunity for implementation of Bioeconomy principles within Croatian waste management sector.

Table 28 SWOT analysis for waste sector

<p>Strengths</p> <p>Development of waste management infrastructure that can be used for energy and/or material recovery</p> <p>High existing potential for utilization which is currently still going to landfill</p> <p>Development of separate waste collection on household level</p>	<p>Weaknesses</p> <p>Implementation of legislation framework slow</p> <p>High collection and operational costs for waste management</p> <p>Lack of knowledge on Bioeconomy principles and its possibilities</p> <p>Significant amount of waste that could be energy/materially recovered ends up in landfills and unused</p> <p>Poor public awareness of waste separation/ management</p>
<p>Opportunities</p> <p>Implementation of "Waste Market"</p> <p>Innovative ways of biodegradable waste utilization are possible given that this still needs to be largely build up</p> <p>Knowledge transfer from more advanced countries in EU</p> <p>Utilization of biodegradable waste that is currently landfilled</p> <p>Financing from EU funding, aligned with financing of waste management system (waste management centers)</p>	<p>Threats</p> <p>Lack of recognition for the opportunities in waste utilization within Bioeconomy principles</p> <p>Backwardness and lack of change within legislation and strategic framework</p> <p>Negative public opinion in terms of waste separation, utilization for energy/recovery purposes</p> <p>Indifference of sector stakeholders</p>

5. BIO-BASED PRODUCTS INDUSTRIES AND MARKETS

Bio-based products make about 1/3 of the total gross value added in manufactured products in Croatia. Since there are a lot of SMEs and industries that are contributing to the development of the Croatian bioeconomy sector, this chapter provides an insight in several examples of the industries they belong to. The mentioned companies and organizations are by no means preferred to other stakeholders in these sectors, but represent a representative sample and overview of the stakeholders in the selected sectors.

This is due to the limitations of the project, both by timeframe and budget, which were addressed by creating designated templates for 6 targeted countries: Bulgaria, Croatia, Czech Republic, Hungary, Slovak Republic and Slovenia. This led to several shortcomings across the implementing countries. For Croatia, those were missing assessment of blue growth and maritime bioeconomy as well as limited value chains for such versatile ecosystems and possible cross overs from primary sectors to (future) bio-based industry, to start from.

It is very important to acknowledge that this methodology is focused on three sectors: agriculture, forestry and waste management. It is important to stress out that Croatian potentials for transition to circular and sustainable bioeconomy are beyond those three sectors assessed in this project. Fisheries, aquaculture, hunting, waste, food preparation and processing waste, nature capital, tourism and service sectors, digitalization... are also considered as elements of Croatian bioeconomy but are not assessed as being out of the scope of the project and the templates provided.

5.1. Current bio-based industries

5.1.1. Bioplastics

The bioplastics sector in the Republic of Croatia has several companies that are very ambitious regarding their development and production activities. Although the bioplastics production and processing of bioplastics in Croatia is relatively new, a number of active companies have made significant progress within the scope of numerous EU projects. The production of bioplastic materials has been developed in Bio-Mi while several plastic processing and recycling companies such, as Mi-plast, Weltplast and EcoCortec, are processing bioplastic material.

Weltplast, EcoCortec and Mi-Plast are oriented towards the development of biodegradable packaging products that are not harmful to the environment (Weltplast – packaging material from synthetic biodegradable plastic; EcoCortec – bags and foils from polyester). On the other hand, Bio-Mi is the first producer of bio-degradable and compostable bioplastic materials in Croatia and South East Europe with a certified MI group of materials and products that are made from natural bio-polymers, bio-based and biodegradable polyesters, co-polyesters, etc.

Bio-Mi and Mi-plast are taking part in various EU funded projects, where they are participating in the development of biodegradable materials and products, from bio-based and waste/raw materials. Participation in collaborative projects, with more than EUR 100 million of the overall budget, resulted in creating new, diversified biodegradable, compostable and recyclable thermoplastic materials and products to be used in the packaging and the agro sector.

Bio-Mi d.o.o. is a small and medium-sized manufacturer, R&D oriented enterprise, based on the synergy between 20 years of industrial manufacturing experience in the field of plastic processing and young R&D team with strong experience in EU funded projects. Bio-Mi is dedicated to the development and the production of bio-based, biodegradable, and compostable thermoplastic materials and compounds as well as flexible film products made of its own certified materials used for the production of primary and secondary packaging applications, agro applications etc., with overall capacities of 2500 t/ann. Bio-Mi is a member of several national and international organizations such as BIC (Bio-Based Industries Consortium), Horizon 2020 expert groups for Societal Challenges 2 and 5 and currently implements 8 H2020 projects in the field of bioeconomy and sustainability (EFFECTIVE, ECOFUNCO, BIONTOP, USABLE PACKAGING, NENU2PHAR, etc.)

As a first developer of biodegradable and compostable thermoplastics in Croatia, Bio-Mi has a vast experience and know-how in creating biodegradable blends based on starch, PLA, PHAs, PBS, PBAT, PCL, fillers, fibers, etc. Moreover, it is the first company in East and Southeast Europe that manufactures EN 13432 certified bio-based, biodegradable, and compostable thermoplastics with particular emphasis on MI family of materials, respectively: MI3 (starch-based compounds), MI6 (PLA based compounds) and MI9 (biodegradation in soil, biodegradation in marine). Bio-Mi is also providing tailor-made material solutions for various processing technologies such as extrusion, injection moulding, blow moulding etc.

EcoCortec d.o.o. specializes in developing and manufacturing value-added biodegradable/compostable flexible films that outperform non-degradable and other biodegradable materials currently on the market. EcoCortec strives to develop eco-efficient production of biodegradable films that combines new technology and high productivity with positive effect on environment. Installed production capacity is 5,000 tonnes/year, enabled by state-of-the-art extrusion, converting and regranulation equipment. Together with University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, EcoCortec have been involved in the CIP Eco-innovation project, funded by the

European Union – MarineClean (Marine debris removal and preventing further litter entry), with the scope of developing plastic packaging material, degradable in seawater. Furthermore, EcoCortec is taking part as a project partner in Interreg Central Europe project BIOCOMPACT-CE.

Weltplast d.o.o. is producer of wide range of products, including pressure HDPE pipes, PP pipes for home installation and dressed packaging, industrial films and foils. Weltplast also offers a range of environmentally friendly products, under the EcoWelt brand. EcoWelt® products are completely biodegradable and compostable. Obtained by extrusion process of BASF raw materials. EcoWelt® packaging products fully comply with the requirements of EN 13 432, which establishes criteria for biodegradation and composting, as well as compost quality, and all harmonized with the European Directive 94/62/EC on packaging and packaging waste. Company also has recycling line installed.

Mi-plast d.o.o. Company's main activity is the processing of LDPE and HDPE materials, bio polymers, packaging and production of these materials, as well as regeneration and recycling of these materials. The products obtained by processing of polyolefins and bio-materials are mainly used in the construction sector, agriculture and in retail sector. These products are: agriculture mulch, shopping bags, garbage bags, construction film foils, laminated foils etc. The company is placing its products mainly to the countries in the South Eastern Europe, Slovenia and Italy. Mi-plast d.o.o. works on the research and development of biodegradable biopolymer-based materials and participate in numerous research projects within the EU's R&D and Innovation Programs - FP7, Horizon2020, Life + ESIF. CIRC-PACK, RefuCoat, Afterlife, RES URBIS, PULPACKTION are just few projects that Mi-plast Ltd. conducts in Croatia in field of bio-based research and development framework.

5.1.2. Wood processing industry

Croatia has a broad wood processing industry, which includes 10 pellet producers, 13 wood chips producers, 45 sawmills and 224 contractors from the forestry sector, which are spatially distributed all over Croatia. Within the "Catalogue of wood biomass producers in Croatia"²¹ they are all mentioned, including their basic information – name, address, contact and webpage, but also their business activities.

5.1.3. Food and feed ingredients industries

Compared to the other branches of the manufacturing industry in Croatia, the food (food and beverage) industry achieves the highest total revenue and employs the most people. The food industry has attracted considerable foreign investment and many international companies are successfully operating in Croatia like **Meggle**, **Axereal**, **Coca-Cola**, **Lactalis** and others. Additionally, this sector includes over 3,000 registered companies (Croatian Bureau of Statistics, 2018), such as **Podravka**, **Atlantic Group**, **Ledo**, **Kraš**, and many others.

The meaning of the food-processing industry in relation to the total manufacturing industry is reflected in the fact that even about a quarter of the value of indicators relates to the food processing industry, such as: the number of employed persons (24%), commodities exchange (30%) and added value (24%). The share of companies and organizations in food processing industry is 15% compared to the total manufacturing industry. One of the most

²¹ www.biomassradecentre2.eu/scripts/download

important branches of the Croatian food industry is the confectionery industry. The most important export products of the food industry are food additives, biscuits and wafers, stuffed chocolate, canned fish, instant soups, olive oil, beer and other alcoholic beverages (Croatian Bureau of Statistics, 2018).

5.1.4. Pharmaceutical and cosmetic industry

Pharmaceutical and cosmetic industries have a long tradition in Croatia. Know-how and workforce experience create a pathway for future industry development, but also coordination and communication with related sectors. Moreover, pharmaceutical and cosmetic industries are a part of Croatian economy sectors in which there are a lot of investments in regards to research and development.

Besides **Pliva**, the largest manufacturers of medicinal products in the region, Croatia has other successful companies, such as **Belupo** and **Jadran galenski laboratorij (JGL)**, who achieve excellent cooperation on European and global markets. Additional companies in this segment should be mentioned, such as **PharmaS**, which produces and transports medicinal products.

Moreover, pharmaceutical preparations production in Croatia has a strong increase trend and has a significant impact on the production of the entire industry. Therefore, there are many players who are present on the market – around 49 organizations, such as **GlaxoSmithKline**, **Hospira**, **Galapagos**, **ACG Lukaps**, **Farmal**, etc.

5.1.5. Valorisation of secondary materials from waste sector

In Croatia, waste management is currently one of the largest challenges in the environmental sector and certainly one of the most demanding areas in terms of adjustment to the standards of the EU. Therefore, the companies that are involved in valorisation of secondary materials from waste sector have a lot of potential within the bioeconomy. Some of the organizations and companies that are involved in this sector are mentioned in the following part.

Agroproteinka d.d. is a company with a long tradition in collecting and managing animal by-products, which has been turning to production of renewable energy sources in the last decade. As a part of the global vision of environment protection, in 2008 Agroproteinka started collecting waste edible oil, which is transported to their plants for physical pre-treatment. Waste edible oil is a huge resource of renewable energy sources – it is used for obtaining biodiesel, a fuel for diesel engines.

Regeneracija d.o.o. is doing business in accordance with the world trends. The high environmental awareness of the company is manifested in the positive organization of the production process based on the principles of sustainable development. From fibres obtained from the treatment of waste textile Regeneracija produces floor protection in construction works.

Gumiimpex-GRP d.d. is the first company in Croatia to start recycling waste (used) car tires in 2005. Gumiimpex-GRP is the only NEXT TREAD (Goodyear) and RECAMIC (Michelin) partner in Croatia.

Vetropack Straža d.d. manufactures, sells and distributes glass packaging in the markets of Croatia, Slovenia, Bosnia and Herzegovina, Serbia, Montenegro, Macedonia, as well as in the markets of other Southeast European countries.

Today, Vectropack glass factories consistently rely on recycling. In Vetropack, glass karst has become the most important raw material for glass production: at the Group level, on average, karst accounts for 60% of total raw materials.

5.2. Advanced bio-based initiatives: demo and pilot plants and major innovation activities

In order to stimulate the development and growth of the Croatian economy, the Government of the Republic of Croatia has decided to group all public, private and scientific research representatives in innovative sectors, all to strengthen the competitiveness of Croatian companies, and consequently the Croatian economy and society.

Cluster initiatives have become a popular concept, a policy tool for boosting regional competitiveness and economic growth and an important component in Smart Specialization strategies. Within the strategy, Competitiveness clusters are promoted as a policy tool, and in Croatia they are envisaged as networks of various actors that promote national competitiveness of entire sectors of industries, including bioeconomy (Anić et al., 2018).

Croatian competitiveness clusters are conceived as non-profit organisations that bring together all the best businessmen in a certain sector - small, medium and large entrepreneurs, representatives of regional and local government and research institutions, in order to establish synergy and cooperation to strengthen the competitiveness of economic sectors at national level. The Agency for Investments and Competitiveness and the Ministry of Economy and Sustainable Development (former Ministry of Economy, Entrepreneurship and Crafts) played an essential role in identifying, supporting and creating Croatian Competitiveness Clusters.

13 Croatian Clusters of competitiveness have been established:

1. Croatian Food and Processing Sector competitiveness cluster
2. Croatian Competitiveness Cluster for the Wood Processing Sector
3. Croatian Competitiveness Cluster for the Automotive Sector
4. Croatian Competitiveness Cluster for Creative and Cultural Industries
5. Croatian Cluster of Competitiveness of Textile, Leather and Footwear Industry
6. Croatian Defense Industry Cluster
7. Croatian Construction Industry Competitiveness Cluster
8. Croatian Competitiveness Cluster for the Power and Manufacturing Machinery and Technologies Sector
9. Croatian Health Industry Competitiveness Cluster
10. Croatian Competitiveness Cluster of the Chemical, Plastics and Rubber Industries
11. Croatian ICT Industry Competitiveness Cluster
12. Croatian Maritime Industry competitiveness cluster
13. Croatian competitiveness cluster for the Personalized Medicine

Croatia is a full member of **BIOEAST Initiative** – Central and Eastern European initiative for knowledge-based agriculture, aquaculture and forestry in the bioeconomy. An open initiative started by the Visegrad Group Countries: Czech Republic, Hungary, Poland, Slovakia, and joined by Bulgaria, Croatia, Latvia, Lithuania, Republic of Estonia, Romania, Slovenia. The initiative offers a shared strategic research and innovation framework for working towards sustainable bioeconomies in the Central and Eastern European (CEE) countries. One of the main objectives is to initiate

cooperation and the development of knowledge-based policies: establish a multi-stakeholder network and cluster at European level to facilitate joint actions, backed up by a renewed commitment to closer cooperation at both the political and operational levels through close personal contacts and communication between the countries concerned at the operational level, as well as initiate strategies: create a cross-sectorial approach for the development of a national circular and bioeconomy strategy. Also, the Initiative seeks to provide an evidence base: establish data-driven support for the implementation of policies through the creation of an interoperable, fully integrated observing and forecasting system. This would promote continuous, long-term observation based on open data structures to guarantee easy access. Ministry of Agriculture is the coordinator of one of the five thematic working groups: TWG Bioenergy and new value added materials, with the expert support from the Energy Institute Hrvoje Požar (EHP). Croatia has its representatives in all 5 TWGs: Forestry; Freshwater; Sustainable Agriculture, Food Systems and Bioenergy.

There are no commercial bio-refineries in Croatia, which is the most outstanding barrier to a more bio-based (domestic) industry at large. Oil company INA, together with Faculty of Agriculture, University of Zagreb, is participating in another BBI JU funded project, **GRACE “GRowing Advanced industrial Crops on marginal lands for bioRefineries”** of which the main goal is to produce sustainable products with a strong market potential, to guarantee a reliable and affordable supply of sustainably produced biomass, and to better link biomass producers with the processing industry. To avoid competition with food and feed crops, miscanthus and hemp are cultivated on areas that have been polluted, for example by heavy metals or are unattractive for food production due to lower yields. INA has been given the role of the leader of the demonstration chain for testing the cultivation of Miscanthus hybrids on marginal and lower quality soils for processing into advanced bioethanol. At this point, the first harvest of the miscanthus energy crop was completed at the beginning of the year. The miscanthus (lat. *Miscanthus x giganteus*) was planted on a demonstration farm in Rugvica in cooperation with BC Institute, near Zagreb, and this season's harvest yielded around 30 tonnes of biomass. Collected biomass was sent to Clariant, a focused and innovative speciality chemical company to their pre-commercial sunliquid@plant in Straubing, Germany, for processing and conversion into lignocellulosic sugars and ethanol. The results give cause for optimism as they show that the sunliquid@technology can successfully convert miscanthus into lignocellulosic sugars and ethanol.

Moreover, there are many other projects in Croatia, that are within bio-based initiative. One of them is **Usable Packaging** project, covered from Croatian side by Bio-Mi. The development of biodegradable and bio-based plastics is key to implementing circular economy models in the plastics sector and this project builds an entire value chain for high performance bioplastic packaging, that is both bio-based and biodegradable, but also does not compete with the food chain.

Another project by Bio-Mi is **Mandala**. Mandala presents a sustainable solution for the plastic packaging sector, focusing on 3 fundamental pillars: eco-design, dual functionality and end of life, with the aim of finding a sustainable and effective solution for multi-layer packaging in the medium term, insofar as recycling conventional plastic materials as well as the use of biopolymers. The project will develop a sustainable packaging format, which in addition to satisfying business needs thanks to its barrier properties, its design will facilitate recycling as it will be possible to separate the multiple layers through the development of a thermo-reversible adhesive.

BIONTOP project has a goal to create recyclable and cost competitive packaging solutions that can be mechanically recycled, industrially/home composted or even suitable for anaerobic digestion, using sustainably sourced comonomers, additives and fillers to formulate novel PLA copolymers and compounds. Moreover, the barrier properties of the produced bio-packaging trays, films and derived packaging, will be enhanced by using removable protein-

based coatings and a novel fatty acid grafting technology to decrease permeability and compete with fossil packaging.

ECOFUNCO project selects and extracts functionalizing molecules (proteins, polysaccharides, cutin) from widely available, low valorised biomass such as tomato, legumes, sunflower etc. for the development of new bio-based coating materials to be applied on two different substrates (cellulosic and plastic based), with improved performances compared to currently available products and, at the same time, with more sustainable end-of-life options. The project partner from Croatian side is Bio-mi, as a Work package 6 leader (WP6) that will be responsible for scaling up and validation of coatings on plastic substrates.

upPE-T project will solve the problem and challenge of PE and PET recycling, through an innovative solution for the upcycling PE and PET post-consumer packaging wastes by transforming them into a range of biodegradable & recyclable bioplastics (PHBVs) for food & drink packaging manufacturing.

There are also many more EU-funded projects, within the Horizon 2020, that fall under the work programme "Climate action, environment, resource efficiency and raw materials", that are connected with bioeconomy. Some of them are **ROSEWOOD, GROW GREEN, REGREEN, URBAN-WASTE** and many others, which include one or more Croatian partners.

Moreover, the Croatian Science Foundation has regular open calls for project financing, that include research project on national level. Within these calls, more than 500 project were funded, from which around 50 projects are related to bio-based and bioeconomy-related sectors.

Additionally, one specific project needs to be pointed out, which put Croatia on the EU map of biotechnology, and that is **BioProspecting of the Adriatic Sea** project. The project includes the strengthening of the capacities of the Center of Excellence for Bioprospecting of the Sea (BioProCro), through the implementation of top-level interdisciplinary research in the field of biotechnology of the sea, in order to obtain biologically active molecules of desirable properties for use in the pharmaceutical, food and cosmetic industries. It will also enable cooperation with international institutions and the transfer of technology since the biotechnology industry of natural compounds is a fast-growing market that will significantly improve the growth of the entire Croatian economy.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

5.3. Future Biomass valorisation options

At present, BBI project GRACE is ongoing in Croatia represented by two project partners, Faculty of Agriculture, University of Zagreb and INA d.d., oil company in 44.8% ownership of Croatian government. The GRACE project is demonstrating the biobased value chains below in 10 Demo Cases presented in *Figure 23*. INA d.d. is interested in developing a biorefinery based on project result in Croatia.

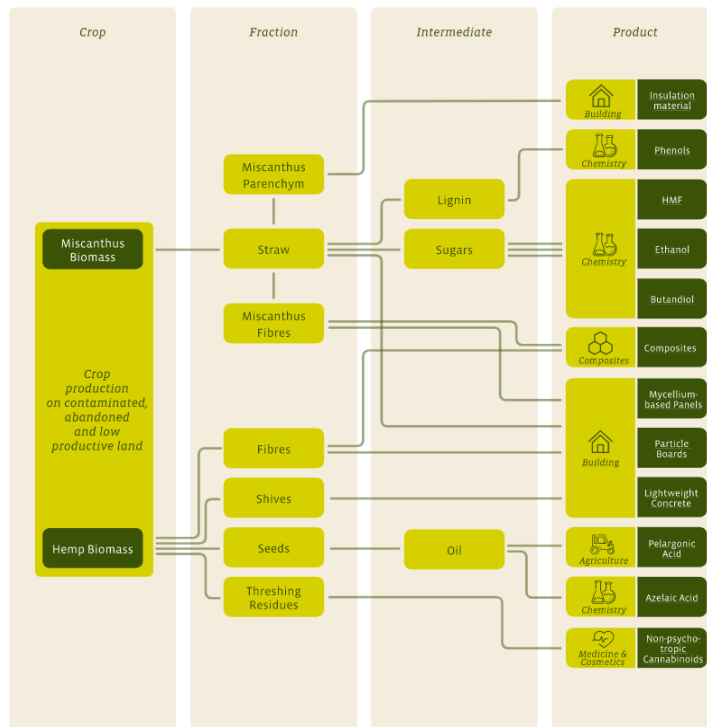


Figure 23 Value chains in GRACE project

5.4. Summary and conclusions in relation to SWOT elements

Croatia has great potential to foster bioeconomy development. With a strong foothold in wood processing and food and beverage industry, there is room for significant innovation activities and new business models. Regional leaders in bio-based activities such as Mi-plast d.o.o. and Weltplast d.o.o. could be used as examples of good practice. However, there is still a lack of communication between important stakeholders and leaders of the bioeconomy sector in Croatia, which could be a potential for improvement and closing the circle of material and energy management in each company.

Table 29 SWOT analysis of bio-based products, industries and markets

<p>Strengths</p> <ul style="list-style-type: none"> Strong academic community Interest in following global and European trends On-topic ongoing research projects Start-up entrepreneurship Proof Of Concept programme 	<p>Weaknesses</p> <ul style="list-style-type: none"> The insufficient connection and research projects between academia, public and the private sector A small rate of high TRL (6-9) research/development infrastructure The loss of engineers (scientists, engineers, doctors, ...) due to "brain drain" No PPP in other sectors except construction Development based on individual approach
<p>Opportunities</p> <ul style="list-style-type: none"> Pilot projects to connect the academy community and private investors The underexploited potential of agricultural residues Connection with the tourism sector Programmes to keep the young people in the country (decrease "brain drain") and engage them in bio-based industry PPP expanding to other sectors Expansion of food and processing industry, pharmaceutical and cosmetic industry into bio-based products and markets Financing from EU funding, aligned with financing of waste management system (waste management centers) 	<p>Threats</p> <ul style="list-style-type: none"> The loss of experts (and young people) due to rising competitiveness in other countries The loss of start-up companies due to lack of recognition of the legislative framework

6. INFRASTRUCTURE, LOGISTICS AND ENERGY SECTOR

6.1. Existing industrial hubs and harbours

Three major Pan-European corridors pass through Croatia and make it the shortest route between Western Europe and Asia, Eastern Europe and the Mediterranean. Located in Southeast Europe, bordered by Italy, Slovenia, Hungary, Serbia, Bosnia and Herzegovina and Montenegro, Croatia is perfectly positioned for reaching the EU market as well as the markets of Southeast Europe.

Transport in Croatia relies on several main modes, including transportation by road, rail, water and air. Road transport incorporates a comprehensive network of state, county and local routes augmented by a network of highways for long-distance travelling.

Water transport can be divided into sea, based on the ports of Rijeka, Ploče, Split and Zadar, and river transport, based on Sava, Danube and, to a lesser extent, Drava. Croatian ports annually reload about 20 million tonnes of cargo and transport more than 16 million passengers (Table 30).

Table 30 Maritime transport statistics in Croatia²²

Year		2016	2017	2018
Cargo [t]		18,551,030	20,797,543	21,572,694
Passengers	arrival	16,398,962	17,171,859	17,872,846
[person]	departure	14,584,374	15,351,342	16,101,093

Croatian ports are integrated into a comprehensive network of European transport corridors, which represents a growth potential that allows the inclusion of trade flows to the intra-European and world markets, as well as the transformation of port systems in modern logistics and distribution of economic centres.

Six major ports (Rijeka, Zadar, Šibenik, Split, Ploče and Dubrovnik) are located along the mainland coast, and all are declared ports of special (international) economic interests for the Republic of Croatia (Figure 24) (Božičević, 2008). Croatian seaports are conveniently positioned to facilitate maritime transport between Central and Eastern Europe and Southern Asia, Australia and Oceania and Europe (via the Suez Canal). They enable shortening of voyages by 5-8 days, or by a minimum of 2,000 km compared to north European ports. Currently, on the EU market, Adriatic ports take only 3% of total freight. Therefore, there is a vast potential to increase freight transport of all Adriatic ports.

²² www.dzs.hr

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

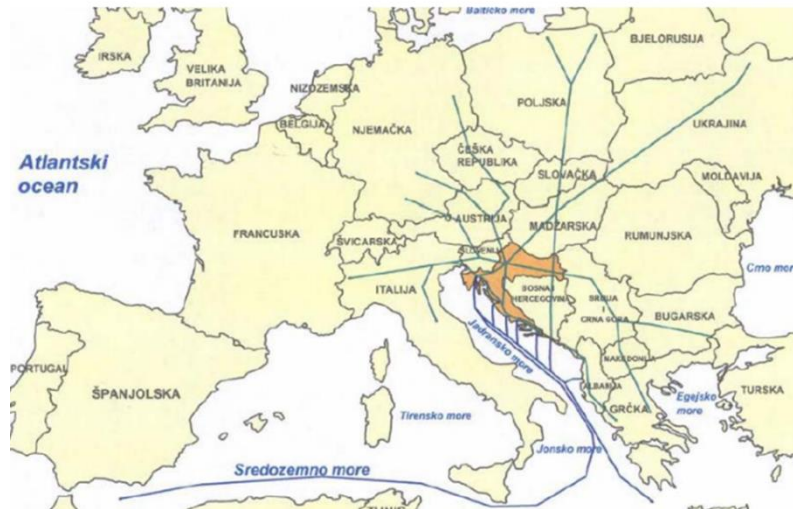


Figure 24 Maritime transport statistics in Croatia (Božičević et al., 2008)

Further development of Ports of Rijeka and Ploče depends partially on the development of their connections to the railways. The most important joint interest project for cargo maritime sector is the development and reconstruction of railway section from Rijeka to Hungary while further railway development in Bosnia and Herzegovina is of crucial importance for the development of the port of Ploče. Ports Pula, Zadar, Šibenik, Split, Dubrovnik and Ploče are classified as comprehensive ports on the Trans-European Transport Network (TEN-T). Regarding inland waterways, Croatia's network stretches 804 km, 287 km of which is a part of an international waterway network²³. Croatia lies on the important Danube waterway, one of Europe's main cargo transport routes which is a part of the Pan-European Corridor VII, which connects Croatia with the North Sea and the Black Sea. The major ports are Vukovar on the Danube, Osijek on Drava River, Sisak and Slavonski Brod on Sava River (Figure 25).

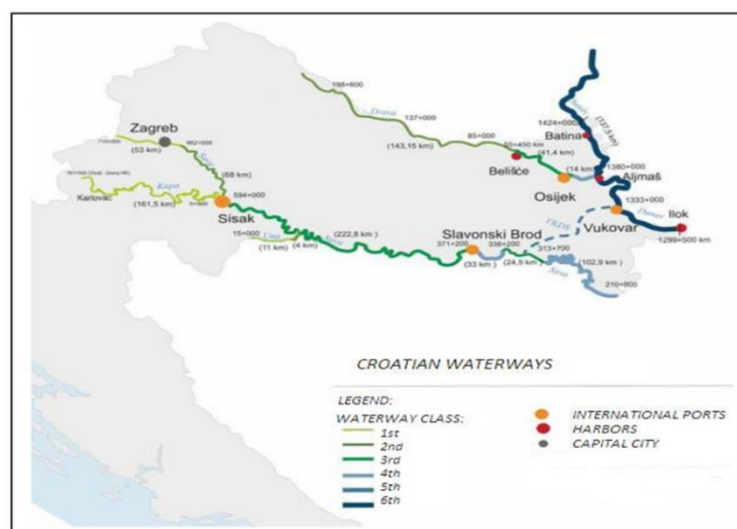


Figure 25 River transport on main Croatian inland waterways (Valleyo Saarmiento et al., 2016)

²³ <http://www.investcroatia.hr/investors-guide/infrastructure/river-transport/>

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

The Croatian network of inland waterways represents a significant, but at the same time, completely unexploited part of national values of Croatia. This mean of transport has a high potential for increase if appropriately managed (Table 31).

Table 31 Transport of Goods on Inland Waterways in Croatia in tonnes²⁴

Year	2016			2017			2018		
	Total	National transport	International transport	Total	National transport	International transport	Total	National transport	International transport
Total	677,549	96,439	581,110	574,236	57,525	516,711	591,667	72,470	519,197

Large scale bio-based production chains require transportation of large volumes of materials, i.e. the supply of biomass and the export of (intermediate) products. The only cheap options for the transportation of large volumes are waterways and railways. Experts indicated that hubs are essential for establishing successful biorefineries. In 2017, Croatia had 1,300 registered industrial hubs, from which around 450 were industrially active, with cca. 70,000 employees. These hubs are divided by size to: 0-1,000 m²; 1,001-10,000 m²; 10,001-100,000 m² and 100,001-1,000,000 m² and founded by local municipalities and three counties. Their geographical distribution is presented in Figure 26, with the allocation of closest airports and harbours.

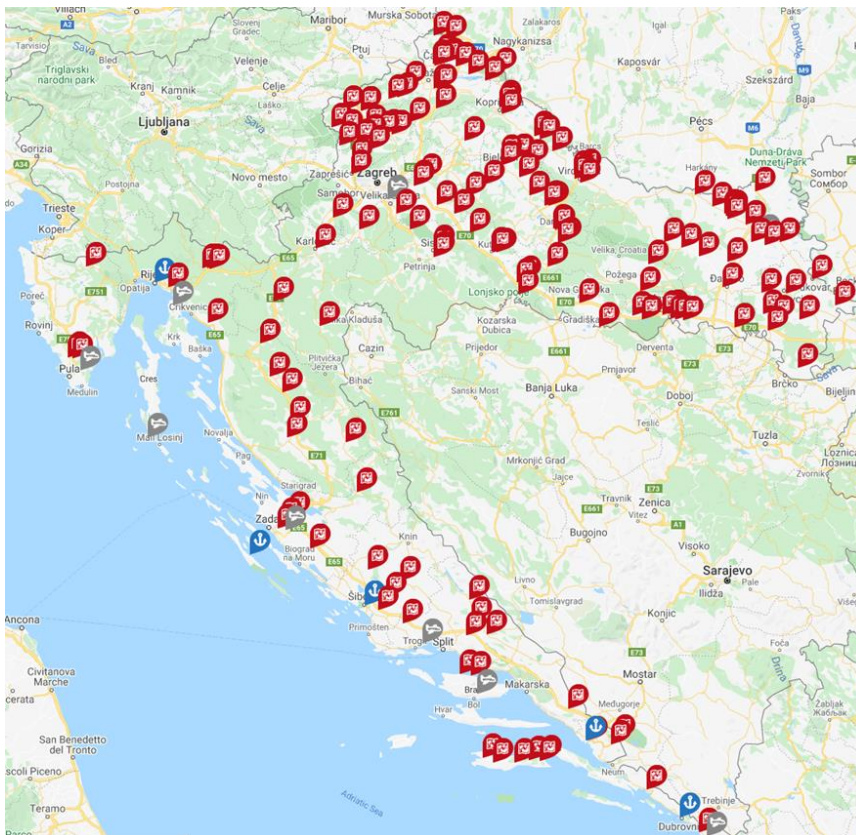


Figure 26 Map of Croatian industrial hubs²⁵

²⁴ www.dzs.hr
²⁵ <http://investcroatia.gov.hr/en/zone/>

6.2. Existing railway

The Croatian railway network comprises 2,617 km. A good ratio of railway line kilometres and the country's population (1,556 people per kilometre) ranks the Republic of Croatia among developed European countries. However, 90% are single-track lines and only 36% of lines are electrified. Almost 55% of the network is dedicated to those lines that are significant for international transport. Of this 2,604 km, only 5.4% is capable of reaching speeds between 141 and 160 km/h, 17% has a maximum speed above 100 km/h, and 37,5% has maximum speeds below 60 km/h (Valleyo Sarmiento et al., 2016).

Three companies control the Croatian railway network: HŽ Infrastruktura Ltd., HŽ Putnički prijevoz Ltd. and HŽ Cargo Ltd.. On its network, it maintains 546 stations and stops, 1,503 level crossings, 109 tunnels and 544 bridges (Figure 27). Many of these facilities are also protected cultural heritage. HŽ Infrastruktura is responsible for traffic management and operation, for rehabilitation, maintenance and construction of railway infrastructure, which is a public good in general use. On average, around 709 passenger and 120 freight trains operate on the network on a daily basis.

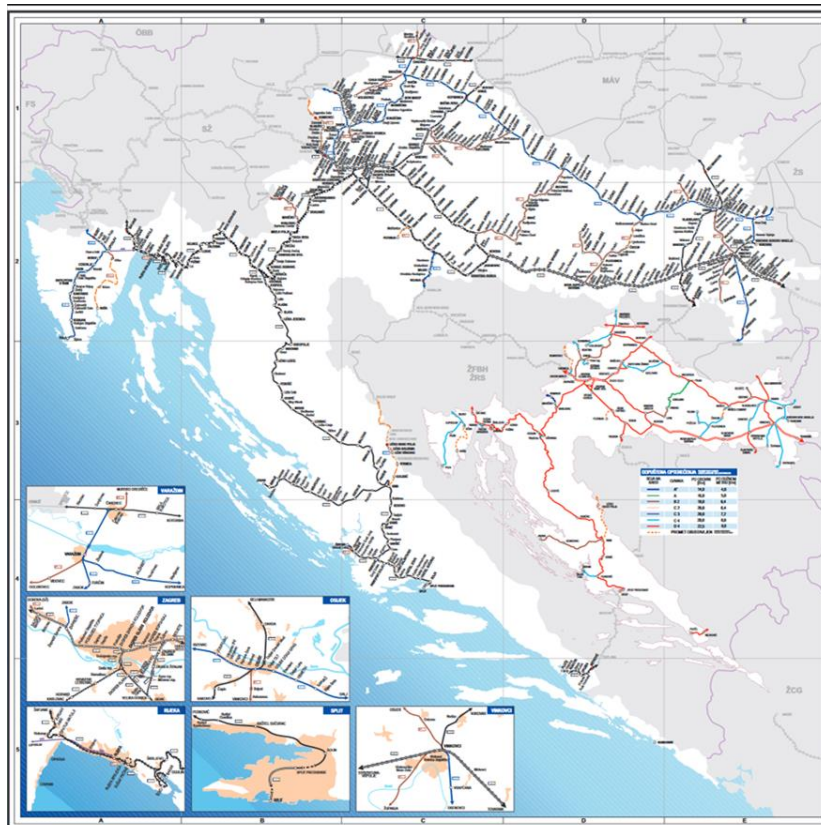


Figure 27 Railway network map with stations and stops in Croatia²⁶

The access to the Croatian railway network for freight operators was liberalized on July 1, 2013, upon Croatia's EU accession. Currently, there are eleven operators on the network, ten freight and one passenger operator.

²⁶ http://www.eng.hzinfra.hr/?page_id=418

With Croatian accession to EU, the authorities were determined to reform and rethink the transport system, with special focus on railway transport. In order to benefit from the future financial support of the EU, they have to provide the right administrative capacity to manage funds and elaborate viable projects. Many projects were financed since the accession, until 2019, and around additional 1.24 billion EUR are planned to be invested in period 2019-2023, from which 60% is co-financed by EU funds²⁷.

Therefore, work on three international corridors were intensified (Figure 28):

- TEN-T core and comprehensive network (Pan European Corridor X), Salzburg –Thessaloniki;
- TEN-T Mediterranean corridor (Pan European corridor Vb), Budapest – Rijeka and
- TEN-T comprehensive network (Pan European corridor Vc), Budapest –Ploče.



Figure 28 Pan-European corridors in Croatia (Božičević, 2008)

Moreover, modernisation of the remaining sections of the TEN-T core network lines according to their functionality is underway. Croatia, the European Union and the World Bank are expected to invest more than 3 billion EUR in designing, renovating and upgrading Croatian railway infrastructure over the next ten years. HŽ Infrastruktura is carrying out projects with investments promoted by the government and local authorities aimed to encourage cross-border railway traffic. There are 18 projects in different stages of progress, of which only the Gradec - Sv. Ivan Žabno line has been finished (Figure 29)²⁸.

²⁷ <https://www.hzinfra.hr/za-zeljeznicku-infrastrukturu-do-2023-u-planu-93-mlrd-kuna-investicija/>
²⁸ http://www.eng.hzinfra.hr/?page_id=321

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

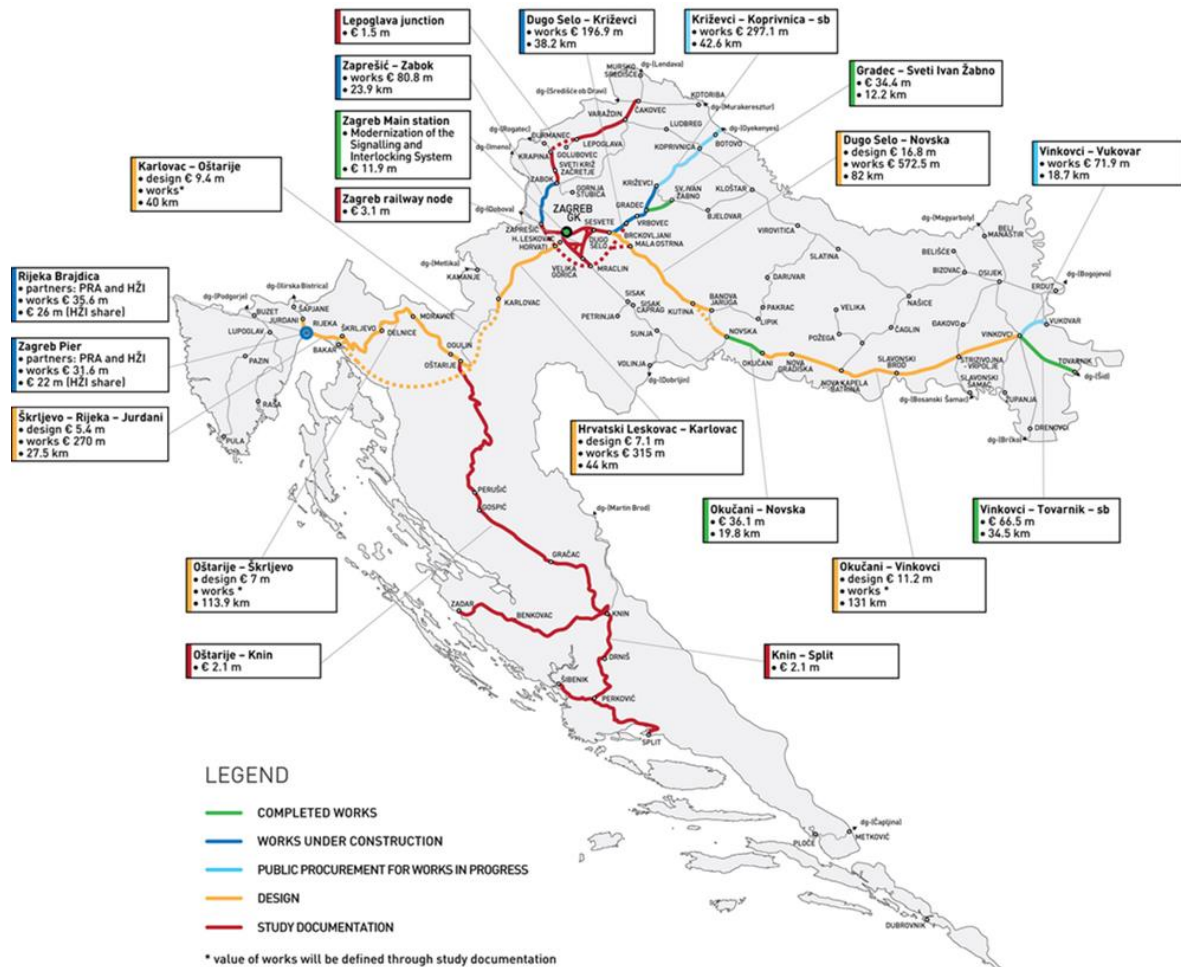


Figure 29 Status of EU projects on modernizing the railway structure in Croatia²⁹

Additionally, HŽ Infrastruktura is using funds from Connecting Europe Facility (CEF), a EU funding instrument for the financial framework 2014 – 2020. It supports the development of high performing, sustainable and efficiently interconnected trans-European infrastructure networks in the fields of transport, energy and digital services. The following projects are funded by CEF:

- Reconstruction of the existing track and construction of the second track on the section Križevci – Koprivnica – state border;
- Preparation of project and other documentation for construction of second track, upgrade and modernization of the railway line on rail section Škrletjevo – Rijeka – Jurdani;
- Designs for the upgrade of the railway section Oštarije – Škrletjevo;
- Preparation of design documentation for the reconstruction of the Okučani – Vinkovci railway section;
- Port of Rijeka multimodal platform development and interconnection to Adriatic Gate container terminal;
- Upgrade of the Rijeka Port infrastructure – Zagreb Pier container terminal;
- Technical assistance to improve capacity building for railway infrastructure manager in Croatia;
- Enhancing the cooperation between Railway Infrastructure Managers for better safety management.

²⁹ http://www.eng.hzinfra.hr/?page_id=321

6.3. Existing road infrastructure

Regarding its integration in international traffic, it should be emphasized that Croatia is already today, with its highly developed motorway network (90% constructed), close to high European standards regarding international road connections.

The road network of the Republic of Croatia is being managed by Hrvatske autoceste Ltd., Hrvatske ceste Ltd. and concession societies (societies for the construction, maintenance and operation of motorways and objects for toll collection).

Hrvatske Autoceste is a company that operates the largest motorway network in the Republic of Croatia.

This network of 918.5 km includes the following motorways:

- Motorway A1 Zagreb - Split - Dubrovnik (Bosiljevo - Split - Ploče - Karamatići) of 415.3 km;
- Motorway A3 Bregana - Zagreb - Lipovac of 306.4 km;
- Motorway A4 Zagreb - Goričan of 96.9 km;
- Motorway A5 Beli Manastir - Osijek - Svilaj of 58.7 km;
- Motorway A10 B&H border - Ploče of 8.5 km;
- Motorway A11 Zagreb - Sisak of 32.7 km.

On behalf and for the account of the company Autocesta Rijeka - Zagreb d.d. the company maintains and collects toll on the following motorways whose total length is 187.03 km:

- A6 Rijeka - Zagreb of 146.5 km;
- A7 Rupa - Križšće of 28 km;
- Rijeka town bypass
- D102 Krk Bridge of 12.53 km.

Included in this network are several important European traffic roads (*Figure 30*):

- TEN-T Mediterranean corridor/PanEuropean corridor;
- Vb: Rijeka-Zagreb-Budapest; TEN-T comprehensive network/Pan-European corridor;
- Vc: Ploce- Sarajevo- Osijek- Budapest; TEN-T core network/Pan-European corridor;
- X: Salzburg- Ljubljana- Zagreb- Beograd- Niš- Skopje- Veles-Thessaloniki;
- TEN-T comprehensive network/Pan-European corridor;
- Xa: Graz- Maribor- Zagreb

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087



Figure 30 Road Network Map (Valleyo et al., 2016)

The construction and opening to traffic of motorway sections exceeding 600 km over the past 14 years has contributed to the overall traffic safety on motorways in the Republic of Croatia and has decreased the number of accidents in the whole country.

Moreover, modernisation and construction of new roads are funded mainly through EU funds, through Connecting Europe Facility (CEF) and Operational Programme Competitiveness and Cohesion (OPCC) funds. The latter has three ongoing projects: Svilaj bridge, Crocodile 2 and Crocodile 3, which are international projects between the EU-Member States from the Central European region, who are working together to improve cross-border traffic and transport.

Tourism is of major importance for the Croatian economy, and most tourists come on vacation to Croatia in their cars. Without adequate roads, the traffic would get rather jammed during the summer months. For this reason, and as a means for stimulating urgently needed economic growth, highways have become indispensable for the sustainable development of this country. Croatia already has a considerable highway density for a country that still has to cope with the consequences of Communism and the recent war. As of 2006, Croatia has 28,344 kilometres of roads. Out of these, there is 23,979 km of paved and 4,365 km of unpaved roadways.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

6.4. Energy sector

The Croatian power system comprises plants and facilities for electricity production, transmission and distribution in the territory of the Republic of Croatia. For security reasons, quality of supply and exchange of electricity, the Croatian power system is interconnected with the systems of neighbouring countries, and together with them, it is connected into the synchronous network of continental Europe (Figure 31).

By its size, the Croatian power system is one of the smallest power systems in Europe. Due to its geographical position and location of generating plants, electricity is transported for most of the year from the south to the north and vice versa, and from the north toward the east. The Croatian power system is a control area by Croatian Transmission System Operator (HOPS). Together with the Slovenian power system and the power system of Bosnia and Herzegovina it constitutes the control block SLO – HR – BIH within the ENTSO-E association.

Croatia has an electrification rate of 100% with well-developed grid and all settlements connected to the power grid. Grid connection is not an obstacle for using biomass as an energy source for electricity, although with the market premium system, the focus will be generating electricity from fuel-less sources: PV and wind.

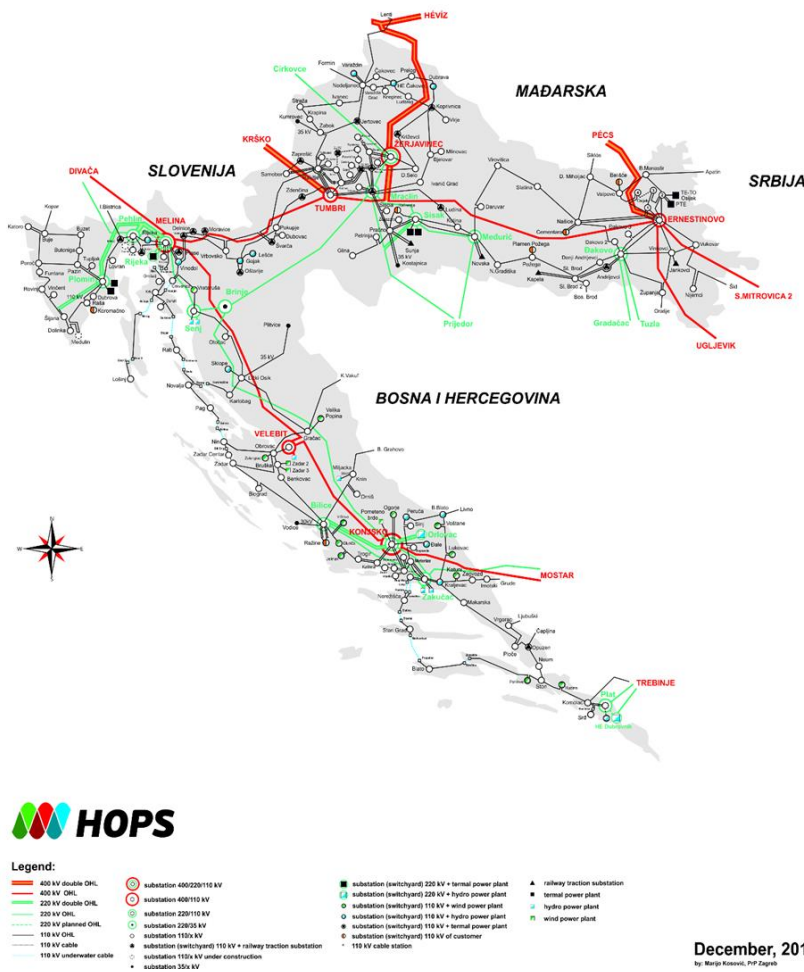


Figure 31 Croatian transmission network³⁰

³⁰ <https://www.hops.hr/en/system-scheme>

The Energy Law and the Electricity Market Law create the fundamental conditions for an electricity market in Croatia. Preparing and adopting Electricity Market Rules and other secondary legislative acts have created the condition for the operation and the gradual opening of the market.

	2013.	2014.	2015.	2016.	2017.	2018.	2018./17.	2013.-18.
	PJ						%	
Ogrjevno drvo i biomasa Fuel Wood and Biomass	61,45	57,97	64,19	64,15	64,67	63,06	-2,5	0,5
Sirova nafta Crude Oil	25,71	25,38	28,62	31,47	31,79	31,26	-1,7	4,0
Prirodni plin Natural Gas	63,11	60,52	61,61	57,52	51,76	43,07	-16,8	-7,4
Vodne snage Hydro Power	84,92	88,99	61,63	65,63	53,81	66,98	24,5	-4,6
Toplinska energija Heat	0,63	0,52	0,62	0,66	0,67	0,63	-5,4	0,1
Obnovljivi izvori Renewables	7,71	10,58	10,99	12,90	16,10	16,21	0,7	16,0
UKUPNO TOTAL	243,53	243,95	227,65	232,33	218,79	221,21	1,1	-1,9

Figure 32 Primary energy production in Croatia (EIHP, 2018)

However, Croatia is still dependent on energy import from neighbouring countries. Even though the import related to specific energy sources has fallen, it has increased in terms of biomass (Figure 33). Krško nuclear power plant in Slovenia, of which HEP owns 50%, also contributes to Croatia's electricity supply but is counted under imports in the statistics (electricity). This fact presents a significant potential for bioeconomy, where agricultural, forestry and waste biomass could contribute in terms of energy generation and covering of growing energy demand in Croatia.

	2013.	2014.	2015.	2016.	2017.	2018.	2018./17.	2013.-18.
	PJ						%	
Ugljen i koks Coal and Coke	36,10	30,46	32,11	34,49	22,57	19,69	-12,7	-11,4
Sirova nafta Crude Oil	105,12	79,05	99,41	107,32	120,33	126,63	5,2	3,8
Derivati nafte Petroleum Products	60,30	80,78	85,49	83,33	93,48	86,75	-7,2	7,5
Prirodni plin Natural Gas	43,19	39,19	36,33	44,01	63,10	55,05	-12,8	5,0
Električna energija Electricity	24,64	24,40	31,93	31,43	34,16	26,66	-22,0	1,6
Drvo i biomasa Biomass	0,42	0,49	1,18	1,21	1,54	3,02	96,3	48,5
UKUPNO TOTAL	269,77	254,36	286,45	301,80	335,16	317,79	-5,2	3,3

Figure 33 Energy import in Croatia (EIHP, 2018)

Additionally, the energy sector represents the largest source of greenhouse gas (GHG) emissions, and climate change are one of the greatest threats to modern mankind. According to preliminary calculation results for 2018., emissions from stationary and non-stationary energy sources amounted to 15.3 million tonnes of CO₂, which is 5.8% less compared to the previous year (Ministry of Environment and Energy, 2019).



This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Energy transition, which is closely linked with economic development, in Croatia represents a possibility for industrial development and new job openings. To ensure a complete insight in expected and wanted of energy sector development, Ministry of environmental protection and energy ordered the creation of "*Energy Development Strategy for the Republic of Croatia for 2030 with a view to 2050*", in which renewable energy sources utilization is promoted, including biomass and biodegradable waste. In terms of bioeconomy, this is a significant step forward, where bio-based resources can contribute to energy production in Croatia, without jeopardising its sustainability.

6.5. Summary and conclusions in relation to SWOT elements

Croatia is a significant part of Trans-European Transport Network (TEN-T), with 6 important coastal ports (Rijeka, Zadar, Šibenik, Split, Ploče and Dubrovnik) and a significant potential within inland marine ports. Its strategic geographical position is exceptionally favourable for supplying markets in Central and Eastern Europe and has a high impact on markets as a leader in the Balkan area. The aforementioned ports are well connected with railway and especially the road network.

Furthermore, the energy sector is well connected all along the country, but also with neighbouring countries through the transmission network.

However, all of the above requires modernization, especially railway and inland marine ports network. The railways are being modernized because since the disintegration of Yugoslavia there have been hardly any investments in railway infrastructure. Since it is a quality way to connect industry hubs, along with the inland and marine ports, it has great potential for utilization as a transport mean for bioeconomy purposes (transport of feedstock, new products, biofuels, etc.).

Additionally, the Croatian network of inland waterways represents a significant, but at the same time, completely unexploited part of the national values of Croatia. The overall length of the current inland waterways in Croatia is 1016.8 km, of which 601.2 km has been integrated into the European network of inland waterways of international importance. The Danube part of the Republic of Croatia's inland waterways system forms a part of the RhineDanube Corridor. Ports Vukovar and Slavonski Brod are classified as core ports in the EU TEN-T network but require modernization and investments. They also have the potential for utilization for bioeconomy purposes in terms of transporting feedstock and new products. In conclusion, it can be seen that railway and inland marine ports have potential to increase and strengthen Croatia's connection with the EU through bioeconomy.

Furthermore, by implementing bioeconomy in Croatia, the energy sector would benefit the most, since the import of biomass as an energy source has lately significantly increased (96.3%). Utilizing biomass (agricultural, forestry and waste) as an energy source, within sustainability limits, would prove to have a significant impact on energy autonomy and balance.

Table 32 summarises SWOT elements of Infrastructure, logistics and energy sector of Croatia.

Table 32 SWOT analysis of the infrastructure, logistics and energy sector in Croatia

<p>Strengths</p> <p>Good connection with European countries (Central and Eastern Europe)</p> <p>Well-developed motorway network</p> <p>Established positions in EU hinterland transport</p> <p>Access to the sea</p> <p>Large number of existing and active industrial hubs</p>	<p>Weaknesses</p> <p>Underdeveloped railway system</p> <p>Lack of sustainable planning</p> <p>Lack of inland waterway network</p> <p>Lack of modernised transportation networks</p>
<p>Opportunities</p> <p>Increasing investments in ports, railways, airports and other transportation infrastructure</p> <p>Central position of Croatia in TEN corridors (Baltic-Adriatic and Mediterranean corridors)</p> <p>Established strong position of road network (esp. in freight transport)</p>	<p>Threats</p> <p>Worrying condition of the state road network</p> <p>Condition of the railway network.</p> <p>Increased congestion in the country during tourist seasons</p> <p>Competition from other corridors (Slovenia, Hungary, Italy)</p> <p>Competition from other ports (Trieste, Venice)</p>

7. SKILLS, EDUCATION, RESEARCH AND INNOVATION POTENTIAL

7.1. Availability of skilled operators and service providers

According to the statistical information of Croatian Bureau of Statistics, the total number of employed persons in 2019 in Croatia was 1,679,000 out of which 909 thousand are men and 771 thousand are women³¹. The highest share of employed people is working in manufacturing industry (17.8%). Data on education are showing the rising number of students graduated from university studies in the last 3 years. Also, in 2019 there were 498 new Masters of Science, Masters and University specialist and 680 Doctors of Science.

Number of unemployed people indicates the availability of work force. Unemployment rate in 2019 was 7.6%. The majority of people that are unemployed were working in the manufacturing industry.

³¹ Croatian Bureau of Statistics, Labour force survey: Labour force in the Republic of Croatia, 2019 annual average, Zagreb, April 2020 (https://www.dzs.hr/Hrv_Eng/publication/2020/09-02-07_01_2020.htm)

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

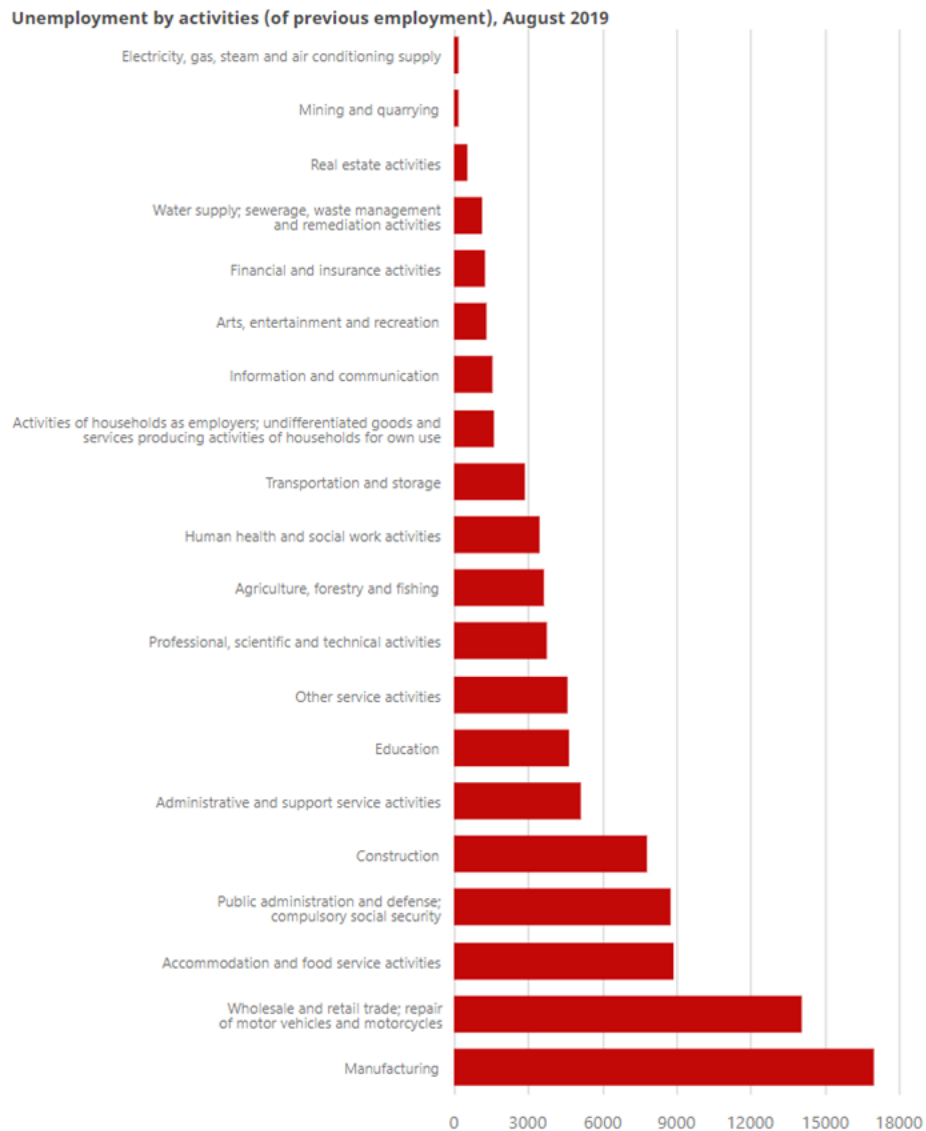


Figure 34 Unemployment by activities in Croatia for 2019 (Croatian Bureau of Statistics, 2018a)

Educational background shows that most unemployed persons have 1 to 3-year vocational secondary school. The number of unemployed persons with university level and postgraduate degrees equals 11,835 while there are 8,559 persons with non-university degree. The age of most of the unemployed persons in the Republic of Croatia is above 50 and majority of unemployed are women. The Figure below shows potential available workforce by age and sex. Emigration of people also affects the availability of work force. In 2019, 40,148 people emigrated from Croatia. At the same time there were 37,726 immigrations.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

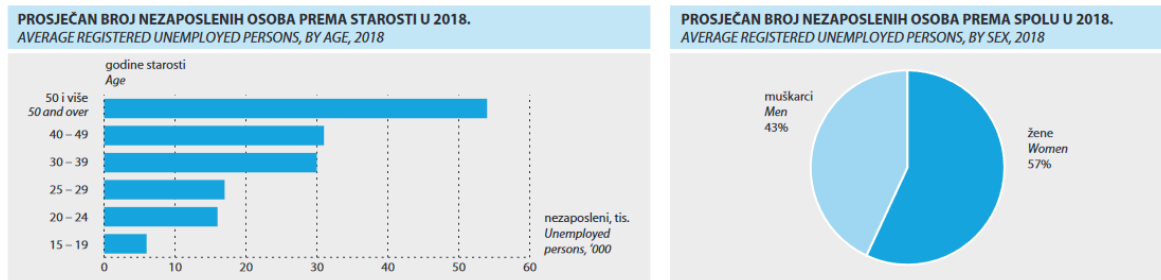


Figure 35 Average registered unemployed persons by age and sex, 2018 (Croatian Bureau of Statistics, 2019)

Number of wanted employees in 2019 was 224,187. The largest number of required labour force is in the manufacturing industry (31,112).

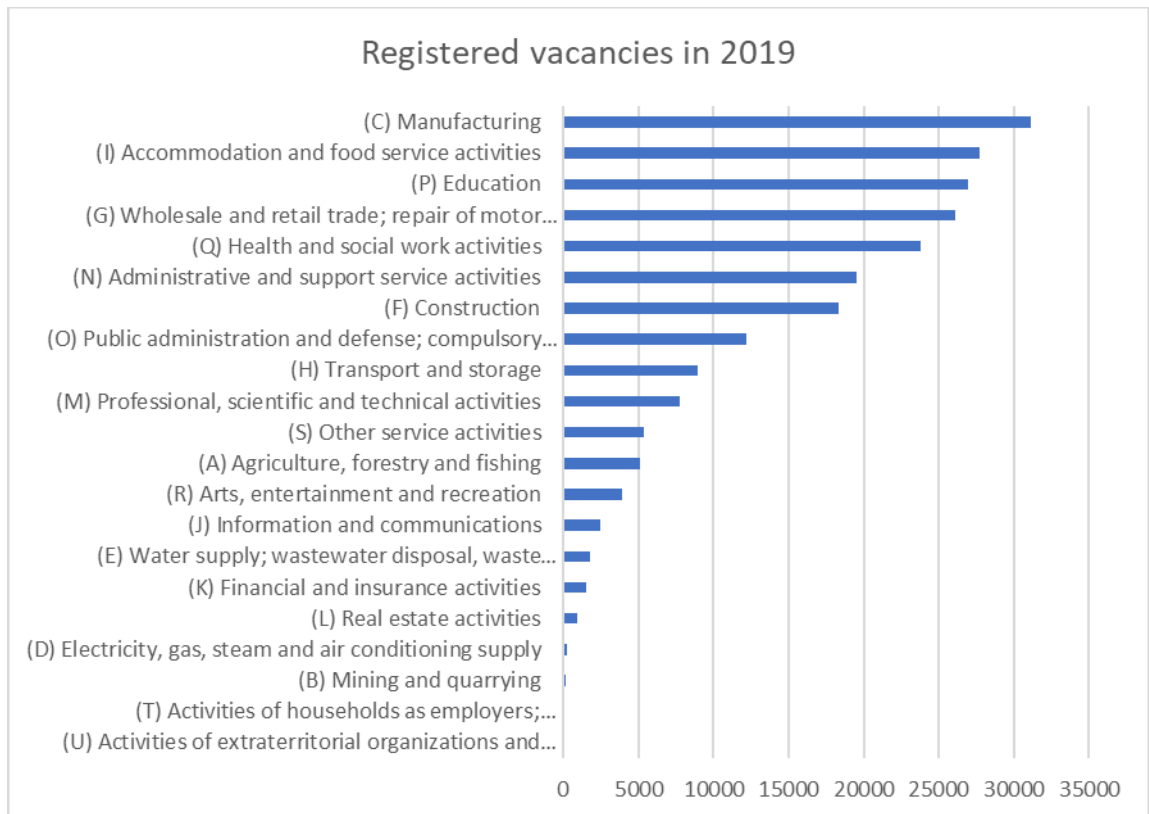


Figure 36 Registered vacancies in 2019 (Source: Statistics of Croatian Employment Service)

7.2. Research infrastructure

The most research infrastructure equipment, related to bio-based industrial development may be found at the Institute Ruđer Bošković, Faculty of Agriculture, Faculty of Chemical Engineering and Technology, Faculty of Science, Faculty of Pharmacy and Biochemistry, Faculty of Food Technology and Biotechnology, Faculty of Forestry all as members of the University of Zagreb, but also many others. Furthermore, there are Institute of Agriculture and Tourism, Faculty of Food Technology Osijek and Faculty of Agrobiotechnical Sciences Osijek. Alongside with Universities in Croatia, there are few research institutions more involved in bio-based development.

As a leading and largest Croatia's multidisciplinary research centre, **Institute Ruđer Bošković (IRB)** employs valuable human capital of over 890 employees, of which over 500 scientists and researchers in 82 laboratories which are engaged in research in the fields of theoretical and experimental physics, material physics and chemistry, electronics, physical chemistry, organic chemistry and biochemistry, molecular biology, and biomedicine, and exploring sea and environment. The Institute participates in numerous internationally and nationally funded and internationally peer-reviewed research projects such as those under Horizon 2020, IAEA, FP7, HRZZ, NATO, NSF, ICGEB and other foreign scientific foundations. The Institute is currently implementing more than 200 projects, with more than half of the total funding being funded by EU projects and other international sources. The Institute also houses capital research equipment worth over HRK 100 million.

As it was mentioned, IRB is leading the *BioProspecting of the Adriatic Sea* project, which includes the strengthening of the capacities of the Center of Excellence for Bioprospecting of the Sea (BioProCro). Additionally, together with the Institute of Physics (IF) and University of Slavonski Brod (UNISB), IRB is a partner on the project '*Adaptation of Vegetable Crops to New Agro-Meteorological Conditions in Slavonia*' worth almost HRK 3 million. Also, Institute is participating in *BIO-ECOmy Research Driven Innovation (BIOECO-R.D.I.)* which aims at developing a Regional Innovation System for the Adriatic-Ionian area based on a structured bio-economy sector through the development of Research Driven Innovation (R.D.I.) strategy at regional and transnational level.

Faculty of Agriculture (FAZ), University of Zagreb has over 100 national and international ongoing scientific projects which contribute to sustainable agriculture development. With 9 undergraduate, 14 graduate and 4 postgraduate programmes in the field of agriculture Faculty of Agriculture aims to become the leading scientific institution in this region. The FAZ owns 6 experiment stations which are used for teaching, scientific research and technical activities. The FAZ has also started setting up a Bioengineering Research Center (ABIC) in the city of Zagreb. Furthermore, there are 28 laboratories among which is a Reference laboratory for milk and dairy products (RL). Faculty of Agriculture Council decided to establish a research-teaching station in the open state hunting ground no. III / 29 - "PROLOM", located in the Sisačko-moslavačka county in 1999. The Research-teaching station is named "Ban Josip Jelačić" and is intended for teaching work and scientific research related to wildlife management, hunting, fishing, beekeeping, mushroom science, meat production, botany, horticulture and other related areas. The hunting ground is mountain character, includes extreme western slopes and parts of the massif Zrinski Mts., and it was named after the forest complex Prolom. It is located south of the town Glina, and the total area is 7,709 hectares. The research station is equipped with accommodation facilities, science research unit, laboratory and all the necessary agricultural machinery for management of hunting ground.

FAZ is included in various research projects, such as:

- Biodiversity and molecular plant breeding (KK.01.1.1.0005)
- CroVitiRestart – Novi početak za stare hrvatske sorte vinove loze (KK.01.1.1.04.0031)
- Potential of microencapsulation in cheese production (KK.01.1.1.04.0058)
- Archeogenetics lab establishment (KK.01.1.1.06.0002)
- Sustainable biogas production by replacement of maize silage with agricultural energy crops (KK.01.1.1.07.0078)
- Qua/Qua Protein: Kvantitativna i kvalitativna analiza proteina za potrebe biomedicine i biotehnološke industrije (KK.01.1.1.07.0023)

Moreover, FAZ is a project partner in ongoing BBI funded project GRACE which is made up of a unique consortium of 22 partners from both academia and industry and also includes SME's, farmers and an industrial cluster. The ten value chains under consideration will be demonstrated from the production of the crop through to the final bio-based product. Also, the environmental, economic and social sustainability of each value chain will be assessed using LC-SA tools.

Faculty of Chemical Engineering and Technology, University of Zagreb is an educational institution in the scientific field of chemical engineering and chemistry, it realizes projects for the real sector in cooperation with industry. Priority research topics are environmental protection and environmental management, development of new advanced materials and sustainable technologies, energy, alternative and renewable energy sources, development of new drugs and industrial biotransformations. Furthermore, Faculty participates in designs processes, devices, equipment, facilities and complex systems, produces studies, audits studies and projects, provides consulting services, supervises construction works, ensures and controls the quality of materials and processes, issues certificates of properties of materials etc.

Faculty of Food Technology and Biotechnology, University of Zagreb, is a leading scientific research and teaching institution in the Republic of Croatia in the field of biotechnology, food technology and nutrition. At the Faculty, students can enrol in one of three undergraduate studies: the study of Food Technology, the study of Nutrition and the study of Biotechnology. Currently, 27 laboratories are fully equipped. The Faculty also conducts professional activities through the Food Control Centre as an accredited laboratory for the control of the safety and quality of food and general use products in the European Union. Within the institution of higher education, the Centre has been one of the first spin-off companies for over 50 years. Since 2007, the Centre for Food Technology and Biotechnology has been operating in Zadar at the Faculty of Food Technology and Biotechnology. The Centre has a Laboratory for Drying Processes and Stability Monitoring of Bioactive Compounds and since 2015 a Laboratory for Honey Quality Control. The Faculty actively participates in numerous research and networking projects funded both from national and international funds. Some of the research topics that the Faculty is involved in are Development and selection/construction of biotechnologically important microorganism strains, Production of biofuels and biochemicals from renewable raw materials, Biotechnology in environment, water resources and sea protection etc. The projects of the Faculty related to biobased sector are:

- *From Grain Byproducts to Functional Food through Innovative Processing; Sustainable production of biochemicals from waste lignocellulose containing feedstocks;*
- *People for the European bioENERgy MIX;*
- *SOURDOugh biotechnology network towards novel, healthier and sustainable food and bioproCesseS;*

- *Opremanje poluindustrijskog praktikuma za razvoj novih prehrambenih tehnologija (KK.01.1.1.02.0001);*
- *Bioaktivne molekule ljekovitog bilja kao prirodni antioksidansi, mikrobiocidi i konzervanski (KK.01.1.1.04.0093)*
and
- *Održivo gospodarenje otpadom od proizvodnje vina (KK.01.1.1.07.0007).*

At the moment, around one hundred research projects are being carried out at the **Faculty of Electrical Engineering and Computing (FER)**, University of Zagreb, as well as dozens of cooperation projects with the economic sector. According to the European Commission report, FER is among leading institutions in Croatia in terms of successful applications for EU funds. FER represents an IT component to bioeconomy development in Croatia through different projects such as *Structured organic farming using autonomous greenhouse robots (HRZZ)*, *Extraction of bioactive compounds from Mediterranean plants with 'green solvents' using high voltage discharge (HRZZ)*, *Agrivi Smart - Increase Potato Growing Productivity Using Machine Learning Algorithms (EFRR)* and *Improving the efficiency of manufacturing through research and development of innovative ICT services to increase energy efficiency - ComEnergy (EFRR)*. Their contribution to smart farming could be seen through collaboration with Agrivi. Agrivi and Faculty of Electrical Engineering and Computing in Zagreb have signed an agreement with the Ministry of Economy and Sustainable Development to award a HRK 6.35 million grant for the development of the Agrivi SMART self-learning system, which will by help of AI advise farmers on how to use agronomic practices to achieve optimal yields and increase in profitability. Additional project in which FER is included are: *DATA CROSS – Advanced data methods in science and cooperative systems (KK.01.1.1.01.0009)*, *Heterogenous autonomous robotic system in viticulture and mariculture (KK.01.1.1.04.0036)* and *IoT-polje: Ekosustav umreženih uređaja i usluga za Internet stvari s primjenom u poljoprivredi (KK.01.1.1.04.0108)*.

Croatian Forestry Institute actively contributes to the research community in Croatia with numerous collaborations in the geographical region in the forestry-based sector. Some of the projects conducted at Forestry institute in the bio-based sector are *Capacity Building in Forest Policy and Governance in Western Balkan Region (CAPABAL)*, *Sustainable Wood for Europe - ROSEWOOD*, *Modelling of forest stocks and carbon flows and risks under future climate scenarios (MODFLUX)* etc.

Institute for Development and International Relations conducts a BBI funded project: *Innovative VET for key competences in the emerging field of forest bioeconomy (VET4BioECONOMY)* which aims to increase the knowledge and provide key competences in forest bioeconomy to forestry-related professionals and increase current base of VET and LLL programmes in partner countries with innovative and comprehensive forest bioeconomy training programme.

Energy Institute Hrvoje Požar with its Department for RES, energy efficiency and climate protection established a leadership role when it comes to bioeconomy development in Croatia. There are numerous projects funded from Horizon2020, Interreg Programme, IEA, COST, World Bank, as well as nationally funded projects. Currently, one Horizon2020 project should be emphasized in the context of bioeconomy - *Advancing Sustainable Circular Bioeconomy in Central and Eastern European countries: BIOEASTsUP*. This project aims at supporting the BIOEAST Initiative in developing Bioeconomy Strategies and Action Plans in the Central and Eastern European countries (CEEC). It is a catalyst for research, innovation, and rural development, and it assists in the development of bioeconomy-related policies in the CEEC. Energy Institute Hrvoje Požar as a partner in this consortium works closely with the Ministry of Agriculture on the establishment of Taskforce for Bioeconomy Strategy development.

Some additional projects that are implemented by research facilities in Croatia include the following (within food and bioeconomy calls):

- ZCI za personaliziranu brigu o zdravlju (KK.01.1.1.01.0010) - implemented by **University Josip Juraj Strossmayer in Osijek**;
- Centar za sigurnost i kvalitetu hrane (KK.01.1.1.02.0004) – implemented by **Public Health Institute dr. Andrija Štampar**;
- Atrij znanja (KK.01.1.1.02.0005) – implemented by **Polytechnic of Karlovac**;
- Tehnološko inovacijski centar Virovitica (KK.01.1.1.02.0010) – implemented by **Virovitica –Podravina county**;
- Funkcionalna integracija Sveučilišta u Splitu, PMF-ST, PFST te KTF-ST kroz razvoj znanstveno-istraživačke infrastrukture u Zgradi tri fakulteta (KK.01.1.1.02.0018) – implemented by **University of Split**;
- Implementacijom suvremene znanstveno-istraživačke infrastrukture na FGAG Split do pametne specijalizacije u zelenoj i energetski učinkovitoj gradnji (KK.01.1.1.02.0027) – implemented by **Faculty of Civil Engineering, Architecture and Geodesy**;
- Nove metode u suzbijanju štetnika masline primjenom biljnih hlapivih tvari (KK.01.1.1.04.0002) – implemented by **Institute for Adriatic Crops and Karst Reclamation**;
- Razvoj hibridnog skidera – HiSkid (KK.01.1.1.04.0010) – implemented by **Faculty of Forestry and Wood Technology**;
- Inovativna proizvodnja organskih gnojiva i supstrata za uzgoj presadnica (KK.01.1.1.04.0052) – implemented by **Faculty of Agrobiotechnical Sciences Osijek**;
- HIDROLAB - Integrirani hidrografski sustav za održivi razvoj morskog ekosustava (KK.01.1.1.04.0053) – implemented by **Faculty of Geodesy Zagreb**;
- Odgovor ozime pšenice na biotičke i abiotičke stresove izazvane klimatskim promjenama (KK.01.1.1.04.0067) – implemented by **Agricultural Institute Osijek**;
- Razvoj inovativnog brzog testa za dijagnostiku subkliničkog mastitisa u mliječnim krava (KK.01.1.1.04.0086) – implemented by **Faculty of Veterinary Medicine Zagreb**;
- Dizajn naprednih biokompozita iz energetski održivih izvora (KK.01.1.1.04.0091) – implemented by **Faculty of Textile Technology Zagreb**;
- Modifikacija procesa zrenja sira i razvoj proizvoda na bazi sirutke – SIRENA (KK.01.1.1.04.0096) – implemented by **Polytechnic of Karlovac**;
- Biokonverzija lignoceluloznog materijala u visokovrijednu hranu za životinje (KK.01.1.1.04.0107) – implemented by **Faculty of Food Technology Osijek**;
- Pametna naljepnica za mjerenje i praćenje uvjeta skladištenja i transporta proizvoda (KK.01.1.1.04.0116) – implemented by **Faculty of Electrical Engineering, Computer Science and Information Technology Osijek**;
- CALT (KK.01.1.1.05.0001) – implemented by **Institute of Physics**;
- Uspostava višenamjenske učionice na Ekonomskom institutu, Zagreb - ElZmetrics (KK.01.1.1.06.0003) – implemented by **Faculty of Economy Zagreb**;
- Omika pristup u veterinarskoj molekularnoj medicini (KK.01.1.1.06.0004) – implemented by **Faculty of Veterinary Medicine Zagreb**;
- Proizvodnja i prerada prehrambenih proizvoda (KK.01.1.1.07.0036) – implemented by **Faculty of Electrical Engineering, Computer Science and Information Technology Osijek**;
- Primjena inovativnih bioloških pripravaka u održivim tehnologijama biljne proizvodnje (InoBioTeh) (KK.01.1.1.07.0053) – implemented by **Faculty of Agrobiotechnical Sciences Osijek**;
- Centar za istraživanje i razvoj sigurnog i održivog izgrađenog okoliša (KK.01.1.1.09.0011) – implemented by **Faculty of Civil Engineering Zagreb**;

- *Znanstveno-istraživački centar elektrotehnike i računarstva – ZICER (KK.01.1.1.09.0026)* – implemented by **University Josip Juraj Strossmayer in Osijek**;
- *Projekt znanstvene infrastrukture Instituta za kompleksne sustave Hrvatskog katoličkog sveučilišta (KK.01.1.1.09.0027)* – implemented by **Catholic University of Croatia**;
- *Znanstveno-inovacijski centar Sveučilišta u Splitu-ZIC (KK.01.1.1.09.0035)* – implemented by **University of Split**.

Within the framework of the Instrument for Pre-Accession Assistance (IPA) - Operational Program for Regional Competitiveness, **HAMAG-BICRO**, in cooperation with **the Ministry of Science, Education and Sports, University of Zagreb** and **the City of Zagreb**, prepared the project "Incubation Center for Bio- science and commercialisation of technology - BIOCenter". The BIOCentre is conceived as an active factor in ensuring productive relationships between basic and applied scientific research and the economy, technological infrastructure and new biotechnology companies in the process of developing new products. The planned infrastructure consists of business and laboratory facilities for the needs of small, high-tech enterprises and a central laboratory designed to develop the production process for bio-products, in accordance with Good Manufacturing Practice (GMP) including:

- Bank of stations
- Cell Growing Laboratory
- Microbiology laboratory
- Product Insulation Unit
- Laboratory for purification
- Bio-analytical laboratory
- Substrate and Buffer Preparation Unit
- Bio-test preparation unit

7.3. Educational infrastructure

The educational system in the Republic of Croatia is divided into preschool education, elementary education, secondary education and higher education. Preschool education in the Republic of Croatia encompasses education and care of the children of preschool age, realised through educational, health care, nourishment and social care programs for children from six months of age until school age. Elementary education in the Republic of Croatia lasts for eight years and is compulsory and free for all children between the ages of six and fifteen (this refers to all children with permanent residence in the Republic of Croatia, irrespective of their citizenship). There are around 860 elementary schools on the territory of the Republic of Croatia.

7.3.1. Secondary education

Secondary education is implemented through a network of more than 700 secondary schools that are divided according to the program they offer as follows:

1. Gymnasiums (general or specialised) – offer a program that lasts at least four years
2. Vocational or trade schools (technical, industrial, trade and others) – offer a program that lasts from one to five years, and programs from one to two years
3. Art schools (music, dance, visual arts and others) – offer a program of at least four years

7.3.2. Higher education

Croatia has three types of higher education institutions: universities, polytechnics and colleges of applied sciences. The Croatian education system is harmonised with the EU education system (Bologna). There are currently 132 higher education institutions in Croatia.

The Croatian higher education system comprises of 8 public universities, two private universities, 11 public polytechnics, four private polytechnics, three public colleges and 22 private colleges.

Faculty of Agriculture, University of Zagreb has adopted a new Master's Degree programme "Renewable Energy in Agriculture". The program aims to provide, through the modern teaching process, the education of students in the field of agricultural sciences and the interaction of agriculture and energy and the sustainable use of biomass, biofuels and waste in agriculture. The aim is, therefore, to equip students to deal with the environmental problems associated with agricultural production and the use of farming resources for the production of renewable energy, as well as the management of various types of waste. Some of the courses are: Biomass and Biofuels, Waste management in agriculture, Energy crops, Bio-based products from lignocellulosic biomass etc.

The graduate study programme INTER-EnAgro offers theoretical and practical knowledge targeted at sustainable use and management of natural resources such as soil and water as well as positive and negative effects of human activities, primarily agriculture, on these resources. It is based on the contemporary teaching process and entirely English taught study programme (with the participation of national and international teachers). The objective is to educate experts who will have the knowledge, skills and competencies in the fundamental and applied scientific fields of agriculture, environmental protection and related natural, engineering and biotechnical sciences. Some of the courses are: Agroclimatology and climate change, Environmental risk analysis and management, Water management in agriculture etc.

7.4. Environment for start-ups

The development of start-up entrepreneurship (start-up culture) is one of the essential factors in creating competitive advantages of the national economy. The largest Entrepreneurship Institution in the Republic of Croatia is the Ministry of Economy and Sustainable Development (former Ministry of Economy, Entrepreneurship and Crafts, followed by the **Croatian Agency for Small Business, Innovation and Investments - HAMAG-BICRO**, Croatian Chamber of Economy (HGK), Croatian Chamber of Trades and Crafts (HOK), Croatian Employers Association (HUP), **Croatian Bank for Reconstruction and Development (HBOR)** and the Croatian Employment Service (CES), through their programs and incentives, help and encourage entrepreneurs to develop their ideas and start their own businesses. Entrepreneurial support institutions are (Nikolić and Zorić, 2014):

- Regional development agencies
- Entrepreneurial centres
- Entrepreneurial incubators (more and more involved are student entrepreneurs' incubators)
- Technology parks
- Entrepreneurial education institutions
- Entrepreneurial accelerators

The newly established **EIT Climate KIC Hub** in **Croatia** is a consortium of eight organisations that are different in structure and mandate, but complementary in their missions and activities. These are the Zagreb Innovation Centre, the

Regional Energy Agency of Northwestern Croatia, the Technology Transfer Office of the University of Zagreb, Geotechnical Faculty, University of Zagreb, Terra Hub, the Green Energy Cooperative, the Knowledge Network and the Impact Hub Zagreb. The consortium aims to promote and establish an economy that is aware of all the effects and challenges of climate change, responsibly acting and working on innovative solutions, operating and building systemic changes in an ecosystem that includes all sectors and levels of society.

CIRTT cooperates with the Croatian Agency for Small Business, Innovation and Investments - HAMAG-BICRO in the implementation of the Proof of Concept (**PoC**). PoC provides funding to demonstrate technical feasibility, prototype and protect intellectual property, and market analysis and commercialisation planning. The goal of PoC is to facilitate the journey from scientific research results to solutions ready for commercialisation. From 2010 to 2015, five PoC calls were concluded and with the support of CIRTT, a total of 46 projects of around HRK 9.5 million in innovation development were implemented. In 2016 23 projects were implemented with a total value of HRK 6.9 million.

Oradian is a Croatian startup that has developed a global microfinance platform, and with Oradian software which is a system for supporting financial institutions in micro-lending, they surpass American startups Prove and Japanese Storygami.

Croatian cloud livestock monitoring platform, or "**Google Farm Analytics**" Osijek-based Farmeron, in 2014, secured a new round of financing of \$ 2.65 million. In practice, it is about keeping track of how much a cow has given milk through integration with technical equipment, as well as a calendar that reminds the client of all the obligations crucial for healthy livestock.

Agrivi's vision to change the way food is produced is in its core and positively impact one billion lives by helping farmers reach sustainable, resource-efficient and profitable production. Agrivi has aggregated the best farming practices for over 100 crops and put them on a dashboard so farmers can make data-driven decisions at all points in the growing season. In 2014 Agrivi won the World Startup Competition in Seoul and now helps thousands of farmers from more than 130 countries, in their native languages. The startup was founded in 2013 and has raised a total of \$ 1.4 million from South Central Ventures.

7.5. Public-private partnerships

Regarding public investments, Government of the Republic of Croatia established Centre for Monitoring Business Activities in the Energy Sector and Investments (CEI), intending to find solutions for improving the financial effectiveness of companies in the energy sector in which the state has shares or holds stock, and appropriate and targeted directing of funds in a manner ensuring biggest and most long-term economic return, stable growth and centralised and systematic monitoring of all investments in the Republic of Croatia. The total capital value of over EUR 2 billion.

The Republic of Croatia made a significant improvement of the legislative framework giving assurance to the investors when entering PPP projects, which contributes to the overall attractiveness of Croatian investments in public infrastructure projects. In April 2012, the Government of the Republic of Croatia adopted a Framework Program for the Construction, Upgrading and Reconstruction of Public Buildings under the Contract Form of Public-Private Partnership (PPP), with a total capital value of over € 2 billion.

Ongoing private-public partnerships in Croatia:

- **Justice Square in Zagreb**
- **Neuropsychiatric Hospital "Dr. Ivan Barboš" Popovaca**
- **Istria County & Town of Poreč - Schools**
- **Varazdin County - Schools**
- **General Hospital Varaždin**
- **Koprivnica - Schools**

Croatia is open to all potential investors having an interest in investing in the projects in Croatia, whether they are private or public.

O.n.	Name of PPP project	CAPEX (excluding VAT)*	INFORMATION ON THE INTENT OF THE IMPLEMENTATION OF THE PROJECT	DYNAMICS OF PROJECT IMPLEMENTATION (COMPLETED ACTIVITIES AND EXPECTED DATES)				CONTRACTING	START OF USING - AVAILABILITY PAYMENT OF THE PUBLIC PARTNER
				PROJECT SUBMITTED TO THE PPP AGENCY FOR APPROVAL (INCL. PSC, CONTRACT DOCUMENTATION)	APPROVAL OF PPP AGENCY	PUBLIC PROCUREMENT			
1	JUSTICE SQUARE - ZAGREB	1.350.000 HRK	FINISHED	PERFORMED	APPROVED	FINISHED (1st LVL OF COMPETITIVE DIALOGUE, WAITING FOR THE DECISION OF DUUDI TO CONTINUE THE PROJECT)	8 MONTHS UPON THE BEGINNING OF THE 2ND LVL OF COMPETITIVE DIALOGUE	5 YEARS FROM BEGINNING OF CONSTRUCTION	
2	NEUROPSYCHIATRIC HOSPITAL "Dr. Ivan Barbot" POPOVAČA	124.500 HRK	FINISHED	PERFORMED	APPROVED	IN PROGRESS	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2 YEARS FROM CONSTRUCTION COMMENCEMENT	
3	GENERAL HOSPITAL VARAŽDIN	370.000 HRK	FINISHED	PERFORMED	APPROVED	IN PROGRESS	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2.5 YEARS FROM CONSTRUCTION COMMENCEMENT	
4	CROATIAN HISTORY MUSEUM	48.684 EUR	FINISHED	PERFORMED PSC, CONTRACT IN PROGRESS	TO BE DEFINED	TO BE DEFINED	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2 YEARS FROM CONSTRUCTION COMMENCEMENT	
5	VARAŽDIN COUNTY SCHOOLS (4 schools)	137.000 HRK	FINISHED	PERFORMED	APPROVED	IN PROGRESS	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2 YEARS FROM CONSTRUCTION COMMENCEMENT	
6	ISTRIA COUNTY & TOWN OF POREČ SCHOOLS (4 schools)	145.760 HRK	FINISHED	PERFORMED	APPROVED	IN PROGRESS	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2 YEARS FROM CONSTRUCTION COMMENCEMENT	
7	TOWN OF KOPRIVNICA SCHOOLS (3 schools)	100.000 HRK	FINISHED	PERFORMED	APPROVED	IN PROGRESS	UP TO 3 MONTHS UPON SELECTION OF PRIVATE PARTNER AND FINANCIAL CLOSE	2 YEARS FROM CONSTRUCTION COMMENCEMENT	
8	BUELOVAR COUNTY SCHOOLS (11 schools)	120.000 HRK	TO BE DEFINED	IN PROGRESS	TO BE DEFINED	TO BE DEFINED	TO BE DEFINED	TO BE DEFINED	
9	CLINICAL HOSPITAL CENTER RIJEKA	3.900.000 HRK	FINISHED	TO BE DEFINED	TO BE DEFINED	TO BE DEFINED	TO BE DEFINED	TO BE DEFINED	
TOTAL		6.464.120 HRK							
		854.489 EUR							
PPP PROJECTS IN STRUCTURING									
OTHER INFORMATIONS WILL BE AVAILABLE UPON PROJECT STRUCTURATION									
1	CITY OF ZAGREB SCHOOLS (6 schools)								
2	TOWN OF ŠIBENIK SCHOOLS (2 SCHOOLS)								
3	KOPRIVNICA KRIZEVCI COUNTY SCHOOLS (7 schools)								

Figure 37 List of PPP in Croatia (Source: Centre for Monitoring Business Activities in the Energy Sector and Investments (CEI))

7.6. Summary and conclusions in relation to SWOT elements

Croatia is in the near future threatened by the outflow of skilled labour, which in turn has a negative impact on economic performance and the economic situation in general. The relationship between the labour market and skilled labour force indicates a slow adaptation of the education system to new business trends and required skills.

In terms of higher education, Croatia inherits a long tradition of participation of its universities at the global level. Strong foothold in research community plays a crucial role in setting a milestone for bioeconomy development. There is a need for the research community to expand their work into applied research to create a pathway for bioeconomy stakeholder development. The lack of cooperation between the private sector and academia is evident and needs more encouragement on the government level. While there is existing infrastructure within BIOCentar and it could be used as a tool for strengthening these relations, this option has not yet taken effect. Start-up culture in Croatia is gaining momentum, but slow administration and outdated regulations make it difficult to move forward. At this moment, start-up companies are reduced to an individual approach. In terms of PPP, the broadening of the framework programme is necessary.

Table 33 SWOT analysis of educational, innovation and skills sector in Croatia

<p>Strengths</p> <ul style="list-style-type: none"> Strong academic community High potential for knowledge transfer (quality schools, universities) Laboratory equipment at universities On-topic ongoing research projects Start-up entrepreneurship Proof of Concept programme 	<p>Weaknesses</p> <ul style="list-style-type: none"> The insufficient connection between academia, public and the private sector A lack of applied research A small rate of medium TRL (3–6) research/development infrastructure The loss of experts (scientists, engineers, doctors, ...) due to "brain drain" No PPP in other sectors, except construction Lack of individual approach at academia level
<p>Opportunities</p> <ul style="list-style-type: none"> Pilot projects to connect the academy community, public and private investors PPP expanding to other sectors Programmes to keep the young people in the country (decrease "brain drain") 	<p>Threats</p> <ul style="list-style-type: none"> The loss of experts (and young people) due to rising competitiveness and better work conditions in other countries The loss of start-up companies due to lack of recognition of the legislative framework

8. POLICY FRAMEWORK: REGULATIONS, LEGISLATION, RULE OF LAW & TAXES AND TARIFFS

8.1. Introduction

Croatia does not have a strategy for fostering bioeconomy. However, there are regulations, strategic goals and priorities that are encompassed in the different national strategies i.e. Smart Specialization Strategy and Action Plan (S3), Rural Development Programme, Energy Development Strategy of the Republic of Croatia By 2030, with a view of 2050 and National Development Strategy of the Republic of Croatia until 2030. It directs the use of funds in the context of the Operational Programme for the execution of the European cohesion policy for the 2014-2020 period. The S3 also applies to other funds and instruments of the developmental policy. Several other frameworks serve as a general support for bioeconomy in Croatia, and they include funding from the EU, as well as from the Ministries.

8.1.1. National Development Strategy of the Republic of Croatia until 2030

National Development Strategy is hierarchically the highest act of strategic planning in the Republic of Croatia and is used to design and implement development policies in Croatia. The National Development Strategy contains a long-term vision of the development of the Republic of Croatia and priorities for investment over a ten-year period.

Within the four development directions, strategic goals have been defined that will contribute to the realization of the vision of Croatia in 2030. The four development directions are defined as follows together with strategic goals): "Sustainable Economy and Society" (Competitive and innovative economy, Educated and employed people, Efficient and efficient judiciary, public administration and management of state property, Global recognition and strengthening of Croatia's international position and role), "Strengthening Crisis Resilience" (Healthy, active and quality life, Demographic revitalization and better position of the family, Security for stable development), "Green and Digital Transition" (Ecological and energy transition for climate neutrality, Self-sufficiency in food and development of the bioeconomy, Sustainable mobility, Digital transition of society and economy), "Balanced regional development" (Development of assisted areas and areas with development specifics, Strengthening regional competitiveness).

8.1.2. Smart specialisation strategy 2016-2020.

S3 presents a comprehensive assessment of the country's governance structure, innovation facilitating instruments, and key innovation assets –research and human capital. It proposes a strong monitoring and evaluation (M&E) framework and provides a sectoral analysis of five priority sectors of the economy and their innovation potential. The main purpose of Smart Specialization is to transform the Croatian economy and increase its competitiveness by concentrating knowledge resources and linking them to a limited number of priorities. The identification of the Smart

Specialization priorities will allow the concentration of research capacities and infrastructure. It will provide an advantage to both the public and private sector and will bring together the critical mass of researchers who will jointly work on strategic R&D topics with the goal of research excellence and its commercialisation. The Croatian S3 embraces product, process, service, marketing and organisational innovations in line with the definitions laid out in the Oslo Manual: (1) product innovations - market introduction of a new or significantly improved good or service with respect to its capabilities, user-friendliness, components or sub-systems; (2) process innovations - implementation of a new or significantly improved production process, distribution method, or supporting activity; (3) marketing innovations - significant changes to design, packaging, product promotion, placement, and pricing; (4) organisational innovations - new or improved business practices for organising procedures, work responsibilities and decision making, service delivery, and external relations.

8.1.3. Industrial Strategy of the Republic of Croatia 2014.-2020.

The main objective of Croatian industry has been defined by this strategy, and it states the following: repositioning of identified strategic activities in the global value chain towards the development of activities that create added value. Alongside the main goal, several other goals have been defined, and they are the following:

1. Increase in industrial production at an average annual rate of 2.85%
2. Increase in the number of new employees by 85,619 by the end of 2020., of which at least 30% are highly educated
3. Increase in labour productivity by 68.9% between 2014.-2020.
4. The increase in export between 2014.-2020. by 30% and transformation of export structure in favour of export products with high added value

8.1.4. CAP: Croatian Rural Development Programmes 2014-2020

The European Common Agricultural Policy (CAP) provides a framework for financial support to farmers (Pillar 1 - Direct Payments), and national rural development programmes (Pillar 2 - Rural Development). The new CAP 2014-2020 has been presented in 2014, and the Member States has adapted their national approach within this framework. In 2015 the new Croatian CAP came into force.

The Rural Development Program of the Republic of Croatia for the period 2014-2020, by analysing the context (SWOT analysis) and conducted assessment, defines the priorities and areas of intervention, the selection of relevant measures and the allocation of funding based on expected outcomes. One of the goals of the Program is resource efficiency and climate change resilience in agriculture, food processing and forestry, emphasizing that renewable energy production from these sectors is a priority for developing the bioeconomy and reducing greenhouse gases by 2020. Furthermore, the importance of the use of wood biomass, biomass from agriculture and solar energy in agriculture and the food processing industry is emphasized.

The program defines 19 measures aimed at increasing the competitiveness of Croatian agriculture, forestry and the processing industry, as well as improving living and working conditions in rural areas in general.

8.1.5. Vision and Plan for Strategic Transformation of Agriculture and Rural Area– More than a Farm

It highlights innovation as a horizontal strategic goal and highlights the role of RDI in bioeconomy: "Technological development in genetics, nanotechnology and precision technologies, remote sensing, traceability (blockchain), analysis of (big) data, the Internet of Things, artificial intelligence, robotics, e-commerce, etc. create increased opportunities for production growth, cost reduction, risk reduction, value added increase and the development of new markets for the Croatian agri-food sector. Digital technologies have a particularly great potential because they significantly reduce the costs of information sharing and the implementation of transactions in agri-food chains and knowledge and innovation systems. They provide easy access to capital goods at lower prices as well enable the efficient use of inputs that improve economic and environmental performance and overall resilience agri-food producers and processors."

In this draft document of 78 pages, bioeconomy is mentioned 54 times. The document highlights the need to transition to circular and sustainable bioeconomy as a horizontal measure and Implementation of national action plan for circular bioeconomy as targeted intervention (Intervencija E.2): "A participatory approach to planning would be adopted in the development and implementation of the national circular bioeconomy plan evidence-based (see also Intervention A.3) in coordination with the Ministry of Economy and Sustainable Development (former Ministry of Environment and Energy, the Ministry of Economy, Entrepreneurship and Crafts) and the Ministry of Science and Education.

Key analytical contributions to the strategic planning process would be

- i. identifying existing stakeholders and initiatives in high-potential value chains in the bioeconomy, including energy, plastics, health products and cosmetics;
- ii. a review of the legislative and regulatory framework for value chain management high potential; and
- iii. an assessment of biomass potential (raw materials) and value chain differences high potential in bioeconomy with the help of the National Agroecological Zoning (NAEZ) and the system land management (LRMS) (see also Intervention B.3).

The plan would contain specific activities, investments and sources of financing (EU and national) for the development of selected value chains in the bioeconomy, with continuous support, from research and development to piloting and enlargement. Proposed investments in sustainable biomass production, circular refining / processing of available biomass and product marketing mainly would be implemented through investment grants (see also Intervention A.1), cooperation mechanisms (LEADER, agri-food chain, EIP) (see also Interventions C.1., E.1., F.4.), and interventions in the field of knowledge and information (see also Interventions F.1., F.2., F.3.) proposed for future NSPRD. In that sense increased investments for agricultural research conducted by domestic scientific institutions would be directed to develop solutions for sustainable food and biomass production in the service of the circular bioeconomy. Ultimately, funding opportunities from other EU programs, in particular Horizon Europe, ERDF, and ESF + will be assessed in coordination with the Ministry of Regional Development and European Union Funds."

Key needs related to primary links:

- Increase the added value of agricultural production
- Improve the environmental sustainability of agricultural practices

- Improve compliance between production systems and the characteristics of agro-ecological zones
- Improve entrepreneurial skills and opportunities for producers in agri-food sector
- Improve coordination and complementarity between interventions in rural areas, including basic services
- Improve public infrastructure to enable the modernization of agricultural production
- Facilitate capital investments focused on technology and innovation (horizontal)
- Improve access to research and development (R&D) and the use of knowledge and technology in decision-making and investments (including climate and sustainability) (horizontal).

Specific objectives where circular bioeconomy is suggested as a solution to the key need is bolded in the following text. The RDI needs identified in SWOT SRIA should be complemented with these key needs.

The document lists key needs for RDI in agri-food sector:

1. Promotion of capital investments with focus on technology and innovation (a horizontal need)
2. Improving access to research and development (R&D) and innovation and use knowledge and technology in decision making and investment (including climate and sustainability) (horizontal)

However, the all other 3 strategic goals reflect in the EU bioeconomy goals and RDI needed to achieve them:

- 1) Strategic objective 1: Increasing productivity and resilience of production in agriculture production to climate change
 - a) Key needs:
 - i) Increasing efficiency and added value agricultural holdings
 - ii) Improving sustainable soil management, waters and biodiversity
 - iii) Reducing sensitivity to climate change and encouraging low-emission production
 - iv) Ensuring higher and more stable incomes for small manufacturers
 - b) Specific objectives:
 - i) Increase the added value of agricultural production
 - ii) Improve the environmental sustainability of agricultural practices
 - iii) Increase the fairness of aid to agricultural holdings
 - iv) Improve the harmonization between production systems and the properties of agro-ecological zones
 - v) Use better and more effective risk management instruments
- 2) Strategic objective 2: Improving competitiveness of agro-food sector
 - a) Key needs:
 - i) Expansion and diversification of the market for Croatian agri-food products
 - ii) Integration of MSMEs and young farmers in food and agriculture value chains
 - iii) Facilitating producer access to strategic market segments
 - iv) Facilitating access to agriculture land
 - b) Specific objectives (RDI):
 - i) Strengthen the link between the agri-food sector and the market, including consolidation of supply
 - ii) Improve entrepreneurial skills and opportunities for producers in agri-food sector
 - iii) Better respond to customer requirements in the agri-food sector
 - iv) Encourage greater use of public and private quality systems in agri-food sector
 - v) Improve the skills of the workforce in the agri-food chain
 - vi) Improve the functioning of the agricultural land market

- 3) Strategic objective 3: Reconstruction of rural economy and improving life in rural areas
 - a) Key need:
 - i) Poverty reduction in rural areas
 - ii) Creating more and better jobs in rural areas areas
 - iii) Accelerate the transition to smart and green rural economy
 - b) Specific objectives (RDI):
 - i. Improve coordination and complementarity between rural interventions areas, including basic services
 - ii. Improve public infrastructure to enable modernization agricultural production

8.1.6. Vision and Plan for Strategic Transformation of Fishery and Aquaculture – More than a fishpond

It highlights innovation as a horizontal strategic goal and highlights the role of RDI in bioeconomy:

"The latest technologies in aquaculture, including digital technologies, show significant the potential to improve efficiency both inside and outside aquaculture farms, as well as to reduce costs, facilitating the redistribution of production resources, improving productivity, encouraging innovation and capital investment in production, improving the environmental footprint and connecting aquaculture producers and MSMEs with customers.

Increase the use of new (digital) technologies can positively affect the quality of life in rural and coastal areas and attract the opening of new companies (startups).

It is important to point out that new (digital) technologies can contribute transition to more integrated, sustainable and circular bioeconomy value chains in aquaculture (and other sectors) in rural and coastal areas. By encouraging local bioeconomy value chains, while exploiting technological ones innovation for further valorization of biological resources and waste streams, more efficient use of resources, reduced pollution and mitigates the effects of climate change, but also increases and diversifies producers' incomes and enables economic diversification of rural and coastal areas."

In this draft document of 68 pages, bioeconomy is mentioned 25 times. The document highlights the need to transition to circular and sustainable bioeconomy as a horizontal measure. Specific objectives where circular bioeconomy is suggested as a solution to the key need is bolded in the following text. The RDI needs identified in SWOT SRIA should be complemented with these key needs.

The document list key needs for RDI in aquaculture sector:

- Promotion of capital investments with focus on technology and innovation (a horizontal need)
- Improving access to research and development (R&D) and innovation and use knowledge and technology in decision making and investment (including climate and sustainability) (horizontal)

However, the all other 3 strategic goals reflect in the EU bioeconomy goals and RDI needed to achieve them:

- 1) Strategic objective 1: Increasing productivity and resilience of production in aquaculture to climate change
 - a. Key needs:
 - i. Increasing the added value of production in aquaculture
 - ii. Improving the environmental sustainability of production practices in aquaculture

- iii. Improving compliance between production systems and properties of ecological zones
 - iv. Better and more effective use of risk management instruments
 - b. Specific objectives:
 - i. Increasing efficiency and added value
 - ii. Improving sustainable natural management resources
 - iii. Reduction of sensitivity to climate change and encourage low-carbon production
- 2) Strategic objective 2: Improving competitiveness of aquaculture sector
 - a) Key needs:
 - i) Strengthening market linkages in the aquaculture sector, including consolidation of supply
 - ii) Improving entrepreneurial capacities and capabilities of enterprises in aquaculture
 - iii) Improving the stimulating environment in response to demand consumers for aquaculture products
 - iv) Improving the use of public and private quality standards
 - v) Improving workforce skills in the aquaculture chain
 - vi) Improving the functionality of the agricultural land market
 - b) Specific objectives (RDI):
 - i) Expansion and diversification of the market for Croatian aquaculture products
 - ii) Integration of MSMEs and young producers into value chains in aquaculture
 - iii) Facilitate producers' access to strategic market segment
- 3) Strategic objective 3: Reconstruction of rural and coastal economy and improving life in rural and coastal areas
 - a) Key need:
 - i) Improving coordination and complementarity between interventions in rural and coastal areas, including basic services
 - ii) Improvement of public infrastructure in order to modernize aquaculture production
 - b) Specific objectives (RDI):
 - i) Create more and better jobs in rural and coastal areas
 - ii) Accelerate the transition to a smart and green rural and coastal economy

The document indicates Connecting aquaculture with growth options in circular bioeconomy, which would address the following key needs of the primary sector:

- Increasing the added value of production in aquaculture
- Improving the environmental sustainability of aquaculture production practices
- Improving entrepreneurial capacities and opportunities of companies in aquaculture
- Improving the enabling environment in response to consumer demand for aquaculture products
- Improving coordination and complementarity between interventions in rural and coastal areas, including basic services
- Improvement of public infrastructure in order to modernize aquaculture production
- Encouraging capital investment with a focus on technology and innovation (horizontal)

Improving access to research and development (R&D) and innovation and the use of knowledge and technology in decision making and investment (including climate and sustainability) (horizontal)

8.2. Summary and conclusions in relation to SWOT elements

Ministry of Agriculture took the lead in the development of Bioeconomy Strategy and Action Plan which are expected to be adopted in 2021. At this moment, bioeconomy is not the central topic of any specific Croatian framework or policy. There are, however, several national and EU frameworks that touch on the topic of bioeconomy: Smart Specialization Strategy (S3) (it focuses on economy and increase its competitiveness by concentrating knowledge resources and linking them to a limited number of priorities), Industrial Strategy (emphasises the opportunities Croatia has identified as strategic activities in the global value chain towards the development of businesses that create added value) and the Rural Development Program (mentions the conventional use of agricultural and forest biomass, as well as energy production).

However, in order to develop the legal framework, all stakeholders from the bioeconomy sector need to be included and contribute to the creation of a quality strategy: Ministry of energy and environmental protection, Ministry of infrastructure, Ministry of education, etc.

Table 34 SWOT analysis of the Croatian policy framework

<p>Strengths</p> <ul style="list-style-type: none"> Raising awareness of bioeconomy potential for strengthening the agricultural sector and economy in general Thematic Innovation Council for food and bioeconomy within S3 Development phase of National Energy and Climate Action Plan for 2021-2030 CAP post-2020 BIOEAST initiative 	<p>Weaknesses</p> <ul style="list-style-type: none"> Slow policy-making framework Most measures rely on voluntary pledges from the private sector A lack of financial incentive/subsidies to foster bioeconomy development
<p>Opportunities</p> <ul style="list-style-type: none"> Development of Bioeconomy Strategy Policies for improved biomass managing, increase in the use of residues Strong agri-food sector Stimulation of the use of recognised certificates Removing exhaustive administrative regulations Programmes to keep the young people in the country (decrease "brain drain") 	<p>Threats</p> <ul style="list-style-type: none"> Continuous relying on voluntary pledges from companies

9. FINANCING

9.1. Introduction

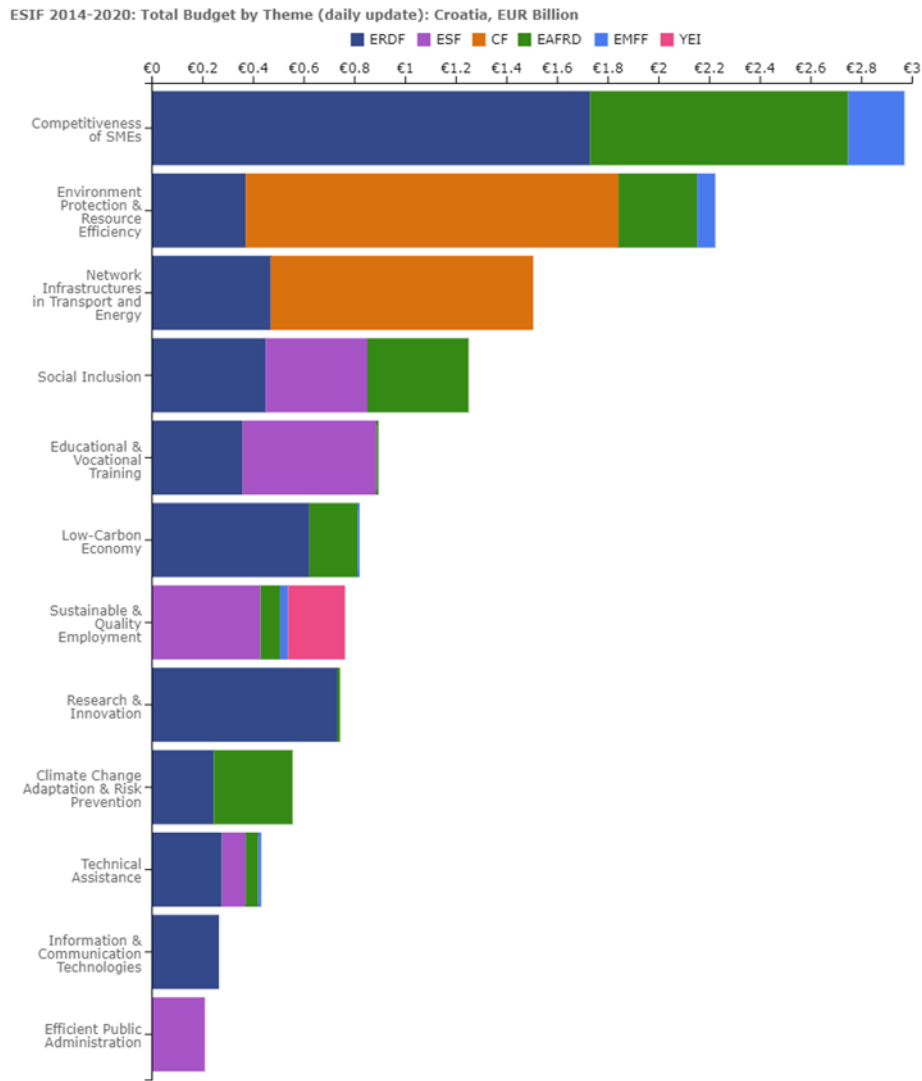
Business activities in Croatia can be financed either through standard loans of commercial banks or institutions offering more favourable interest rates or issuing guarantees for bank credits. Consisting of 25 banks, 1 saving bank and 5 building societies, a traditionally stable and highly developed sector, the Croatian banking system offers high diversification and good quality of financial products and services.

An important role in helping companies in their further developing and exporting activities has the Croatian Bank for Reconstruction and Development (HBOR). Through its specialized programs HBOR provides support to start-ups, exporting companies, new production and companies from different sectors of economy such as industry, tourism, environmental protection and energy efficiency, agriculture, etc. More information about HBOR programs can be found on its web site www.hbor.hr. Additional support to business activities is provided by the Government Agency for SMEs, Innovations and Investments (HAMAG-BICRO). HAMAG-BICRO issues guarantees for bank credits approved by credit institutions and other legal entities approving loans to SMEs and makes direct financial contributions to SMEs in a form of grants. More information about HAMAG-BICRO guarantees and grant schemes can be found on its web site www.hamagbicro.hr. There is an additional financing option for entrepreneurs and investors in developing their projects in Croatia, and that are EU funds. As 28th full member state of the European Union, the Republic of Croatia has possibility of using the assets from the Structural Funds and Cohesion Fund. The total budget of Croatia for the financial period 2014-2020 is EUR 12 645 636 148, which includes the Cohesion Fund (CF), the European Social Fund (ESF), the European Regional Development Fund (ERDF), the European Agricultural Fund for Rural Development (EAFRD), the European Maritime and Fisheries Fund (EMFF) and the Youth Employment Initiative (YEI).

As of 2018, Croatia contracted 68% of the estimated amount (selection decisions), while payments to end users were 17%³². For individual funds the amounts by financed theme are as shown on the graph below.

³² <https://razvoj.gov.hr/UserDocImages/Istaknute%20teme/MRRFEU%20rezultati%202018..pdf>

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087



Refresh Date: 15/03/2021

Figure 38 Total budget by theme³³

³³ <https://cohesiondata.ec.europa.eu/countries/HR>

9.2. Summary and conclusions in relation to SWOT elements

Croatia has a high potential for fostering bioeconomy, but the realisation of this potential ultimately depends on the financing. There are different possible funding schemes, but the most significant problem is the slowness of the system. EU funding provides resources for research and innovation and SME's competitiveness. HAMAG-BICRO recently increased visibility of financial lines towards family farms, SME's and entrepreneurs in the tourism sector which resulted in rising of new applications and development of new business activity in these sectors. HBOR has introduced a new line of business financing for young entrepreneurs, women and beginners. Therefore, monetary funds are available, but the barrier needs to be bridged.

Table 35 SWOT analysis of the Croatian financing sector

<p>Strengths</p> <ul style="list-style-type: none"> EU funds Financial lines available to entrepreneurs Areas of excellence in academia and industrial research 	<p>Weaknesses</p> <ul style="list-style-type: none"> Low investment activity in processing activities in the direction of transitioning to bio-based alternatives Insufficient supporting activity of financial institutions towards bioeconomy projects (e.g. venture capital funds) Complicated procedure of public procurement Low level of trust in public institutions
<p>Opportunities</p> <ul style="list-style-type: none"> Enhance State or Government funding and subsidies for fostering bioeconomy Better use of available EU funding in the field of bioeconomy Regional resource connecting (RDI, production, logistics) 	<p>Threats</p> <ul style="list-style-type: none"> Rising competitiveness of bio-based industries in neighbouring countries Reduced government funding and use of EU funds Possible risky nature of investment A lack of agencies providing equity and loans for bio-based initiatives



PART B

BIO-ECONOMY STAKEHOLDERS IN CROATIA

10. ACTORS IN AGRICULTURAL AND AGRO INDUSTRIAL SECTOR³⁴

As it was mentioned in the Disclaimer section, this project was time and budget limited. Therefore, it was not possible to make a complete overview of all the players in specific industries that were covered. This would require more significant effort, which will be conducted in future projects, on topic of Croatian bioeconomy (e.g. stakeholders overview for the preparation of National Bioeconomy Strategy).

Therefore, the overview in this chapter provides a general overview of a representative sample of stakeholders and a starting point for future projects. It should be noted that there are many more stakeholders in this industry and sector, and the mentioned stakeholders are not favoured in any way. They are selected only due to limited scope of the project's activities.

Moreover, the information gathered in this chapter are validated by experts in the examined fields: Croatian Chamber of Agriculture (CCA) in the agriculture sector, and Croatian Forest Research Institute in the forestry sector.

Furthermore, the stakeholders report is defined within the templates of the project's activities and designed by coordinating project partners. The table is presented as following, with the description of each segment:

10.1. Actors in primary agricultural sector

Agricultural production is mainly oriented through family farms. In 2019, the number of family farms was 162,966 and they are cultivating a total area of 869,093.0 hectares (Ministry of Agriculture, 2020). Most manufacturers represent small and medium-sized economies, while smaller but more significant holdings are large companies. Farmers are also grouped into sectoral associations and unions. Since Croatia's accession to the European Union, farmers have also been joining producer organizations. 17 producer organisations (PO), mostly from the dairy sector, have been

³⁴ Approach: In this chapter we present an overview of all actors and actor groups that need to be involved when setting up biomass delivery chains. To ensure a complete mapping of these actors several stakeholder exchanges at national stakeholder workshops were held.

The actors presented can be specific persons, companies, and other type of organisations (e.g. farmers organisations. In case of listing companies in certain sectors we listed the top largest and/or most influential ones.

For the actors presented in this report the following information is provided:

- Company name/person name
- Company location in town/municipality
- Company location in region
- Type of activity (for company)/ type of function (for person) / public sector (government)
- (if company/organisation) specify number of employees
- Already involved in bio-based activities (Y/N)
- If yes, describe bio-based activity it is involved in

established so far. Setting up new POs and joining more and more farmers in them, gives them the opportunity to compete on the market and achieve good product prices. Farmers' strength is achieved through joint action so they can compete on the large European market.

Croatia is a land of small farmers and micro-agricultural lands (under 2 hectares) and small agricultural lands (2-20 hectares) make up more than 90% of agricultural land.

The number of employed people in agriculture in 2019 was 37.774. The share of young farmers (up to 41 years) is 12.7%.

According to Ministry of Justice and Public Administration, there are over 2,000 associations related to the agriculture sector in Croatia³⁵. Main agricultural organisation is Croatian Chamber of Agriculture (CCA) that represents 75,000 farmers, carrying out their activities within 18 agricultural committees, operating under the CCA. Also, in CCA are also active farm associations and they are: Croatian Central Association of Simmental Cattle Breeders, Croatian Central Association of Holstein Cattle Breeders, Croatian Central Association of Pig Breeders, Croatian Association of Sheep and Goat Breeders, Central Association of Croatian Cold Blood Breeders, Central Horse Breeders Association "Croatian Posavac", Croatian Poultry Breeders' Association, Croatian Beekeepers Association, Central fruit and vegetables organization, Croatian Fruit Community, Community of vegetable growers associations, Croatiastočar, Cromilk, Association of Family farms – Life, Milk Association Drava – Sava, Croatian Young Farmers Association, Association Baby Beef. All the above communities, associations and federations are active members of the CCA.

In addition to the CCA, active associations in Croatia are: Croatian Chamber of Economy, Croatian Chamber of Trades and Crafts.

According to statistics from the Central Bureau of Statistics, in 2018, there were 3,253 registered companies and 58,184 workers were employed in the food and beverage sector.

According to Paying Agency for Agriculture, Fisheries and Rural Development (APPRRR) data statistics³⁶ in 2019 there were 8,240 agricultural holdings in Croatia, with an agricultural area of up to 100 ha; 1,299 holdings with an area of up to 1,500 ha; and 16 holdings with an area of more than 1,500 ha.

The Agricultural Advisory Service has been under the authority of the Ministry of Agriculture since 2019. The main objective and purpose of the Advisory Service is to develop competitive and advanced farms and fisheries entities through information, consultation and education, while respecting the principles of good agricultural practice and preserving rural space by nurturing traditions and customs. The Advisory Service operates through 21 support centres by county, where they have 121 offices throughout Croatia, 300 professionally trained staff and 240 specialists on the field. In addition to this national advisory body, there are about 10 private advisory institutions in Croatia - environmental control bodies.

Croatian Agency for Agriculture and Food carries out programmes that are of strategic interest to the Republic of Croatia and establishes an infrastructure in cooperation with scientific institutions that is of interest to the entire agricultural system of the Republic of Croatia. The Agency should ensure and develop excellence in technological research and experimental development in the fields of agriculture and food safety and thus improve food and bioenergy production, the supporting industry and natural resource management in the national, regional and European context, with special emphasis on the development of sustainable and viable national agriculture. Its

³⁵ <https://registri.uprava.hr/#ludruga>

³⁶ <https://www.apprrr.hr/arkod/>

activities have been prescribed by the Act on the Croatian Agency for Agriculture and Food and other special regulations (more than 19 different acts, more than 200 different rules, ordinances and instructions), and consists of 8 centres³⁷:

- Centre for Seed and Seedlings
- Centre for Quality Control and Livestock Products
- Centre for Plant Protection
- Centre for Viticulture, Enology and Edible Oils Analysis
- Centre for Soils
- Centre for Pomology and Vegetable Crops
- Centre for Food Safety and
- Centre for Livestock Breeding.

National and regional CAP information officers

The Croatian Chamber of Agriculture was established by the Croatian Parliament in 2009 in order to prepare farmers for CAP. The CCA functions as an umbrella organization for associations, cooperatives, family farms, businesses and trade in agriculture. The organization is a full member of the COPA-COGECA, the strongest association for European farmers. As a member of these groups it has access to EC Civil dialogue groups (CDG) on forest, CAP, direct payments, and other agricultural sectors. On national level, CCA is member of approximately 30 Working parties in Ministry of Agriculture, including Bioeconomy.

There are also 56 Local Action Groups (LAG) under Croatian Rural Development network. LAGs are the establishments of local partnerships, which have a task of creating and implementing local development strategies, making decisions on the allocation of available funds and management of the funds. A LAG needs to bring public and private sector partners together, seeing to the balanced representation of local interest groups, whose members belong to different socio-economic segments. At the level of decision-making, at least 50% of members must come from the business and civil society sectors³⁸. A LAG can be founded ad hoc, or it can build upon existing partnerships.

³⁷ <https://www.hapih.hr/about-us/>

³⁸ <https://hmr.hr/en/leader-approach/what-is-lag/>

10.2. Actors in agro industries

Name:	Atlantic Grupa
Location:	Croatia
Region:	Central Croatia
Type of activity:	Functional food, beverages and pharmaceuticals
Website	https://www.atlanticgrupa.com/hr/
Bio-based activity involved in:	Functional food, beverages and pharmaceuticals

Name:	Bobis
Location:	Croatia
Region:	Split Dalmatia County
Type of activity:	Production of bakery products, cereals
Website	https://bobis.hr/

Name:	Cetina (pasta factory)
Location:	Croatia
Region:	Međimurje County
Type of activity:	Production of macaroni, gnocchi, couscous

Name:	Dukat
Location:	Croatia
Region:	Central Croatia
Type of activity:	Production of milk and dairy products
Website	https://www.dukat.hr/

Name:	Franck
Location:	Croatia

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Region:	Central Croatia
Type of activity:	Production of food and beverages, seasoning, coffee and tea
Website	https://www.atlanticgrupa.com/hr/

Name:	Gavrilović
Location:	Croatia
Region:	Sisak Moslavina County
Type of activity:	Meat processing
Website	http://www.gavrilovic.hr/

Name:	Kandit
Location:	Croatia
Region:	Osijek Baranja County
Type of activity:	Confectionery company with a long tradition of manufacturing
Website	https://www.kandit.hr/hr/naslovna/

Name:	KOKA
Location:	Croatia
Region:	Varaždin County
Type of activity:	Koka is the only Croatian poultry industry with an integrated production cycle – from farm flocks for the production of hatching eggs, through the hatchery, the fattening of broilers, the veterinary service, the laboratory and the animal feed factory to the meat industry. Under Vindija Group.
Website:	http://www.vindija.hr/en-GB/About-us/Member-Firms/Koka.html?Y2lcNjY%3d

Name:	Koestlin
Location:	Croatia
Region:	Bjelovar-Bilogora County

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Type of activity:	Production of confectionery products
Website	https://www.koestlin.hr/en

Name:	Kraš
Location:	Croatia
Region:	Central Croatia
Type of activity:	Leading manufacturer of confectionery in south-eastern Europe
Website	https://www.kras.hr/en/about-us/about-us

Name:	Ledo
Location:	Croatia
Region:	Central Croatia
Type of activity:	Largest domestic manufacturer of industrial ice cream and the largest distributor of frozen foods (fish, fruits and vegetables, pastry doughs, ready-made meals)
Website	https://www.ledo.hr/hr-en/about-us

Name:	PIK Vrbovec
Location:	Croatia
Region:	Zagreb County
Type of activity:	Meat industry (red meat and meat products from red meat)
Website	https://www.pik-vrbovec.hr/about-us-company-info-a82-89?lang=en

Name:	Podravka
Location:	Croatia
Region:	Koprivnica Križevci County
Type of activity:	Food and pharmaceutical company
Website	https://www.podravka.com/about/

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Sladorana Županja
Location:	Croatia
Region:	Vukovar Srijem County
Type of activity:	Processing of sugar beet production and sugar processing, sugar beet, ethyl alcohol, protein powder, and feeding of livestock production with the product "Sladoliq"
Website	http://www.secerana.hr/

Name:	Tvornica šećera Osijek
Location:	Croatia
Region:	Osijek Baranja County
Type of activity:	Processing of sugar from sugar beet, soil improver from carbocalk, mollasses from sugar beet and raw sugar, sugar beet noodle from dry brikets and pressed noodle
Website	https://www.atlanticgrupa.com/hr/

Name:	Vindija
Location:	Croatia
Region:	Varaždin County
Type of activity:	Today, the Vindija Group comprises 14 companies, 8 of which are in Croatia and 6 in the countries of the region. Vindija's range today includes more than 1000 different products in seventeen brands, the most famous of which are 'z bregov, Cekin and Vindon.
Website	https://www.atlanticgrupa.com/hr/

Name:	Viro tvornica šećera
Location:	Croatia
Region:	Virovitica Podravina County
Type of activity:	Sugar factory
Website	http://www.secerana.hr/default.aspx?id=3

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Zdenka
Location:	Croatia
Region:	Bjelovar Bilogora County
Type of activity:	Cheese production
Website:	https://www.zdenka.hr/en/stranice/o-nama

Name:	Zvečevo
Location:	Croatia
Region:	Požega Slavonia County
Type of activity:	Confectionery manufacturer
Website:	http://www.zvecevo.hr/en/

10.3. Other actors related to agriculture & agro-processing chain

Name:	Žito Ltd.
Location:	Osijek
Region:	Osijek-Baranja County
Type of activity:	Production of cereals, feed for food, energy
Already involved in bio-based activities:	The basis of energy production in the Žito Group is the use of manure from Group farms, silage and other organic residues in biogas plants - 4 biogas plants; Digestate, a by-product of biogas production rich in micro and macro nutrients, is used as organic fertilizer on the Group's arable land. The Vitalka animal feed factory is one of the most modern animal feed factories in the region. The production process is fully automated and computer controlled. Great importance is attached to the control of raw materials and finished products and traceability. The raw material base of production is the crops grown on the surfaces of the Žito Group. The mixing capacity is 20 t/h, while the annual production is 100,000 tonnes of feed for pigs, cattle, poultry, game and fish.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Belje d.d.
Location:	
Region:	Osijek-Baranja County
Type of activity:	Dairy Factory, meat processing, wine production, corn flour production and tomato cultivation
Already involved in bio-based activities:	Animal feed factories Belje are today the largest producer of animal feed in Croatia, with a total production capacity of 300,000 t. Mitrovac agricultural complex combines a dairy farm, a biogas power plant and a greenhouse for the production of tomatoes, in which 2,800 tons of tomatoes are produced annually on 4.5 hectares. Wine production on 650 ha is base for tourism related activities (wine roads, guided tours, souvenir shop and events).

Name:	PPK Valpovo
Location:	Valpovo
Region:	Osijek-Baranja County
Type of activity:	Production of cereals, industrial plants and other crops
Already involved in bio-based activities:	The Valpovka animal feed factory has a production capacity of 35,000 tonnes of animal feed per year. It is at the top of the domestic animal feed industry, in quality and equipment, with a wide variety of finished products. Within the Valpovka Animal Feed Factory there is a separate premixed plant, which for the needs of the factory as well as for end consumers produces a series of premixes, mineral mixtures and supplementary feeds.

Name:	Osječka pivovara ltd.
Location:	Osijek
Region:	Osijek-Baranja County
Type of activity:	Beer production, research

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Karolina ltd.
Location:	Osijek
Region:	Osijek-Baranja County
Type of activity:	Production (biscuit and waffle factory)
Already involved in bio-based activities:	Nursery production is organized on an area of 14 ha with fruit planting material and ornamental plants. Carolina d.d. owns native nurseries for the production of vegetative and generative rootstocks and parent crops for own production of scions and resale. Annual production of fruit seedlings for the sales season is around 110,000 pieces.

Name:	Osatina grupa d.o.o.
Location:	
Region:	Osijek-Baranja county, Vukovar-Srijem County
Type of activity:	Production, research
Already involved in bio-based activities:	Osatina Group's activities include farming, cattle breeding, pig breeding, animal feed, humus production, vegetable and fruit production and meat processing. Osatina Group currently operates 3 biogas plants with a total capacity of 6 MWe / 6 MWt. After the fermentation process in the biogas plant and with specific processing technology high quality humus is produced.

Name:	Osilovac d.o.o.
Location:	Feričanci
Region:	Osijek-Baranja County
Type of activity:	Wine Production, research
Already involved in bio-based activities:	Wine production on 160 ha with annual production around 900,000 liters is a base for tourism related activities (wine roads, guided tours, school for winegrowers, souvenir shop and events).

Name:	Pivac Group
Location:	
Region:	Split-Dalmatia County
Type of activity:	Meat processing industry
Already involved in bio-based activities:	Meat processing, distribution and sales. 3 meat processing factories.

Name:	Mini dairy farm Veronika ltd.
Location:	Desinić
Region:	Krapina-Zagorje County
Type of activity:	Production of milk and milk products
Already involved in bio-based activities:	Mini dairy farm Veronica ltd. processes 20,000 liters of milk per day.

10.4. Clusters and organisations

Croatia has 362 farm cooperatives and 17 Producer organisations. Yet, there is still a negative opinion on cooperation, due to historical background. Many farmers are still small, single players and these cooperatives and POs are having approximately 7 members (Broz and Švaljek, 2019). In cooperatives, most of them are not in primary production. Cooperatives are mostly active in Mediterranean part.

Name:	Croatian Chamber of Agriculture
Location:	Croatia
Region:	City of Zagreb
Type of activity:	Consulting and advisory
Website	https://komora.hr/

11. ACTORS IN FORESTRY AND FOREST INDUSTRY

As already mentioned, there is more than 250-years long forestry tradition and organised sustainable forest management in Croatia. At the present, forest management and other forestry activities are regulated by several laws and legal acts. Therefore, there are many stakeholders in the Croatian forestry sector, that can be related to bioeconomy segment. However, due to limitations of the project's scope, this chapter only presents a representative sample of stakeholders, which are in no way favoured before others.

Forestry companies

Public companies

In the actual management of state-owned forests, a state-owned company Croatian Forests Ltd. (Hrvatske šume d.o.o.), has a key role. The company carries out the following activities: silvicultural activities, forest protection, on-field inventory, production of woody assortments, and selling the produced assortments. The company is obligated by the Law on forests (Official Gazette 68/18, 115/18, 98/19) to make detailed Forest Management Plans (FMP) and to keep a precise bookkeeping of growing stock for every Forest Management Unit (FMU). The average size of FMU is around 3,000 ha. FMP for each FMU has to be renewed every 10 years on the basis of data from the previous FMP and forest measurements with the intensity of up to 10% of the area.

All State-owned forests managed by the Croatian Forests Ltd. are certified according to FSC certification standard. The company has been actively involved in the process of certification since 2000. At the beginning, only respective Forest Administrations had been certificate holders (since 2002), and later the whole area managed by Croatian Forests was subjected to the certification monitoring, on which basis a mutual certificate for the whole group consisting of 16 members (Forest Administrations) was issued. It can be also referenced by all wood processors down the chain of custody, who obtained the raw material from Croatian Forests Ltd. The use of FSC certificate, FSC logo and COC number is subject to strictly regulated FSC rules and its abuse is forbidden (Croatian Forests, 2008).

Croatian Forests Ltd. is also in charge of developing a General Forest Management Area Plan (FMAP) on the national level every 10 years. The FMAP is made by compiling and summarizing data from existing FMPs for the state-owned forests and data available for private forests. The Ministry of Agriculture gives approval for the FMP as well as forest management plans of private forests.

Besides Croatian Forests Ltd., there is also the Faculty of Forestry, University of Zagreb, who is involved in forest management activities, but only of special purpose forests used for education and training of students.

Individual private forest owners (not part of associations of private forest owners)

Most of All the Croatian wood-buyers are wood processing companies, but there is an unknown number of intermediaries. Private companies for forest utilisation provide services to Croatian Forests Ltd. company based on subcontracting or to private forest owners. Those SMEs (stakeholders) in forestry providing services to state-owned company or private forest owners are considered as licenced Forestry Contractors. There is a significant number of Forestry contractors, and as example of small enterprises there are Trgovački obrt i izvoz drveta iz šume "START" (Otok), TOP DRVO d.o.o. (Apatovec), MALI-logging d.o.o. (Karlovac), Uslužni obrt "KIRO" (Petrovci), and as example of medium enterprises there are "ČANDIĆ" izvoz trupaca iz šume (Gunja), G.T.P. Šošarić (Jastrebarsko), Ice Eurotransport d.o.o. (Karlovac), MANDA-RAD obrt za šumarske usluge (Brod Moravice) etc.³⁹ According to comprehensive analysis of forestry contractors and services provided to the company Croatian Forests Ltd. in the period 1998-2002 by Šporčić and Martinić (2004), forestry contractors have carried out around 14% of all tree-felling activities and around 44% of all wood skidding (calculation based on extracted wood volume). According the three Annual reports of Croatian Forests Ltd. (2017⁴⁰, 2018⁴¹, 2019⁴²), the share of services provided by forestry contractors to the company has significantly increased, compared to results from Šporčić and Martinić (2004). After the establishment of Forestry Extension Service in 2006, provision of forest management services by forestry contractors increased, based on experts' opinion.

Forestry organisations

Establishment of the Croatian Chamber of Forestry and Wood Technology Engineers in 2006 affected forest management of private forests due to obligatory licensing of contractors who are providing services in forestry (usually wood logging) and voluntary licensing of forestry and wood processing engineers (Law on Croatian Chamber of Forestry and Wood Technology Engineers, OG No. 22/2006).

The Association of Forestry Professionals is also a non-governmental body, acting as a professional association of forest engineers and technicians. It provides training to its members and works on promotion of forestry and forest-related science.

Regarding the Croatian Academy of Forestry Sciences, it is a non-governmental body for promotion of forest-related science.

³⁹ Croatian Chamber of Forestry and Wood Technology Engineers, List of licenced forestry contractors on 2nd Feb 2020

⁴⁰ https://www.hrsume.hr/images/stories/godisnja-poslovna-izvjesca/godisnje_izvjesce_za_2017.pdf

⁴¹ https://www.hrsume.hr/images/stories/godisnja-poslovna-izvjesca/godisnje_izvjesce_za_2018.pdf

⁴² https://www.hrsume.hr/images/stories/godisnja-poslovna-izvjesca/godisnje_izvjesce_za_2019.pdf

Forestry advisory organisations

Forestry Extension (Advisory) Service as an independent agency existed from 2006 until 2010, when it became a unit within the Croatian Forests Ltd. In 2014 the extension service was moved again out of the Croatian Forests Ltd. company to an independent agency, that was established as a result of merging forestry and agricultural advisory services in one agency. The Advisory Service existed until the end of 2018, after which the Ministry of Agriculture took over the roles and activities of the Advisory Service. The roles of the Ministry regarding forest management of private forests are: advisory services and promotion of knowledge on forests, organisation of education activities for private forest owners, preparation of expertise for forest management in private forests, preparation of documents for forest roads and forest fire brakes, keeping records on private forests and monitoring the implementation of forest management plans, establishment of special conditions for forest infrastructure in private forests, marking the trees in private forests via licenced contractors etc. (Law on termination of the Law on Croatian agriculture and forestry advisory service, OG No. 111/18).

Land-owner organisations

The associations of private forest owners are non-governmental organisations (NGO). The first meeting of forest owners was held 2005 in Delnice (Posavec et al., 2011) which was the basis for setting up the private forest sector reform, and where key problems were highlighted. The Croatian Union of Private Forest Owners Associations (CUPFOA) was established in 2008, whose role is representation of private forest owners associations (PFOA) on the national level and lobbying for private forest owners interests. Their main objective is to represent forest owners' interests on national level through collaboration with public institutions and participation in several professional committees which deal with forestry issues. The funding of the CUPFOA is based on membership fee, donations and project acquisition. CUPFOA cooperates with the PFOAs from the Western Balkan region and is a member of the Confederation of European Forest Owners (CEPF). Not all associations of private forest owners are members of the umbrella association.

Basic PFOAs are small NGOs with up to 100 members and usually cover an area of one municipality. PFOAs are weak, because private forest owners do not play an important role in the wood supply chain and they used their forests mostly for firewood, the reason why most forest owners are not more members of these associations according to expert opinion⁴³.

The role of PFOAs is to educate the members about sustainable forest management, to participate in the elaboration of forest management plans and to cooperate with local and national government. The main goals of PFOAs are the improvement in forest management; collaboration and exchange of knowledge and experiences; access to information; expert education; cooperation with public institutions; to enhance financial possibilities and the utilisation of incentives and other funds. PFOAs are usually working on the municipality basis and implement different projects (education, information, management plans, forest roads).

At the moment, 18 associations of PFOs are registered, according to the Register of associations in the Republic of Croatia. Also, there are two umbrella associations, one at the national and one at the regional level.

⁴³ Validated by Croatian Forest Research Institute

Actors in forest industries

The main forest industries in Croatia are Wood processing industry and Furniture manufacture which have a significant role in the national economy, what is reflected in the economic contribution (7% equity share in total exchange of the country) and the wider social contribution (1/3 of the total number of employees in wood manufacturing, 0.9% equity share in GDP), which greatly contributes to harmonisation of the total development process within the country.

This industry is traditionally dominant in the rural areas of the country and occupies a significant place in the rural development, and most importantly, in areas of special State's concern that lie mostly in rural areas.

According to the average number of employees per an economic entity, around 95% of the wood processing and furniture production have the small business (small and medium-sized enterprises) characteristics.

The employment trends in wood processing and manufacture of furniture register more than 21,000 workers, in both industrial sectors. One must also consider the number of workers employed in craft, paper production and forestry which is to say that Croatia's wood-based industry currently employs over 40,000 workers.

Decreasing trend of the number of employees in companies operating in wood-processing sector, furniture production and forestry sector has started in Croatia even before beginning of last global economic crisis. In order to increase employment in these sectors and to balance and regulate mutual relationship, Wood Processing Industry Association of the Chamber of Commerce and Croatian Forests Ltd. made an agreement in 2012.

The Croatian wood processing industry is export-oriented, together with part of furniture manufacture, and in the past few years total exports exceeded imports, owing to the increased export of raw wood and wood products, while the import of furniture still exceeds exports.

The most important export markets are Germany, Italy and France where more than 60% of product value is exported. At the same time, furniture from Italy is the most imported (25%), Slovenian is second (14%) and China (10%), figures valid for 2012.

In Croatia wood-pellets production is increasing since its beginning in mid-of-2000.

11.1. Actors in wood pellet production

Name:	Špačva LLC.
Location:	Vinkovci
Region:	Vukovar-Srijem County
Type of activity:	Wood processing, manufacture of furniture, pellets and plates and glued elements
Already involved in bio-based activities:	Installed capacity (ktons): 50,000 Manufactured (tons): 0

Name:	Mundus Viridis Ltd.
Location:	Gradec
Region:	Zagreb county
Type of activity:	Wood processing, manufacturing of solid laminated wood panels, sawn timber, wooden elements, pellets and firewood
Already involved in bio-based activities:	Installed capacity (ktons): 10,000 Manufactured (tons): 0

Name:	Drvenjača LLC.
Location:	Fužine
Region:	Primorje-Gorski kotar county
Type of activity:	production of conifers, mechanical pulp (RMP) and wood pellets.
Already involved in bio-based activities:	Installed capacity (ktons): 15,000 Manufactured (tons): 6,000

Name:	Energy Pellets Ltd.
Location:	Delnice
Region:	Primorje-Gorski kotar county
Type of activity:	Production of wood pellets (wooden pellets, pallets and sawn timber)

Already involved in bio-based activities:	Installed capacity (ktons): 70,000 Installed production capacity: 20,000 m ³ pelletized firewood annually
---	---

Name:	Finvestcorp d.d.
Location:	Čabar
Region:	Primorje-Gorski kotar county
Type of activity:	Production of wood pellets
Already involved in bio-based activities:	Installed capacity (ktons): 20,000 Manufactured (tons): 10,000

Name:	Šišarka ltd.
Location:	Županja
Region:	Vukovar-Srijem county
Type of activity:	Pellet production
Already involved in bio-based activities:	Installed capacity (ktons): 50,000 Manufactured (tons): 25,000

The newcomers after 2009 are companies: Moderator d.o.o. Udbina and Pin d.o.o. Jasenovac, while Spačva d.d. Vinkovci and Mundus Viridis d.o.o. Gradec have already started production.

11.2. Clusters and organizations

In Croatia there are various wood-based clusters or associations. These clusters were established with the following objectives: to use domestic wood resource and to process it in Croatia as much as possible; to maximise the share of wood(-based) products of the highest product finalisation stage in the forestry value chain; profit increase of all cluster members; productivity and employment increase in the country; stimulating wood-processing industry and furniture manufacture; increasing the share of final products in the export of wood-based products; providing own products to domestic tourism sector as well as other domestic sectors using wood(-based) products, etc.

Historically observed, The following clusters were established: Cluster TEHNOINTERIJERI (2006) Croupelets cluster (2007), Wood cluster of Northwest Croatia (2007), Wood cluster of Vukovar-Srijem County (2010), Association of wood pellets and woody biomass producers (2010), VIRIDIS cluster (2011), Croatian Wood Cluster (2012), The association of small sawmills Primorsko-Goranska County, Croatian Interiors, Croatian Biomass Association (CROBIOM). Most of all wood clusters and wood & furniture industries are members of Croatia Wood Cluster.

12. ACTORS IN THE WASTE SECTOR

Waste management and efficiency of waste management in Croatia is secured by the Government of Republic of Croatia and Ministry of Economy and Sustainable Development (former Ministry of Environment and Energy), through provision of measures for waste management, adoption of laws and strategic documents. The Ministry conducts administrative supervision and inspections of implementation of the Act on Sustainable Waste Management (OG 14/19), and its statutes. The inspections are done by environmental protection inspectors. The main goal of the Ministry in this area is to protect the environment and human health through responsible management of waste.

Since January 2019, the Ministry incorporated the Croatian Agency for Environment and Nature, whose activities are taken over by Institute for Environment and Nature, within the Ministry. The Institute gathers, consolidates and manages data, according to the Act on Sustainable Waste Management, manages the information system for waste management, develops reports on national status of waste and conducts reporting pursuant to EU standards in waste management sector.

The executive body on the national level is the Environmental Protection and Energy Efficiency Fund. The Fund secures additional funds for financing projects, programmes and similar activities in areas of environment protection and improvement. Moreover, it has jurisdiction over establishment of administrative acts for compensation fees and register of payers.

On regional and local levels, the responsibility for waste management and implementation of acts and prerequisites lies on Regional and Local self-government units and their administrations for waste management. Several Regional and/or Local self-government units can enter in an agreement, to conduct common waste management measures.

In municipalities and cities, businesses related to waste management are conducted by different governing bodies (mostly specialized administrative departments). Moreover, there is a great number of utility companies, working in municipalities and cities, on waste management activities (collection, treatment, management, etc.) – state-owned and private. Regarding waste management sector, there were 616 companies dealing with waste and environmental protection in 2017 in Croatia.

Utility companies in private ownership may be included in waste management by conducting the activities of waste transport, intermediation in waste management, waste trading, waste collection, waste recovery, waste disposal, other waste treatment and exportation and importation of waste, conducting waste collection actions, providing the public service of municipal waste collection and laboratory activities.

Since bioeconomy in Croatia is not yet fully developed and its implementation is in process, It is difficult to differentiate the companies working with waste on the ones using bioeconomy principles and the ones that implement circular economy principles.

12.1. Clusters and organizations in by-products creating sector

As it was the case in previous chapters, this section presents the representative sample of companies and organisations operating in the waste management sector, that have by-products that can be utilized within the bioeconomy. It is important to mention that there are many other stakeholders in Croatian economy that are operating in this sector, which are related to bioeconomy, but the ones presented here are selected only within the projects scope and are selected due to no favouring of specific stakeholders.

Wood processing industry

Croatia has a significant number of wood processing industries, which produce a lot of sawdust, woodchips, wood residues, etc., that can be utilized and energy or materially recovered.

Some companies that are listed in the Register of by-products producers are following: A.D. GAJ Ltd.; CALLIGARIS Ltd.; KULA-PROMET Ltd.; DRVODJELAC Ltd.; DRVO SAMARŽIJA Ltd.; POŽGAJ Ltd.; TVIN Ltd.; Vedrana Ltd.; Olovka Ltd.; various woodwork shops and companies, etc.

Food processing industry

Name:	Dukat d.d.
Location:	Zagreb
Region:	City of Zagreb
Already involved in bio-based activities:	Production of liquid fat residue and cheese residues.

Name:	HIPP CROATIA d.o.o.
Location:	Glina
Region:	Sisak-Moslavina county
Already involved in bio-based activities:	Cereal by-products

Name:	CEDEVITA, Prehrambena industrija, društvo s ograničenom odgovornošću
Location:	Zagreb
Region:	City of Zagreb

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Already involved in bio-based activities:	Production residue that can contain: cedevita granules, sugars, vitamins, other compounds.
---	--

Name:	VETERINARSKA AMBULANTA ANIMALIA d.o.o.
Location:	Zadar
Region:	Zadar county
Already involved in bio-based activities:	Olive pomace

Name:	AGROLAGUNA d. d.
Location:	Poreč
Region:	Istra county
Already involved in bio-based activities:	Whey

Name:	PIK VRBOVEC-MESNA INDUSTRIJA, d.d.
Location:	Vrbovec
Region:	Zagreb county
Already involved in bio-based activities:	By-product of animal origin, categories 2 and 3

Name:	Podravka d.d.
Location:	Koprivnica
Region:	Koprivnica-Križevci county
Already involved in bio-based activities:	Residues of vegetables, herbs, brine and process water that is produced exclusively during production and processing of vegetables.
Bio-based activity involved in:	

Name:	Olikom, d.o.o.
-------	----------------

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Location:	Makarska
Region:	Split-Dalmatia county
Already involved in bio-based activities:	Olive pomace

Name:	BELJE d.d
Location:	Darda
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Manure.

Name:	Gala d.o.o.
Location:	Bjelovar
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	Chicken manure.

Name:	MARINADA d.o.o.
Location:	Slatina
Region:	Virovitica-Podravina county
Already involved in bio-based activities:	Parts of fruits and vegetables.

Name:	VIRO TVORNICA ŠEĆERA d.d.
Location:	Zagreb
Region:	City of Zagreb
Already involved in bio-based activities:	Process residues of sugar beet.

Name:	ŽITO d.o.o. , Osijek Gnoj kokoši nesilica
Location:	Osijek
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Manure from laying poultry.

Name:	ADRIA SNACK COMPANY d.o.o. , Zagreb Ljuska krumpira, Sivi škrob, Obresci krumpira, Sirovi listići krumpira, Bijeli škrob, Prženi čips, Prženi peleti, Klice krumpira, Talog iz taložnice, Voda s ostacima organskih tvari
Location:	Zagreb
Region:	City of Zagreb
Already involved in bio-based activities:	Potato peelings, grey starch, potato parings, raw potato slips, white starch, fried chips, fried pellets, potato sprouts, sludge from settlement ponds, water with organic matter residues.

Name:	Tvornica šećera Osijek d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Sugar beet process residues, pressed sugar beet pulp.

Beverage industry

Name:	ZAGREBAČKA PIVOVARA d.o.o.
Location:	Zagreb
Region:	City of Zagreb
Already involved in bio-based activities:	Brewer's grains, Kieselguhr (diatomaceous earth).

Name:	HEINEKEN HRVATSKA d.o.o.
-------	--------------------------

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Location:	Karlovac
Region:	Karlovac county
Already involved in bio-based activities:	Brewer's grains, brewer's yeast.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	CARLSBERG CROATIA d.o.o.
Location:	Koprivnica
Region:	Koprivnica-Križevci county
Already involved in bio-based activities:	Brewer's grains.

Name:	HAMER d.o.o.
Location:	Čakovec
Region:	Međimurje county
Already involved in bio-based activities:	Apple pulp.

Paper industry

Name:	DS Smith Belišće Croatia d.o.o.
Location:	Belišće
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Short paper fibers.

Chemical industry

Name:	PETROKEMIJA, d.d.
Location:	Kutina
Region:	Sisak-Moslavina county
Already involved in bio-based activities:	Phosphogypsum.

12.2. Clusters and organisations creating by-products

This section will point out the companies and organisations operating in the waste management sector, that have been registered in the Register for end-of-waste status.

Name:	UNIVERZAL društvo s ograničenom odgovornošću za proizvodnju, gospodarenje otpadom, trgovinu i hotelijerstvo
Location:	Varaždin
Region:	Varaždin county
Type of activity:	Waste management, sales and hotel industry.
Already involved in bio-based activities:	Solid biofuel production.

Name:	Energija Gradec, društvo s ograničenom odgovornošću za proizvodnju, distribuciju i trgovinu električnom energijom
Location:	Zagreb
Region:	Zagreb county
Type of activity:	Energy production from biogas.
Already involved in bio-based activities:	Anaerobic digestate.

Name:	AEKS društvo s ograničenom odgovornošću za proizvodnju, usluge i trgovinu
Location:	Ivanić Grad
Region:	Zagreb county
Type of activity:	Industrial cleaning.
Already involved in bio-based activities:	AEKS fuel oil production, from waste (incl. biowaste – oils).

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Gradsko komunalno poduzeće PRE-KOM društvo s ograničenom odgovornošću za obavljanje komunalnih djelatnosti
Location:	Prelog
Region:	Međimurje county
Type of activity:	City utility company.
Already involved in bio-based activities:	Compost.

Name:	Gradsko komunalno poduzeće KOMUNALAC, društvo s ograničenom odgovornošću
Location:	Koprivnica
Region:	Koprivnica-Križevci county
Type of activity:	City utility company.
Already involved in bio-based activities:	Compost 1st class.

Name:	Eko-Flor Plus d.o.o. za komunalne usluge i trgovinu
Location:	Oroslavje
Region:	Krapina-Zagorje county
Type of activity:	Private utility company – collection and treatment of waste.
Already involved in bio-based activities:	Compost of 1st, 2nd and 3rd class.

Name:	Gradsko komunalno poduzeće ČAKOM d.o.o.
Location:	Mihovljan
Region:	Međimurje county
Type of activity:	City utility company.
Already involved in bio-based activities:	Compost – organic fertilizer and soil improver.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	VARKOM dioničko društvo za opskrbu vodom i odvodnju otpadnih voda
Location:	Varaždin
Region:	Varaždin county
Type of activity:	City utility company.
Already involved in bio-based activities:	Compost of 3rd class.

Name:	BIOPLINARA ORGANICA KALNIK I trgovačko društvo za proizvodnju električne energije iz bioplina d.o.o.
Location:	Sveti Petar Orehovec
Region:	Koprivnica-Križevci county
Type of activity:	Energy production from biogas.
Already involved in bio-based activities:	Anaerobic digestate.

Name:	ZAGREBAČKI HOLDING, društvo s ograničenom odgovornošću za javni prijevoz, opskrbu vodom, održavanje čistoće, putnička agencija, šport, upravljanje objektima i poslovanje nekretninama
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	City utility company
Already involved in bio-based activities:	Compost, soil biofuel production.

Name:	BIOPLINSKA ELEKTRANA OREHOVEC trgovačko društvo za proizvodnju električne energije i bioplina d.o.o.
Location:	Sveti Petar Orehovec
Region:	Koprivnica-Križevci county
Type of activity:	Energy production from biogas.
Already involved in bio-based activities:	Anaerobic digestate.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	SOLUTION d.o.o.
Location:	Zadar
Region:	Zadar county
Type of activity:	Recovery of separately collected materials.
Already involved in bio-based activities:	Solid biofuel, sawdust and wood chips.

Name:	Biointegra d.o.o.
Location:	Slatina
Region:	Virovitica-Podravina county
Type of activity:	Energy production from biogas.
Already involved in bio-based activities:	Anaerobic digestate (that cannot be used on agricultural soils for food production).

Name:	Ponikve eko otok Krk d.o.o.
Location:	Krk
Region:	Primorje-Gorski kotar county
Type of activity:	City utility company.
Already involved in bio-based activities:	Compost.

Name:	SEKUNDAR USLUGE d.o.o.
Location:	Jurdani
Region:	Primorje-Gorski kotar county
Type of activity:	Collection, recycling, storage and trade of secondary materials and non-hazardous waste.
Already involved in bio-based activities:	Solid biofuel production.

13. ACTORS IN FISHERIES, AQUA-CULTURE AND OTHER SECTORS

As it was the case in previous chapters, this section presents the representative sample of companies and organisations operating in fisheries, aqua-culture and other bioeconomy-related sectors, whose selection was limited by the scope of project's activities. It is important to mention that there are many other stakeholders in Croatian economy that are operating in this sector, which are related to bioeconomy, but the ones presented here are selected only within the projects scope and are selected due to no favouring of specific stakeholders.

13.1. Actors in fisheries and aquaculture

Croatian mariculture includes farming of white fish, pelagic (tuna) and molluscs. The most significant fish types in farming are: sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*) and bluefin tuna (*Ostrea edulis*).

Freshwater fish farming in Croatia is implemented in two manners – as farming of warm water fish species (pike, carp) and farming of cold water species (salmon and trout)..

The stakeholders in this sector include various licensed owners of fishing vessels (over 200 in Croatia), and over 200 warm water fish species farms registered in the Register of licensed farming and aquaculture, situated on the Croatian coast (mostly Dubrovnik-Neretva and Istra county).

Inland water farming

Name:	RIBNJAČARSTVO KONČANICA d.d.
Location:	Končanica
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca and Acipenser ruthenus.

Name:	RIBNJAK 1961. d.o.o.
Location:	Čazma
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Acipenser ruthenus, Perca fluviatilis, Abramis brama, Barbus barbus and Aspius aspius

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	POLJODAR TIM d.o.o.
Location:	Daruvar
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	(Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca and Esox lucius

Name:	V.I.R.I.B.U.S. d.o.o.
Location:	Zagreb and Šibenik
Region:	City of Zagreb and Šibenik-Knin county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Salmothymus obtusirostris, Thymallus thymallus, Hucho hucho, Cyprinus carpio, Ctenopharyngodon idella and Silurus glanis

Name:	RIBNJAČARSTVO POLJANA d.d.
Location:	Lipik and Garešnica
Region:	Požega-Slavonia and Bjelovar-Bilogora county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Carassius carassius, Squalius cephalus, Acipenser ruthenus, Perca fluviatilis, Micropterus salmoides, Ictalurus punctatus, Abramis brama, Ballerus sapa, Lota lota, Barbus barbus, Leuciscus idus, Aspius aspius and Huso huso

Name:	MIAGRO d.o.o.
Location:	Našice
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Carassius carassius, Acipenser ruthenus, Perca fluviatilis, Micropterus salmoides, Abramis brama, Barbus barbus and Scardinius erythrophthalmus

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	IHOR PARK d.d.
Location:	Klinča Sela
Region:	Zagreb county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca and Abramis brama

Name:	RIBNJACI KUPA d.o.o.
Location:	Bilje
Region:	Osijek-Baranja county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Carassius carassius, Acipenser ruthenus, Perca fluviatilis, Micropterus salmoides, Abramis brama, Clarias gariepinus and Acipenser baerii

Name:	PP ORAHOVICA d.o.o.
Location:	Donji Miholjac, Zdenci, Đurđenovac, Lipovljani, Stara Gradiška, Okučani, pisarovina, Ivanska
Region:	Osijek-Baranja, Sisak-Moslavina, Brod-Posavina, Bjelovar-Bilogora, Zagreb and Virovitica-Podravina county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Abramis brama, Scardinius erythrophthalmus and Rutilus rutilus

Name:	STARI RIBNJAK d.o.o.
Location:	Orlovac, Brodski Stupnik
Region:	Brod-Posavina county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Abramis brama, Scardinius erythrophthalmus, Perca fluviatilis, Micropterus salmoides and Carassius carassius

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	RIBNJAČARSTVO DUBRAVA d.o.o.
Location:	Farkaševac, Dubrava, Čazma,
Region:	Zagreb and Bjelovar-Bilogora county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox Lucius and Tinca tinca

Name:	RIBOGOJILIŠTE BELSKI DOL, vl. Mario Zagorec
Location:	Novi Marof
Region:	Varaždin county
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	LIKAPROMET d.o.o
Location:	Plaški
Region:	Karlovac county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Salmo trutta lacustris, Thymallus thymallus, Hucho hucho and Sander lucioperca

Name:	RIBNJACI VRABAC, vl. Tomo Vrabac
Location:	Žumberak
Region:	Zagreb county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Salmo trutta lacustris, Thymallus thymallus and Hucho hucho

Name:	LEKO d.o.o.
Location:	Sinac
Region:	Lika-Senj county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Thymallus thymallus, Hucho hucho and Salmo salar

Name:	RIBOGOJILIŠTE HOMER
Location:	Brod na Kupa
Region:	Primorje-Gorski kotar county
Already involved in bio-based activities:	Oncorhynchus mykiss and Salmo trutta

Name:	RIBARSTVO d.d.
Location:	Suvaja
Region:	Zadar county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Salmo trutta lacustris, Thymallus thymallus, Hucho hucho, Cyprinus carpio, Tinca tinca, Acipenser ruthens, Perca fluviatilis, Sander lucioperca and Micropterus salmoides

Name:	ŽIVA PRIRODA - EKO CENTAR d.o.o.
Location:	Velika Gorica
Region:	Zagreb county
Already involved in bio-based activities:	Cyprinus carpio, Tinca tinca, Carassius carassius, Ballerus sapa, Lota lota and Acipenser ruthenus

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	RITTERMAN d.o.o.
Location:	Solin
Region:	Split-Dalmatia county
Already involved in bio-based activities:	Oncorhynchus mykiss, Salmo trutta, Salmothymus obtusirostris

Name:	RIBNJAK ŠTEFANJE d.o.o.
Location:	Blatnica
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Acipenser ruthenus, Perca fluviatilis, Abramis brama, Barbus barbus and Aspius aspius

Name:	RIBNJACI d.o.o.
Location:	Mačkovec
Region:	Međimurje county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca, Abramis brama and Micropterus salmoides

Name:	RIBOGOJILIŠTE I KERAMIKA OŽBOLT, vl. Goran Ožbolt
Location:	Čabar
Region:	Primorje-Gorski kotar county
Already involved in bio-based activities:	Oncorhynchus mykiss and Salmo trutta

Name:	HOLDY j.d.o.o.
Location:	Ogulin
Region:	Karlovac county
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	IRASO d.o.o.
Location:	Bjelovar
Region:	Bjelovar-Bilogora county
Already involved in bio-based activities:	Sander lucioperca, Sander volgensis, Perca fluviatilis and Micropterus salmoides

Name:	GACKA d.o.o.
Location:	Ličko Lešće
Region:	Lika-Senj county
Already involved in bio-based activities:	Salmo trutta, Oncorhynchus mykiss and Thymallus thymallus

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	BERNARDA NOVA d.o.o.
Location:	Nedelišće
Region:	Međimurje county
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Silurus glanis, Sander lucioperca, Esox lucius, Tinca tinca and Acipenser ruthenus

Name:	STARA MLINICA d.o.o.
Location:	Grab
Region:	Split-Dalmatia county
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	PASTRVA-VALLIS AUREA, vl. Tatjana Odvorčić
Location:	Šeovci
Region:	Požega-Slavonia county
Already involved in bio-based activities:	Oncorhynchus mykiss and Salmo trutta

Name:	KRO FISH j.d.o.o.
Location:	Sinj
Region:	Split-Dalmatia county
Already involved in bio-based activities:	Oncorhynchus mykiss

13.2. Clusters and organisations

Name:	Croatian sports fishing alliance
Location:	Zagreb
Region:	Croatia
Type of activity:	Recreational and sports fisheries

Name:	AGRO RIBARSKA-ZADRUGA BRANITELJA
Location:	Tisno
Region:	Šibenik-Knin county
Type of activity:	Farming
Already involved in bio-based activities:	Mytilus galloprovincialis and Ostrea edulis

Name:	POLJOPRIVREDNA ZADRUGA SLOGA
Location:	Donje Makojišće
Region:	Varaždin county
Type of activity:	Fresh water fish farming
Already involved in bio-based activities:	Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys nobilis and Hypophthalmichthys molitrix

Name:	FINVEST CORP d.d.
Location:	Čabar
Region:	Primorje-Gorski kotar county
Type of activity:	Fresh water fish farming
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	EKO ZADRUGA - TIĆI
Location:	Moravice
Region:	Primorje-Gorski kotar county

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Type of activity:	Fresh water fish farming
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	AGRO RIBARSKA-ZADRUGA BRANITELJA
Location:	Tisno
Region:	Šibenik-Knin county
Type of activity:	Farming
Already involved in bio-based activities:	Mytilus galloprovincialis and Ostrea edulis

Name:	AGRO RIBARSKA-ZADRUGA BRANITELJA
Location:	Tisno
Region:	Šibenik-Knin county
Type of activity:	Farming
Already involved in bio-based activities:	Mytilus galloprovincialis and Ostrea edulis

Name:	AGRO RIBARSKA-ZADRUGA BRANITELJA
Location:	Tisno
Region:	Šibenik-Knin county
Type of activity:	Farming
Already involved in bio-based activities:	Mytilus galloprovincialis and Ostrea edulis

Name:	AGRO RIBARSKA-ZADRUGA BRANITELJA
Location:	Tisno
Region:	Šibenik-Knin county
Type of activity:	Farming
Already involved in bio-based activities:	Mytilus galloprovincialis and Ostrea edulis

14. ACTORS IN BIO-BASED INDUSTRIES AND MARKETS

As it was the case in previous chapters, this section presents the representative sample of companies and organisations operating in bio-based industry sector, whose selection was limited by the scope of project's activities. It is important to mention that there are many other stakeholders in Croatian economy that are operating in this sector, which are related to bioeconomy, but the ones presented here are selected only within the projects scope and are selected due to no favouring of specific stakeholders.

14.1. Bioplastics

Name:	Bio-Mi d.o.o
Location:	Rijeka
Region:	Primorje-Gorski kotar county
Type of activity:	Development and and the production of bio-based, biodegradable and compostable thermoplastic materials
Already involved in bio-based activities:	First developer of biodegradable and compostable thermoplastics; manufacturing of EN 13432 certified bio-based, biodegradable and compostable thermoplastics (MI family of materials)
Bio-based activity involved in:	Creation of biodegradable blends based on starch, PLA, PHAs, PBS, PBAT, PCL, fillers, fibers, etc.; participation in over 10 EU-funded innovation projects

Name:	EcoCortec d.o.o.
Location:	Beli Manastir
Region:	Osijek-Baranja county
Type of activity:	Development and manufacturing of value-added biodegradable/compostable flexible films
Already involved in bio-based activities:	Development of eco-efficient production of biodegradable films
Bio-based activity involved in:	Various projects in innovation (FMENA – MarineClean, BIOCOMPACT-CE)

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Weltplast d.o.o.
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Producer of wide-range of products, including HDPE, PP pipes and dressed packaging
Already involved in bio-based activities:	A wide range of environmentally-friendly products (EcoWelt brand)
Bio-based activity involved in:	Production of biodegradable and compostable products, installed line for recycling

Name:	Mi-plast d.o.o.
Location:	Rijeka
Region:	Primorje-Gorski kotar county
Type of activity:	Processing of LDPE and HDPE materials, bio-polymers, packaging and production of these materials
Already involved in bio-based activities:	Research and development of biodegradable biopolymer-based materials
Bio-based activity involved in:	Participation in numerous research projects within the EU's R&D and Innovation programs

14.2. Chemical and petro-chemical industries

Name:	Petrokemija d.d.
Location:	Kutina
Region:	Sisak-Moslavina county
Type of activity:	Fertilizer production
Already involved in bio-based activities:	Phosphogypsum production as a by-product

Name:	Saponia d.d.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Production of household products

Name:	Adriatica Dunav d.o.o.
Location:	Vukovar
Region:	Vukovar-Srijem county
Type of activity:	Fertilizer and nitrogen compounds production

Name:	Messer Croatia Plin d.o.o.
Location:	Zaprešić
Region:	Zagreb county
Type of activity:	Production of industrial and medicinal gases

Name:	Hempel d.o.o.
Location:	Umag
Region:	Istra county
Type of activity:	Production of coating for furniture industry, seafaring and boats
Already involved in bio-based activities:	Development of environment-friendly products with bio-based basis

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Scott Bader d.o.o.
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Production of plastics in primary forms

Name:	Ireks Aroma d.o.o.
Location:	Jastrebarsko
Region:	Zagreb county
Type of activity:	Production of confectionery products, meat preparations and forage.
Already involved in bio-based activities:	Environmental-friendly, and natural raw materials.

Name:	Chromos-Svjetlost d.o.o.
Location:	Lužani
Region:	Brod-Posavina county
Type of activity:	Paint manufacturing

Name:	Labud d.o.o.
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Detergent and cleaning product manufacturer

Name:	Biodizel Vukovar d.o.o.
Location:	Vukovar
Region:	Vukovar-Srijem company
Type of activity:	Production of biofuels
Already involved in bio-based activities:	Production of biodiesel and crude glycerin

14.3. Energy

Biomass plants

Name:	MINI HIDROELEKTRANA ČABAR
Location:	Čabar
Region:	Primorje-Gorski kotar county
Type of activity:	Fish farming, energy production (hydro-energy)
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	HEP Proizvodnja d.o.o.
Location:	Vitunj
Region:	Karlovac county
Type of activity:	Fish farming, energy production (hydro-energy)
Already involved in bio-based activities:	Oncorhynchus mykiss

Name:	LIKA ENERGO EKO d.o.o.
Location:	Udbina
Region:	Lika-Senj county
Type of activity:	Cogeneration plant on biomass

Name:	Univerzal d.o.o.
Location:	Varaždin
Region:	Varaždin county
Type of activity:	Cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	STRIZIVOJNA HRAST d.o.o.
Location:	Strizivojna
Region:	Osijek-Baranja county
Type of activity:	Energy production from biomass combustion (cogeneration)

Name:	PELET GRUPA d.o.o.
Location:	Bročice
Region:	Sisak-Moslavina county
Type of activity:	Energy production from household pellet from biomass

Name:	PANA ENERGY d.o.o.
Location:	Čakovec
Region:	Međimurje county
Type of activity:	Cogeneration plant on biomass

Name:	SLAVONIJA OIE d.o.o.
Location:	Slavonski Brod
Region:	Brod-Posavina county
Type of activity:	Energy production from biomass combustion (cogeneration)

Name:	BE-TO GLINA d.o.o.
Location:	Glina
Region:	Sisak-Moslavina county
Type of activity:	Biomass plant – thermal power station

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	UNI VIRIDAS d.o.o.
Location:	Babina Greda
Region:	Vukovar-Srijem county
Type of activity:	Energy production from biomass combustion (cogeneration)

Name:	SPIN VALIS INTERNACIONAL d.o.o.
Location:	Požega
Region:	Požega-Srijem county
Type of activity:	Energy production from biomass combustion (cogeneration)

Name:	SERVICE & ENGINEERING INDUSTRY d.o.o.
Location:	Bjelovar
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biomass

Name:	ASTEK 15 d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biomass

Name:	SENSE ESCO BELIŠĆE d.o.o.
Location:	Belišće
Region:	Osijek-Baranja county
Type of activity:	Gasification cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	SAVA d.o.o.
Location:	Stara Gradiška
Region:	Brod-Posavina county
Type of activity:	Cogeneration plant on biomass

Name:	WHITEFIELD ENERGY d.o.o.
Location:	Bjelopolje
Region:	Lika-Senj county
Type of activity:	Cogeneration plant on biomass

Name:	BIO SNAGA d.o.o.
Location:	Darda
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biomass

Name:	VRBOVSKO EKO ENERGIJA d.o.o.
Location:	Vrbovsko
Region:	Primorje-Gorski kotar county
Type of activity:	Cogeneration plant on biomass

Name:	DRVNI CENTAR GLINA d.o.o.
Location:	Glina
Region:	Sisak-Moslavina county
Type of activity:	Cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	SOLITUDO d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biomass

Name:	ĐAKOVO HRAST d.o.o.
Location:	Đakovo
Region:	Osijek-Baranja county
Type of activity:	Gasification cogeneration plant on biomass

Name:	HEP proizvodnja d.o.o.
Location:	Osijek and Sisak
Region:	Osijek-Baranja and Sisak-Moslavina county
Type of activity:	Biomass plant – thermal power station

Name:	BIOMASS TO ENERGY BENKOVAC d.o.o.
Location:	Benkovac
Region:	Zadar county
Type of activity:	Cogeneration plant on biomass

Name:	KIRCEK ENERGY d.o.o.
Location:	Ljubešćica
Region:	Varaždin county
Type of activity:	ORC cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Brana d.o.o.
Location:	Virovitica
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biomass

Name:	ENERGIJA VOĆIN d.o.o.
Location:	Voćin
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biomass

Name:	Brana Dar d.o.o.
Location:	Daruvar
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biomass

Name:	ENERGIJA INVEST d.o.o.
Location:	Grubišno Polje
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biomass

Name:	ENERGY 9 d.o.o.
Location:	Slatina
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	BIO ENERGANA BJELOVAR
Location:	Bjelovar
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biomass

Name:	ENTRAF d.o.o.
Location:	Logorište
Region:	Karlovac county
Type of activity:	Cogeneration plant on biomass

Name:	ENNA Biomasa Vukovar d.o.o.
Location:	Vukovar
Region:	Vukovar-Srijem county
Type of activity:	Cogeneration plant on biomass

Name:	ENERGOSTATIK d.o.o.
Location:	Grubišno Polje
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biomass

Name:	BIOMASS TO ENERGY ŽUPANJA d.o.o.
Location:	Županja
Region:	Vukovar-Srijem county
Type of activity:	Cogeneration plant on biomass

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	A&A BIOENERGY VIRO d.o.o.
Location:	Darda
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biomass

Biogas plants

Name:	OSATINA GRUPA d.o.o.
Location:	Ivankovo, Tomašanci, Viškovci
Region:	Vukovar-Srijem and Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	BOVIS d.o.o.
Location:	Viškovci
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	BIO DVOR d.o.o.
Location:	Rosulje
Region:	Sisak-Moslavina county
Type of activity:	Cogeneration plant on biogas

Name:	FARMA MUZNIH KRAVA MALA BRANJEVINA d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	NOVI AGRAR d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	LANDIA d.o.o.
Location:	Tordinci
Region:	Vukovar-Srijem county
Type of activity:	Cogeneration plant on biogas

Name:	ENERGIJA GRADEC d.o.o.
Location:	Gradec, Mitrovac, Popovac, Ovčara
Region:	Zagreb, Požega-Slavonia, Vukovar-Srijem county
Type of activity:	Cogeneration plant on biogas

Name:	MOSLAVINA PROIZVODI d.o.o.
Location:	Čazma
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biogas

Name:	BR Bioplin Crnac 1 d.o.o.
Location:	Crnac
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biogas

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	OSILOVAC d.o.o.
Location:	Feričanci
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	Obrt OBITELJSKO POLJOPRIVREDNO GOSPODARSTVO VRČEK
Location:	Varaždin
Region:	Varaždin county
Type of activity:	Cogeneration plant on biogas

Name:	BIOPLIN-MAKS d.o.o.
Location:	Rovišće
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biogas

Name:	BIOEL d.o.o.
Location:	Maslenjača
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biogas

Name:	MIAGRO ENERGO d.o.o.
Location:	Kučanci
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	FARMA MUZNIH KRAVA ORLOVNJAK d.o.o.
Location:	Antunovac
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	BIOPLINARA ORGANICA KALNIK 1 d.o.o.
Location:	Sveti Petar Orehovec
Region:	Koprivnica-Križevci county
Type of activity:	Cogeneration plant on biogas

Name:	Trgovačko društvo SLK PROJEKT d.o.o
Location:	Hercegovac
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biogas

Name:	BIOPLINSKA ELEKTRANA OREHOVEC d.o.o
Location:	Sveti Petar Orehovec
Region:	Koprivnica-Križevci county
Type of activity:	Cogeneration plant on biogas

Name:	BIOINTEGRA d.o.o.
Location:	Slatina
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biogas

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	MATVEJ d.o.o.
Location:	Virje
Region:	Koprivnica-Križevci county
Type of activity:	Cogeneration plant on biogas

Name:	DAR PRIRODE d.o.o.
Location:	Vukovar
Region:	Vukovar-Srijem county
Type of activity:	Cogeneration plant on biogas

Name:	AGROPROTEINKA-ENERGIJA d.o.o.
Location:	Sesvete
Region:	Zagreb county
Type of activity:	Cogeneration plant on biogas

Name:	BIOPLIN GUDOVAC d.o.o.
Location:	Gudovac
Region:	Bjelovar-Bilogora county
Type of activity:	Cogeneration plant on biogas

Name:	MICO d.o.o.
Location:	Hrastin
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Clip Bio Plus d.o.o.
Location:	Črnc Biškupečki
Region:	Varaždin county
Type of activity:	Cogeneration plant on biogas

Name:	BIOENERGIJA KLISA d.o.o.
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	VDM ENERGIJA d.o.o.
Location:	Donji Miholjac, Viljevo
Region:	Osijek-Baranja county
Type of activity:	Cogeneration plant on biogas

Name:	EKO KOTOR d.o.o.
Location:	Kotoriba
Region:	Međimurje county
Type of activity:	Cogeneration plant on biogas

Name:	BIOPLIN PROIZVODNJA d.o.o.
Location:	Slatina
Region:	Virovitica-Podravina county
Type of activity:	Cogeneration plant on biogas

15. ACTORS IN KNOWLEDGE AND INNOVATION

As it was the case in previous chapters, this section presents the representative sample of companies and organisations operating in research and innovation sector, whose selection was limited by the scope of project's activities. It is important to mention that there are many other stakeholders in Croatian economy that are operating in this sector and which are included in various R&D and other types of projects (just within H2020 call, there are 56 implemented projects), which are related to bioeconomy, but the ones presented here are selected only within the projects scope and are selected due to no favouring of specific stakeholders.

15.1. Campus, incubators and technology parks & hubs

Name:	BIOCentar – inkubacijski centar za bioznanosti
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Bioincubation, biofacility, biotransfer, bioeducation, bionetwork

Name:	Tehnološki park Varaždin
Location:	Varaždin
Region:	Varaždin county
Type of activity:	Incubation centre for innovative start-up companies, establishment of a mechanism for improvement of existing technologically innovative companies, improvement of transfer of knowledge from universities and development centres into the economy, networking of companies, educational institutions, development agencies and innovative individuals, and change of perception towards innovation as a foundation of a new economy.

Name:	Technological innovation centre Rijeka (TIC)
Location:	Rijeka
Region:	Primorje-Gorski kotar county

Type of activity:	Retrofitting, innovating & developing solutions to make existing tertiary buildings "greener"
-------------------	---

Name:	ZICER – Zagreb Innovation Centre
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Supporting and advancing entrepreneurial climate as well as society at large. They promote the creation of stimulating entrepreneurial environment and strengthening of entrepreneurial competencies, clarify the best ways to finance entrepreneurial endeavours, and help innovative high-tech companies and teams turn their ideas into actual products.

Name:	Tehnološki centar Split
Location:	Split
Region:	Split-Dalmatia county
Type of activity:	Centre for business development

Name:	Centar za tehnološki razvoj – Razvojna agencija Brodsko-posavske županije
Location:	Slavonski Brod
Region:	Brod-Posavina county
Type of activity:	Research and development, innovation, start-ups, technology transfer

15.2. Scientific and research institutions

Universities

Name:	Faculty of Agriculture, University of Zagreb
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Already involved in bio-based activities:	https://www.grace-bbi.eu/
Bio-based activity involved in:	The FAZ has also started setting up a Bioengineering Research Centre (ABIC) in the city of Zagreb. Furthermore, there are 28 laboratories among which is a Reference laboratory for milk and dairy products (RL).

Name:	Faculty of Chemical Engineering and Technology, University of Zagreb
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	<p>International projects:</p> <p>HORIZON 2020</p> <p>COST</p> <p>CEEPUS</p> <p>National funding:</p> <p>Projects of the Croatian Science Foundation</p> <p>Projects of the European structural and investment funds</p> <p>Projects of the Croatian Agency for SMEs, Innovations and Investments (HAMAG-BICRO)</p>

Name:	Faculty of Electrical Engineering and Computing (FER), University of Zagreb,
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Faculty of Food Technology and Biotechnology, University of Zagreb
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	27 laboratories fully equipped. Food Control Centre as an accredited laboratory for the control of the safety and quality of food and general use products in the European Union. Laboratory for Drying Processes and Stability Monitoring of Bioactive Compounds.

Name:	Faculty of Agrobiotechnical Sciences Osijek
Location:	Osijek
Region:	Osijek-Baranja county
Type of activity:	Research
Already involved in bio-based activities:	27 laboratories fully equipped. Food Control Centre as an accredited laboratory for the control of the safety and quality of food and general use products in the European Union. Laboratory for Drying Processes and Stability Monitoring of Bioactive Compounds.

Research organizations

Name:	Institute Ruđer Bošković
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	The Ruđer Bošković Institute (IRB), together with the Institute of Physics (IF), is a partner of the Polytechnic of Slavonski Brod (VUSB) on the project 'Adaptation of Vegetable Crops to New Agro-Meteorological Conditions in Slavonia' worth almost HRK 3 million. Also, Institute is participating in BIO-ECONomy Research Driven Innovation (BIOECO-R.D.I.) which aims at developing a Regional Innovation System for the Adriatic-Ionian area based on a structured bio-economy sector through the development of Research Driven Innovation (R.D.I.) strategy at regional and transnational level
Bio-based activity involved in:	https://bioecordi.adrioninterreg.eu/

Name:	Croatian Forest Research Institute
Location:	Jastrebarsko
Region:	Zagreb county
Type of activity:	Research
Already involved in bio-based activities:	Structured organic farming using autonomous greenhouse robots (HRZZ), Extraction of bioactive compounds from Mediterranean plants with 'green solvents' using high voltage discharge (HRZZ), Agrivi Smart - Increase Potato Growing Productivity Using Machine Learning Algorithms (EFRR) and Improving the efficiency of manufacturing through research and development of innovative ICT services to increase energy efficiency - ComEnergy (EFRR).

Name:	Energy Institute Hrvoje Požar
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	BIOEASTsUP, IEA Bioenergy: Taks 43 Proof of concept: Degradation of lignocellulose complex during struvite production from digestate for economic and technical efficiency of a biogas plant; FarmCircle
Bio-based activity involved in:	Energy Institute Hrvoje Požar with its Department for RES, energy efficiency and climate protection established a leadership role when it comes to bioeconomy development in Croatia. There are numerous projects funded from Horizon2020, Interreg Programme, IEA, COST, World Bank, as well as nationally funded projects.

Name:	Institute for Development and International Relations
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	VET4BioECONOMY

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Institute of Agriculture and Tourism
Location:	Poreč
Region:	Istria county
Type of activity:	Research
Already involved in bio-based activities:	REDGREENPLANT, OLEUM, WINETWORK, SPRINT

Name:	Institute of Oceanography and Fisheries
Location:	Split
Region:	Split-Dalmatia county
Type of activity:	Research
Already involved in bio-based activities:	ParaFishControl, BLUEMED

Name:	Croatian Veterinary Institute
Location:	Zagreb
Region:	City of Zagreb
Type of activity:	Research
Already involved in bio-based activities:	MedAID

16. GOVERNMENT AND NGOs

Name:	Ministry of Agriculture
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	European agricultural fund for rural development Rural Development Programme of the Republic of Croatia for the Period 2014-2020 Operational Programme for Maritime Affairs and Fisheries of the Republic of Croatia for the programming period 2014-2020 Bioeconomy Strategy development

Name:	Ministry of Regional Development and EU funds
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	European Structural and Investment Funds (ESI Funds) European Regional Development Fund (ERDF) Cohesion fund

Name:	Ministry of Science and Education
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	European Social Fund (ESF)

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Name:	Ministry of Economy and Sustainable Development
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	Various national and international projects

Name:	Ministry of Tourism and Sport
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	Various national and international projects

Name:	Ministry of the Sea, Transport and Infrastructure
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	Various national and international projects

Name:	Ministry of Physical Planning, Construction and State Assets
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Ministry
Already involved in bio-based activities:	Various national and international projects

Name:	Croatian Chamber of Agriculture
-------	---------------------------------

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Chamber (public body)

Name:	Croatian Chamber of Commerce
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Chamber (public body)

Name:	Croatian Employers' Association
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Association (public body)

17. FINANCIAL ORGANISATIONS & BANKS

Name:	Croatian Agency for SMEs, Innovations and Investments (HAMAG-BICRO)
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Public body
Already involved in bio-based activities:	HAMAG-BICRO issues guarantees for bank credits approved by credit institutions and other legal entities approving loans to SMEs and makes direct financial contributions to SMEs in a form of grants. More information about HAMAG-BICRO guarantees and grant schemes can be found on its web site www.hamagbicro.hr .

Name:	Croatian Bank for Reconstruction and Development (HBOR)
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Public body
Already involved in bio-based activities:	Through its specialized programs HBOR provides support to start-ups, exporting companies, new production and companies from different sectors of economy such as industry, tourism, environmental protection and energy efficiency, agriculture, etc. More information about HBOR programs can be found on its web site www.hbor.hr .

Name:	Croatian Science Foundation
Location:	Zagreb
Region:	Grad Zagreb
Type of activity:	Public body



CELEBio

PART C
GUIDELINES FOR
CROATIAN
ACTION PLAN

18. GUIDELINES FOR CROATIAN BIOECONOMY ACTION PLAN

The aim of the chapter is to present a set of specific, attainable, relevant biobased value chains, and time-based guidelines for development of Croatian Bioeconomy Strategy. The work has capitalised on the findings of the work in CELEBIO⁴⁴ and is structured in four sections.

The first presents the current state of bioeconomy, discusses the country's comparative strengths and opportunities, and provides an overview of the existing policy regime per value chain stage (i.e. biomass production, conversion, distribution, end use).

The second introduces the Bioeconomy Vision, possible value chains and outlines how they fit to the three main priorities⁴⁵ from the 2018 Update of the European Bioeconomy Strategy⁴⁶: (a) Strengthen and scale-up the bio-based sectors, unlock investments and markets; (b) Deploy local bioeconomies rapidly across Croatia; (c) Understand the ecological boundaries of the bioeconomy.

The third provides facts tailored to each value chain in terms of current exploitation of biomass raw materials, future actions that could steer innovative and resource efficient market uptake for biobased products, potential interventions and expected added value. This information has resulted from the consultation with national stakeholders within the duration of the project. This section also includes information on the relevance to the UN Strategic Development Goals (SDGs), selected relevant projects and markets for the biobased products that will derive from each value chain.

Finally, the fourth part provides an implementation plan, jointly developed with stakeholders, which includes time specific goals for reaching the Vision.

⁴⁴ <https://celebio.eu/wp-content/uploads/2020/07/Croatia-Country-Report.pdf>

⁴⁵ https://ec.europa.eu/research/bioeconomy/pdf/bioeconomy_line_actions.pdf#view=fit&pagemode=none

⁴⁶ <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0673&from=EN>

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

19. BIOECONOMY IN CROATIA

19.1. Current state

Bioeconomy in Croatia had an annual turnover of eleven billion Euros in 2017 which translates to 52,000 Euros per person employed in the sector with the EU27 average figure being 127,000 Euros.

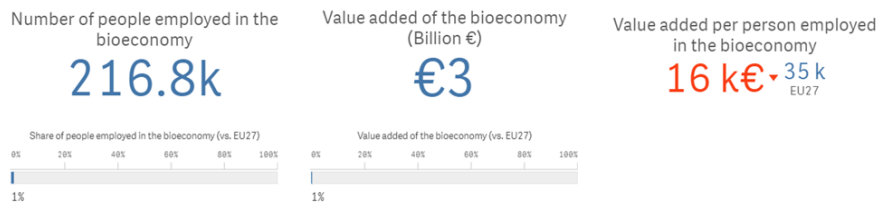


Figure 39 Jobs and wealth in the Croatian bioeconomy in 2017 (source: JRC and nova-Institute⁴⁷)

The value added from the bioeconomy sector in the country was 3 billion Euros and in the same year there were 216,800 people employed.

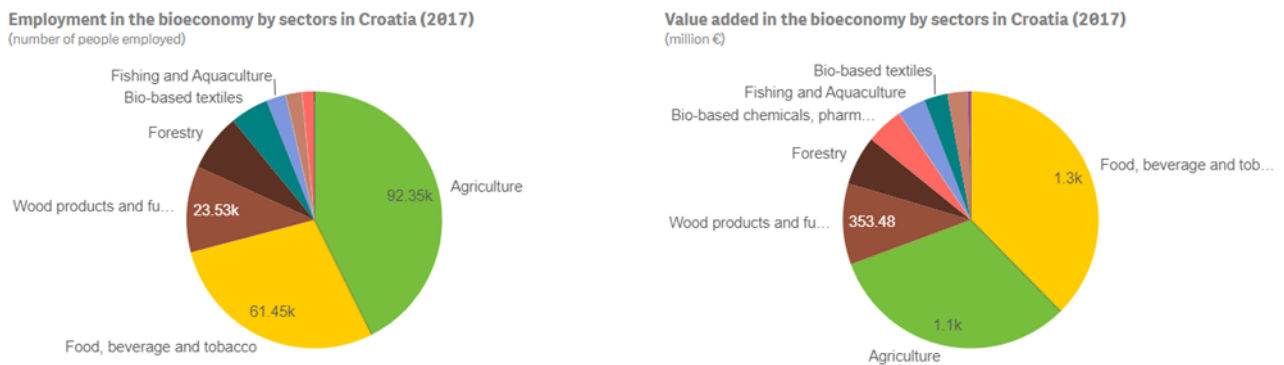


Figure 40 Employment and value added in the bioeconomy by sectors in Croatia in 2017 (source: JRC and nova-Institute⁴⁸)

Agriculture remains the biggest sector in terms of employment (42.5% of the total number of people employed) with food, beverage, and tobacco as well as wood products and furniture following with much smaller shares (28.3% and 10.9% respectively). In terms of value added the aggregate category of food, beverage, and tobacco, is first with 1.3 billion Euros and agriculture follows with 1.1 billion Euros, forestry, wood products and furniture are third with 0.35 billion Euros.

⁴⁷ <https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html>

⁴⁸ <https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html>

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

19.2. Strengths, opportunities and barriers



- Unused potential available from primary residues, secondary residues and unused lands
- Roadside cost relatively low and good road connectivity within the country
- Still many underutilised biomass resources
- Non-utilised arable land
- Rural Development Program
- Cost of biomass resources are relatively low in comparison to many regions in the EU

- Still many biomass resources that can be mobilised
- Because of harbours (coastal and inland), local biomass resources can be combined with imported resources to strengthen security of supply
- Unused land resource is significant, so opportunities to produce low-ILUC biomass on abandoned lands
- Expansion of family farms (both in continental and coastal area) into tourism sector (and diversification to other potential sectors) to generate additional income, entrance to new market - ecotourism
- Production of healthy food for a European market
- Europe is a trend the Croatian market can connect to

- The risk for loss of HNV farmland when demand for biomass takes off
- Lack of rural population to produce and collect the biomass in the long term
- No market for high added value biomass, uses only low-quality chains for heat/electricity
- Impact on the environment – soil erosion and leaching
- Favourable work conditions outside of Croatia – increasing trend of labour outflow
- Raising competitiveness and agricultural development in the EU market could pose a problem for Croatian farmers and their future placement of value-added products



- A long tradition in forestry and wood processing industry
- Tradition of sustainable management of forests - FSC
- 150 wood processing companies have FSC COCs
- Skilled and qualified workforce as result of long tradition
- Large state-owned forest
- Knowledge of cascading use of wood
- Significant additional mobilisation of primary forest resources possible and also already planned
- Forest processing industry is growing and leads to more secondary forestry residues

- Mobilisation of unused biomass
- Development of new bio-based products on lignocellulosic base
- Private forest owners

- Climate changes in terms of
 - increasing numbers of forest fires
 - drought
 - prolonged vegetation season
 - mild winters suitable for diseases and pests
 - infestations with insects and diseases atypical for this geographical and climatic area etc.
- Energy poverty



- Development of waste management sector
- Existing and development of new infrastructure that can be used for energy/material recovery
- High existing potential for utilization of existing waste streams, which are currently still going to landfills
- Development of separate waste collection on household level

- Implementation of "Waste Market"
- Innovative ways of biodegradable waste utilization are possible given that this still needs to be largely build up
- Knowledge transfer from more advanced countries in EU
- Utilization of biodegradable waste that is currently landfilled
- Financing from EU funding, aligned with financing of waste management system (waste management centers)

- Lack of recognition for the opportunities in waste utilization within Bioeconomy principles
- Negative public opinion in terms of waste separation, utilization for energy/recovery purposes

19.3. Policy mechanisms relevant to bioeconomy in Croatia

Some of the policy mechanisms presented in this section have a “final date” until 2020, therefore, new strategies that will be developed for the future period should to be taken into consideration for any future decision.

Strategies:

- **National Development Strategy of Republic of Croatia until 2030 (adopted in 2021)**

The Croatian National Development Strategy is the overarching document aiming to provide strategic guidance to all development policies and lower-ranking strategic planning documents. With a vision to create a competitive, innovative and safe country, with recognizable identity and culture, a country with preserved resources, quality life standards and equal opportunities for everyone, the Government has decided to employ a comprehensive and evidence-based process using a participatory and bottom-up approach. In order to achieve that vision the strategy is focused on four development areas (sustainable economy and society, strengthening their resilience to crises, a green and digital transition, and balanced regional development) as well as 13 strategic objectives and 23 impact indicators.

- **Low Carbon Development Strategy of Republic of Croatia – (to be revised during 2021)**

Low Carbon Strategy sets a path of transition towards sustainable and competitive economy, in which development is achieved with very low greenhouse gas (GHG) emissions. The goals of GHG emissions reduction by 2030 and 2050 in Croatia will be conducted within the political framework, set by the European Union. New EU growth strategy, formulated through European Green Deal plan, sets a goal of transition into a fair and prosperous society, with modern, resource-efficient and competitive economy, in which by 2050, total net emissions will equal to zero. The main goal of this strategy is determining the specific goals, related to specific sectors, in which emission reductions need to be achieved, in order to achieve the main goals of GHG reduction.

- **Energy Development Strategy to 2030 with a View to 2050 for Republic of Croatia (Official Gazette No. 25/2020)**

Croatian Energy Development Strategy presents a step towards accomplishing low-carbon energy vision and secures the transition to a new era of energy policy, which enables accessible, secure and high-quality energy supply, without additional burden on the national budget, in terms of national supports and subsidies. The foreseen energy transition process will be capital-intensive, without the inventive measures, but with anticipated engagement of private sector/capital in financing of RES projects.

- **Integrated National Energy and Climate Plan for the Republic of Croatia for the period 2021-2030⁴⁹**

The key objectives outlined in the Integrated Energy and Climate Plan are the reduction in greenhouse gas emissions for the Republic of Croatia for the year 2030, the share of RES in the gross final energy consumption and energy efficiency, expressed as consumption of primary energy and direct consumption of energy

- **Waste Management Strategy for the Republic of Croatia (OG No. 130/05)**

The goal of this Strategy is to establish a framework within which Croatia will reduce generated waste amounts, and sustainably manage the produced waste. The Strategy, but also its implementing document – Waste management plan – are a part of a continuous waste management planning process, which is reflected on all levels (from national to local) and various sectors (water management, health, urban planning, etc.). This document is in alignment with the EU legislative. Although old and in need for renewal (the original document is from 2005), it still sets the basis for sustainable waste management concept.

- **Smart specialisation strategy 2016-2020. (new document in development – covering period 2021-2027)**

S3 presents a comprehensive assessment of the country's governance structure, innovation facilitating instruments, and key innovation assets –research and human capital. It proposes a strong monitoring and evaluation (M&E) framework and provides a sectoral analysis of five priority sectors of the economy and their innovation potential. The main purpose of Smart Specialization is to transform the Croatian economy and increase its competitiveness by concentrating knowledge resources and linking them to a limited number of priorities.⁴ The identification of the Smart Specialization priorities will allow concentration of research capacities and infrastructure. This will provide advantage to both public and private sector and will bring together the critical mass of researchers who will jointly work on strategic R&D topics with goal of research excellence and its commercialization. The Croatian S3 embraces product, process, service, marketing and organisational innovations in line with the definitions laid out in the Oslo Manual: (1) product innovations - market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems; (2) process innovations - implementation of a new or significantly improved production process, distribution method, or supporting activity; (3) marketing innovations - significant changes to design, packaging, product promotion, placement, and pricing; (4) organisational innovations - new or improved business practices for organising procedures, work responsibilities and decision making, service delivery, and external relations.

⁴⁹https://mzoe.gov.hr/UserDocsImages/UPRAVA%20ZA%20ENERGETIKU/Strategije,%20planovi%20i%20programi/hr%20necp/Integrated%20Nacional%20Energy%20and%20Climate%20Plan%20for%20the%20Republic%20of_Croatia.pdf

- **Industrial Strategy of the Republic of Croatia 2014.-2020. (new document in development – covering period 2021-2027)**

The main objective of Croatian industry has been defined by this strategy, and it states the following: repositioning of identified strategic activities in the global value chain towards the development of activities that create added value. Alongside the main goal, several other goals have been defined, and they are the following:

1. Increase in industrial production at an average annual rate of 2,85%
2. Increase in the number of new employees by 85.619 by the end of 2020., of which at least 30% are highly educated
3. Increase in labour productivity by 68.9% between 2014.-2020.
4. The increase in export between 2014.-2020. by 30% and transformation of export structure in favour of export products with high added value

- *In development:*

Agriculture Strategy for Republic of Croatia for Period 2020-2030

Aquaculture Strategy for Republic of Croatia for Period 2020-2030

19.4. Sector-specific framework

19.4.1. Agriculture

- **Rural Development Programme of the Republic of Croatia for the Period 2014-2020 (new document in development – Strategic plan for period 2023-2027)**

The European Common Agricultural Policy (CAP) provides a framework for financial support to farmers through Pillar 1 - Direct Payments, and Pillar 2 - Rural Development. The new CAP 2014-2020 has been presented in 2014, and the Member States has adapted their national approach within this framework. The CAP 2014-2020 has been in force since 2014.

The Rural Development Program of the Republic of Croatia for the period 2014-2020, by SWOT analysis and needs assessment, defines the priorities and areas of intervention, the selection of relevant measures and the allocation of funding based on expected outcomes. One of the goals of the Program is resource efficiency and climate change resilience in agriculture and forestry, emphasizing that renewable energy production from these sectors is a priority for developing the bioeconomy and reducing greenhouse gases by 2020. Furthermore, the importance of the use of wood biomass, biomass from agriculture and solar energy in agriculture and the food preparing and food processing industry is emphasized.

The program defines 18 measures aimed at increasing the competitiveness of Croatian agriculture, forestry and the processing industry, as well as improving living and working conditions in rural areas in general.

- **Agricultural Land Law (OG No. 20/18, 115/18)**

Defines agricultural land, regulates agricultural land management, protection and usage of such land, land conversions and related fees, management of state-owned agricultural land etc. Agricultural land in Croatia is arable land, gardens, meadows, pastures, orchards, olive trees, vineyards, fish farms, reeds, wetlands and other lands that, with an acceptable economic cost, can be put to the purpose of agricultural production. Forest land not covered with forest or land covered with initial or degradation forest types (maquia, garigue etc.) and which are suitable for agricultural production are also considered as agricultural land.

- **Determination of vulnerable areas (OG No. 141/15)**

Vulnerable areas are areas where enhanced protection of water against pollution by nitrates of agricultural origin is required. In order to achieve a general level of protection against nitrates from all surface bodies, including coastal and groundwater bodies, the principles of good agricultural practice shall be applied in accordance with the agricultural regulations for which appropriate incentive measures may be adopted. This Decision identifies sensitive areas in the Republic of Croatia in the Danube river basin district and in the Adriatic catchment area. The Danube river basin district is entirely defined as a sensitive area. In the Adriatic river basin district, all areas designated as eutrophic, areas intended for the abstraction of water for human consumption and protected areas of nature constitute a sensitive area.

- **Action Program for the Protection of Water from Pollution Caused by Nitrates of Agricultural Origin (OG No. 60/17)**

This Program entered into force on 1 July 2017 and has been adopted for a period of four years from the date of its entry into force. The difference from I. Action Program for Protection of Water from Pollution Caused by Nitrates of Agricultural Origin, is that during one calendar year the farmers can fertilize agricultural land with manure up to a limit of application of nitrogen of 170 kg / ha of nitrogen (N). Transitional period for the construction of suitable storage tanks for manure storage and disposal is over. Accordingly, as of 1 July 2017, manure storage and disposal tanks, by their size, must satisfy the collection of manure for a six-month period.

- **Law on woody short rotation coppices (OG No. 15/18, 111/18)**

This Law regulates the establishment, cultivation and use of woody or other short rotation coppices. The purpose of this Law is to create the conditions for the production of biomass from crops as a renewable and environmentally sustainable energy product on the principles of economic sustainability, social responsibility and environmental acceptability. For the purposes of this Law, considered coppices are intensive plantations of fast-growing species of trees or other plants that are grown on agricultural or forest land in a short period, no longer than eight years between the two cutting or harvesting, in order to achieve a high yield of biomass for energy purposes. Short rotation coppices could be grown on: 1. forest land, if this is not contrary to the forest management plan, 2. agricultural land that is valued as other agricultural lands (PŠ) and 3. other arable agricultural lands (P3), which is overgrown with perennial vegetation, with the approval of the Croatian Agricultural and Forestry Advisory Service.

- **Ordinance on short rotation coppice producer registry (OG No. 110/18)**

The Ordinance proscribes content, structure and management of Short rotation coppice producer registry and provides registry application form.

- **Ordinance on the list of plant species for the establishment of short-rotation woody crops and the methods and conditions under which they may be grown (OG No. 16/19)**

The Ordinance provides list of native and foreign plant species, including their crossbreeds, which is allowed to use for the establishment of woody short-rotation plants.

19.4.2. Forestry

- **Forest Law (OG 68/18, 115/18, 98/19)**

Regulates the overall forest management, cuttings, forest monitoring, financing, usage rights for planting perennial plantations on forest land without tree cover, forest infrastructure issues etc. Only marked trees can be cut, the markation is done by the licenced personnel. In general, clear cutting is prohibited as is branch cutting, collecting and removing moss, humus, peat etc. All activities at forest land need to be done in accordance to forest management plans.

- **Ordinance on forest management (OG 97/18)**

Defines all relevant conditions and purpose of all forest management plans (for both private and state forests etc.). Since all activities at forest land need to be done in accordance to forest management plans, the latter gives this Ordinance significance.

- **Law on implementation of EU Regulation related to wood and wood products market (OG 25/18, 16/20)**

Obligations of operators who place timber and timber products on the market to counter the trade in illegally harvested timber. In line with European Timber Regulation

19.4.3. Biowastes

▪ Law on sustainable waste management (OG No. 98/19)

The Law defines measures for the prevention or reduction of possible waste adverse effects; also it establishes the sustainable waste management system, waste hierarchy including waste to energy field, planning in waste management sector, waste transport, permits for waste management, what can be considered as a byproduct etc. For energy recovery, one needs to be registered in a specific register. Energy recovery is allowed for vegetal waste from agriculture and forestry, vegetal waste from food processing industry if used for heat production, fibrous vegetal waste from pulp and paper industry if used at its place of origin with heat production, wood waste except that having hazardous substances (heavy metals) and wood waste from construction, cork waste. Imports of mixed municipal waste for energy production is forbidden. The Law defines targets for biodegradable municipal waste and its landfilling, that is maximum amount of biodegradable municipal waste that can be landfilled in Croatia. In line with European Waste Framework Directive (2008/98/EC)

▪ Waste Management Plan for Republic of Croatia for period 2017-2022 (OG No. 03/2017)

Waste Management plan in Croatia are created for a 6-year period. It determines the direction of waste management in Croatia, based on the analysis of the current state of the waste sector and goals determined within the Law on sustainable waste management. Withing the plan, current waste types, amounts and origin are determined, but also the current waste management plants that are included in the system (maps with existing and planned facilities). The plan provides guidance for waste reuse and recovery, aligned with principles of environment protection and economy growth. This document is the basis for development of waste management plans on local levels (municipalities, cities, etc.). Specifically, it provides the general technical specifications for buildings and equipment for waste treatment and management in Croatia.

▪ Ordinance on thermal treatment of waste (OG No. 75/16)

Determines the modes and conditions of operation, starting conditions and shutdown of incineration and co-incineration facilities for solid or liquid waste. It also determines types of control for waste entering the facility and management of outputs to the environment (air, soil, water). Moreover, it determines waste management within the incineration and co-incineration facilities, but also specific conditions for other thermal treatment methods (gasification, pyrolysis, etc.).

Additionally it should be mentioned that this ordinance is not applicable for the following waste types: vegetal waste from agriculture and forestry, vegetal waste from food industry if the produced heat is reused, cork waste, radioactive waste, waste of animal origin and waste from experimental facilities for research and development (for purpose of thermal processes improvement and under 50 t per year).

▪ Ordinance on waste oil management (OG No. 124/06)

Determines the management of waste oils; persons liable to pay compensations; types and amounts of compensations; means, deadlines and amounts for compensations payment and other questions regarding waste oils management. The goal of this ordinance is to set up a collection system for waste oils, for environmentally- and human health-friendly recovery and/or treatment purposes.

- **Ordinance on management of wastewater treatment sludge when used in agriculture (OG No. 38/08)**

The ordinance sets the conditions under which wastewater sludge usage in agriculture is allowed and when it is prohibited. In agriculture it is allowed to use treated sludge when the concentrations of heavy metals and organic substances are below the thresholds set for sludge and soil. Also, sludge needs to be stabilized (without pathogens). Monitoring of sludge and soil is prescribed.

- **Ordinance on by-products and end-of-waste status (OG No. 117/14)**

This Ordinance prescribes the content of the application for entry in the End-of-waste Register and the By-Product Register, specific criteria for the abolition of waste status, including limit values for pollutants and the harmful effects of substances or objects on the environment, specific criteria for the determination of by-products, the contents of certificates of entry in the End-of-waste Register and the By-Product Register, content and the manner of keeping the End-of-waste Register and the By-Product Register, as well as the manner and conditions for the implementation of European Union regulations establishing the criteria for the abolition of the waste status of certain types of waste.

19.4.4. Other legislation framework related to bioeconomy

- **Regulation on the quality of biofuels (OG No. 141/05, 145/10, 33/11)**

This Regulation prescribes limit values for the quality characteristics of biofuels placed on the domestic market, the method of determining the quality of biofuels and the method of demonstrating compliance. This Regulation seeks to place biofuels of the prescribed quality on the domestic market as substitutes for diesel or gasoline for transport purposes, in pursuit of the objectives of meeting climate change commitments, environmental security of supply and promotion of renewable energy sources.

- **Law on Biofuels for Transport (OG No. 65/09, 145/10, 26/11, 144/12, 14/14, 94/18)**

This Law regulates the production, trade and storage of biofuels, the use of biofuels in transport, the adoption of programs and plans to encourage the production and use of biofuels in transport, the powers and responsibilities to establish and implement policies to encourage the production and use of biofuels in transport, and measures to encourage production and use biofuels in transportation, and encouraging the research and development of new, advanced biofuels that do not compete with food crops. For the purposes of this Law, the following products shall be considered as biofuels:

1. biodimethyl ether is a dimethyl ether produced from biomass for use as biofuel,
2. biodiesel is a fatty acid methyl ester (FAME) produced from vegetable or animal oil, which has the properties of diesel, to be used as a biofuel,
3. bioethanol is ethanol produced from biomass and/or the biodegradable fraction of waste for use as biofuel,
4. biomethanol is methanol produced from biomass for use as biofuel,

5. biogas is a gaseous fuel produced from biomass and / or from a biodegradable part of waste, which can be purified to the quality of natural gas, to be used as biofuel for blending with natural gas or generator gas,
6. biohydrogen is hydrogen produced from biomass and / or from the biodegradable fraction of waste to be used as biofuel,
7. bio-ETBE (ethyl tert-butyl ether) is an ETBE that is produced on the basis of bioethanol. The volume percentage of bio-ETBE recognized as biofuel is governed by the biofuel quality regulation,
8. bio-MTBE (methyl-tert-butyl ether) is a biomethanol-based fuel. The volume percentage of bio-MTBE that is recognized as biofuel is regulated by the biofuel quality regulation,
9. pure vegetable oil is oil produced from oilseed plants by compression, extraction or similar processes, crude or refined but not chemically modified, in cases where it is compatible with certain types of engine and with appropriate emission conditions;
10. Synthetic biofuels are synthetic hydrocarbons or mixtures of hydrocarbons produced from biomass

▪ **Law on the establishment of alternative fuels infrastructure (OG No. 120/16)**

This law establishes a common framework of measures for establishing alternative fuel infrastructures to minimize oil dependency and mitigate the negative impact of transport on the environment. The law establishes minimum requirements for the construction of alternative fuel infrastructure, including filling sites, establishes common technical specifications for filling and supply sites, information requirements for users, as well as the manner of fulfilling reporting obligations on the implementation of alternative fuel infrastructure establishment measures.

▪ **Regulation on air emission limit values of pollutants from stationary sources (OG No. 117/12, 90/14)**

The regulation defines air emission limit values for certain pollutants from stationary sources, monitoring and reporting, measures for emission reduction etc. Air emission limit values for CO, SO₂, NO₂, particulate matter are set for boilers using biomass as fuel. Emission limit values are also defined for waste combustion and co-firing (SO₂, NO₂, TOC, HCl, HF etc.). In line with European Industrial Emissions Directive (2010/75/EC)

▪ **Decision on publication of rules on state support for environment protection (OG No. 154/08)**

The Decision sets detailed rules for receiving state support for environmental protection activities, by entrepreneurs. Support is given for activities related to RES, waste management, energy savings, research in environment protection field, cogeneration and district heating. Support can also be in the form of reduced or exempted taxes for environment protection. The new Decision on guidelines for state support policy for the period 2014-2016 (OG 130/13) states that energy savings, promotion of RES and high-efficient cogeneration are main goals in the mentioned period.

▪ **Tariff System for Electricity Production from Renewable Energy Sources and CHP (OG No. 133/13, 151/13, 20/14)**

In Croatia, renewable energy is mainly supported through a feed-in tariff. Every producer, who holds the status of "qualified producer" and has signed a formal agreement with the Croatian Energy Market Operator (HROTE)

has the right to receive an incentive depending on the type of RES technology and power output of his RES-E plant or PV installation, as is defined in the Tariff System.

- **Regulation on the Fee to Encourage the Production of Electricity from Renewable Energy Sources and CHP (OG No. 144/11, 128/13)**

This regulation determines the manner of use, the amount, calculation, collection, allocation and payment of fees that are designed to encourage the production of electricity from RES.

- **Fund for Environmental Protection and Energy Efficiency Law (OG No. 107/03, 144/12)**

The Fund for Environmental Protection and Energy Efficiency awards interest-free loans, investment grants/subsidies and donations, to renewable energy projects through a tendering process. They apply to all natural and legal persons with a seat in Croatia.

- **HBOR Loan Programme for Environmental Protection, Energy Efficiency and Renewable Energy Sources**

Renewable energy loans are issued by the Croatian Bank for Reconstruction and Development (HBOR). In accordance with the provisions of the Environmental Protection Law (OG 80/13), the State is bound to support and finance projects aiming at environmental protection. The HBOR is obliged to support projects aiming at environmental protection. On this basis, the HBOR has launched the Loan Programme for Environmental Protection, Energy Efficiency and Renewable Energy, which supports investments in primary sources, such as initial funding, land, buildings, equipment and devices.

20. VISION AND IMPLEMENTATION PLAN

The Vision for the **Croatian Bioeconomy** was developed during the National Workshop, where various stakeholders provided their inputs on current situation and their vision of the Croatian Bioeconomy. These inputs were summarized in the following table:

- ✓ **SUSTAINABLE ACTIVATION OF EXISTING LAND RESOURCES AND ALL AVAILABLE SOURCES (SOIL, WATER, AIR, ...) THROUGH IMPLEMENTATION OF INNOVATIVE APPROACHES, NEW WAYS OF OBTAINING VALUE FROM „GREEN RESOURCES”, MAXIMUM UTILIZATION OF INFORMATION TECHNOLOGIES, NEW SOCIAL NETWORKS FOR STAKEHOLDERS NETWORKING, CONSTRUCTION OF NEW SCIENTIFIC AND VOCATIONAL CAPACITIES**
- ✓ **DEVELOPMENT OF VARIOUS ASSOCIATIONS AND ORGANIZATIONS THAT ENCOURAGE THE IMPLEMENTATION OF CROATIAN SUSTAINABLE BIOECONOMY (THROUGH COMMUNICATION WITH RELEVANT STAKEHOLDERS, ORGANIZATION OF SEMINARS, WORKSHOPS, ETC.)**
- ✓ **UTILIZATION OF RES IN A SUSTAINABLE MANNER, WITH ENVIRONMENT PROTECTION IN MIND (REDUCTION OF PRIMARY RESOURCES CONSUMPTION)**
- ✓ **HELPING THE EXISTING BIOMASS INDUSTRY TO SURVIVE IN NEW, LOW-CARBON ENVIRONMENT, WITHIN THE COOPERATION WITH INNOVATIVE INDUSTRY, SCIENTIFIC DISCIPLINES AND SMES**
- ✓ **STIMULATING CIRCULAR ECONOMY, DEVELOPMENT OF NEW BUSINESS MODELS, RESOLVING WASTE MANAGEMENT PROBLEMS, DEVELOPMENT OF NEW WORKPLACES**
- ✓ **DEVELOPMENT OF BIO-BASED MARKETS AND COMPETITIVENESS**
- ✓ **NEW VALUE CHAINS FOR BIOMASS**
- ✓ **IDENTIFICATION OF POTENTIALS AND NETWORKING BETWEEN STAKEHOLDERS ON TOPIC OF CIRCULARITY WITHIN BIO-BASED POTENTIALS**
- ✓ **DEVELOPMENT OF SME SECTOR AND INNOVATIVE SOLUTIONS, BUT ALSO RURAL AREAS THROUGH BETTER EMPLOYMENT**

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

20.1. Strengthen and scale-up the bio-based sectors, unlock investments and markets

This section focuses the Croatian Action Plan on value chains selected within the CELEBio project and discussed on several round tables within the project activities, national workshop organized by CELEBio team and in communication with project partners. The value chains selected are determined on regional level, due to project's character (examination of the situation within 6 observed countries). In terms of the obtained information and data within the project scope, these value chains have potential for market uptake of domestic raw materials and are suitable to foster innovation for the existing industrial infrastructure.

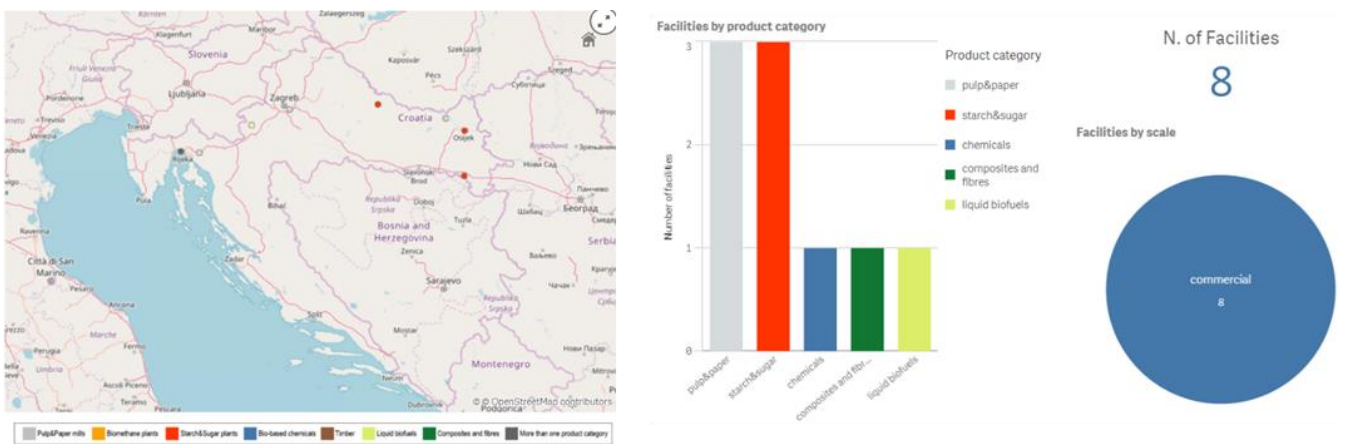


Figure 41 Biorefineries in Croatia

(source: https://datam.irc.ec.europa.eu/datam/mashup/BIOBASED_INDUSTRY/index.html)

Figure 41 provides an overview of the biorefineries in Croatia. There are currently eight facilities operating in the country within the pulp and paper, starch and sugar, chemicals, composites and fibre, and liquid biofuels.

Croatia has great potential to foster bioeconomy development. With a strong foothold in wood processing and food and beverage industry, there is room for significant innovation activities and new business models. Regional leaders in bio-based activities such as Bio-Mi d.o.o., Mi-plast d.o.o., EcoCortec d.o.o. and Weltplast d.o.o. could be used as examples of good practice. However, there is still a lack of communication between important stakeholders and leaders of the bioeconomy sector in Croatia, which could be a potential for improvement and closing the circle of material and energy management in each company.

CELEBIO has also engaged with national stakeholders through several round tables and organization of national workshop, to understand their perspectives of the Croatian bioeconomy and validate the value chains with strong potential to uptake indigenous raw materials, foster the development of innovative products and contribute to the development of Croatian bioeconomy. As aforementioned, the value chains are selected on a regional level basis, within the project scope. The number of value chains satisfies the pre-determined project concept, of covering three sectors (agriculture, forestry, waste management). However, it is important to point out that there are many more potential value chains that can be Croatia-specific, and which were out-of-scope of this project, thus not mentioned in this report.

20.2. Deploy local bioeconomies rapidly across Croatia

The value chains mentioned above and selected by national stakeholders fit well the regional distribution of biomass raw materials across Croatian regions.

20.2.1. Agriculture

Agriculture, forestry and fishing generate 3.0 % of Croatian GDP. About 1.5 million hectares are utilised agricultural land, of which 54.1% refers to arable land and gardens; orchards, vineyards and olive groves occupy 4.9%, and permanent grasslands covering 40.9% of the used surface⁵⁰. Cereals and oilseeds are mainly cultivated in the Pannonian region, which covers 55% of the national territory and is characterized by moderately warm and humid climates⁵¹.

The most important crops in Croatia are cereals and oil crops, e.g. sunflower and rape. Permanent crops cover an intermediate % age of the cropping area in comparison to the rest of the EU countries.

The most important crops in Croatia are cereals and oil crops, e.g. sunflower and rape. Permanent crops cover an intermediate percentage age of the cropping area in comparison to the rest of the EU countries. The increase in crop production in the overall structure of agricultural production after Croatia's accession to the European Union is due to, among other things, significant changes in the economic environment.

Changes in production over the past period are mainly a reflection of market needs for these products and to a lesser extent climate conditions and the prices of oilseeds themselves. The Republic of Croatia is self-sufficient with the production of oilseeds, especially sunflowers, soybeans and rapeseed. Oil crop residues are used for feed (protein cake), energy (husks), chemical compound for detergent, soaps and cosmetics (technical fatty acid) and biogas substrate.

Residues from fruit processing (pits, pulp, water) represent an excellent opportunity to improve cost efficiency of agrifood processing companies. This is particularly urgent for fruit processing companies. While fruit growing agrotechniques are outdated, food processing industry is able to keep up the pace with the technological development. Generating yield from waste streams just started to be considered as a good opportunity to improve competitiveness. It is likely that hesitation lies in the necessity to step out from the current marketplace and food processing as core business. The value chains selected by the national stakeholders are:

<ul style="list-style-type: none"> • Poultry (meat) side streams: <ul style="list-style-type: none"> ◦ (Slaughterhouse waste) → pet food, taurine production ◦ (feathers) → keratin-based sponge and absorbent materials ◦ (chicken litter) → renewable nitrogen sourcing → AD (biogas / digestate) → protein for chicken feed • Unused lands → lignocellulosic crops (SRC, lignocellulosic grasses, ...) → bioproducts (biobased markets) • Secondary residues from food processing → electricity and heat (anaerobic digestion process) → digestate → biorefinery → bioplastic, pharmaceutical industry, construction industry

⁵⁰ Državni zavod za statistiku, Statistički ljetopis 2018.

⁵¹ The Republic of Croatia 2017, Croatian Chamber of Economy, Zagreb June 2017, ISSN 1846-9183

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

20.2.2. Forestry

Forests in Croatia have predominantly natural structure (95%) and are characterised by diversity and productivity differently distributed within the country, ranging from very productive oak and beech forests in the eastern and central part of the country to degraded macchia and bush-wood forests in the south. From total forest land 79% of area are deciduous forests, 16% coniferous and 5% degraded forests in form of shrubs (Strategy of spatial development (OG 106/2017).

Forests are considered as one of the most important resources for Croatian economy, both as energy source and feedstock for wood processing industry (table 3.4). In the previous General FMAP period (2006-2015) the overall forest cut (felling) was achieved at 60% of total area proscribed for cut and accounted for 86% of proscribed cut volume in all forests.

Wood processing and furniture production is an important segment of Croatian economy. It represents 6.14 % of industrial production, contribution 3.6 % to the GDP. There are ~40 sawmills with maximal capacity of stemwood processing 1,1 mil. m³/annually (Energy strategy, White book, 2019).

Most important wood products include furniture (tables, chairs, beds, ...), furniture elements, flooring, dredged boards etc. There are more than 3,500 companies related to wood industry. It is evident that Croatia has well developed wood processing and furniture industry, mostly located in areas with better access to wood supply such as continental Croatia.

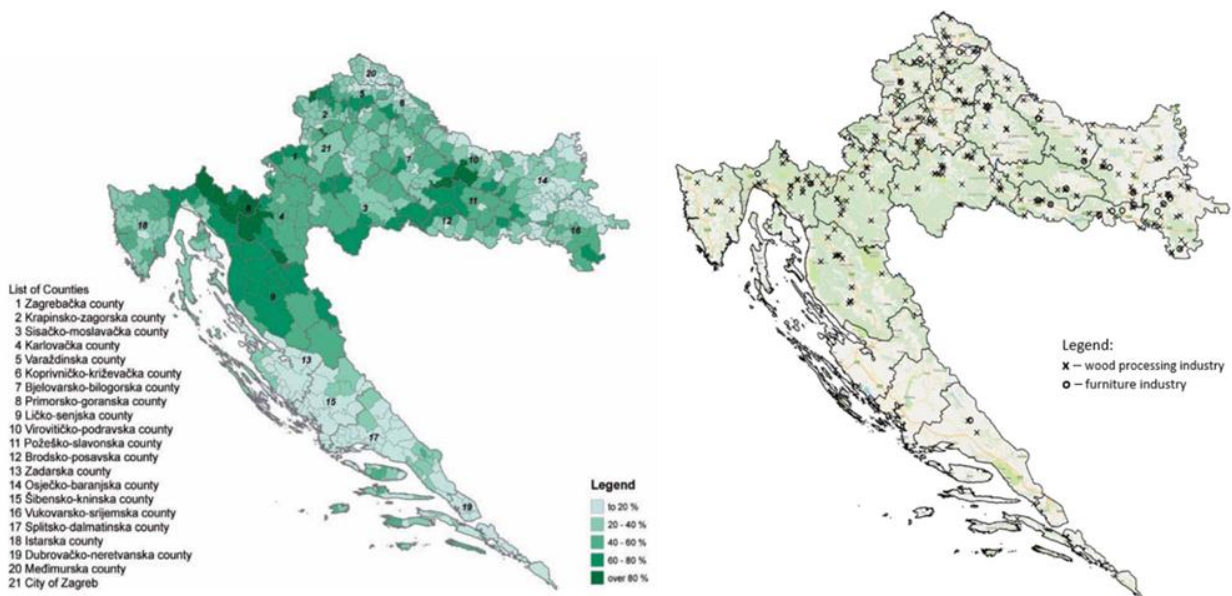


Figure 42: Share of woodland in municipalities/towns (Source:Wisdom)(LEFT) & Distribution of wood processing subjects and furniture industry (Source: Strategy for wood processing and furniture production development, with action plan 2017-2020)(RIGHT)

The value chains selected by the national stakeholders are:

Secondary wood residues → lignin, hemicellulose, cellulose → bioproducts (advanced biofuels, bioplastics, biopolymers, fibres, chemicals)

20.3. Understand the ecological boundaries of the bioeconomy

▪ Land use change

Land use is related to raw material production. Emissions from land use change can be significant in some circumstances, however, the simple notion of land use change emissions is not sufficient reason to exclude biomass from the list of worthwhile technologies for climate change mitigation, bioeconomy and circular economy. The value chains selected for the Croatian bioeconomy comprise of residual and waste fractions so there is no risk expected from their mobilisation and future exploitation.

▪ Biodiversity

Forest biomass: High risks can be anticipated.

- Loss of dead wood and stumps may negatively influence species diversity and soil fauna. Contrary to this, leaving them all on the ground may result in increased fertilisation (N and wood ash) and negative impacts on vegetation
- Wood residues are generated from forests – the same applies for the above comment

Agricultural biomass: Moderate risks can be anticipated without sustainable practices. Biodiversity loss when harvesting too many crop residues. This may also have adverse effect on soil biodiversity

Biowastes: Positive in regions where it avoids landfill

▪ Soil & Carbon stock

Forest biomass: Increased risk of soil erosion; risk to loose soil organic carbon; risk to loose nutrients and risk of reduced soil fertility and soil structure when overharvesting forest residues

Moderate risks due to debates that using the wood in panel boards, creates a carbon stock in comparison to combustion of the wood

Agricultural biomass: Moderate risk to lose soil organic carbon when overharvesting crop residues; risk to loose nutrients when overharvesting.

Leaching from residues can have a moderate impact on soil.

Biowastes: Leaching from residues can have a negative impact on soil.

▪ Water

Forest biomass: No effect on the quantity; If no removal leads to increased fertilisation the leaching on N to water may increase

biomass: Moderate risks can be expected.

- Utilization of agricultural residues may lead to leaching from them to water receivers and have a negative impact on the environment.
- Leaching from residues can have a moderate impact on water receivers.

Biowastes: Leaching from residues can have a negative impact on water receivers.

▪ Air

Forest biomass: High risks can be anticipated.

- Negative impact on the environment due to utilization of forests that produce biodiversity and oxygen.
- Emissions from plants that utilize the wood residues

Agricultural biomass: Moderate risks can be expected.

- Agricultural residues have some elements that are volatile and their utilization can have a negative impact on the climate change and air, due to emissions.

High risks can be anticipated

- Emissions from plants that utilize secondary residues (e.g. biomass and biogas plants) can have a negative impact on the climate change.

Biowastes: Emissions from landfills are reduced, no particles existence in the air.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Feedstock		Sustainability risks (high- red; moderate- yellow; low- green)				
		Land use (ILUC risk)	Biodiversity	Soil & Carbon stock	Water	Air
Primary forestry production	Stemwood from thinnings & final fellings	Utilization of land that can be potentially used for other purposes	Loss of dead wood and stumps may negatively influence species diversity and soil fauna. Contrary to this, leaving them all on the ground may result in increased fertilisation (N and wood ash) and negative impacts on vegetation	Increased risk of soil erosion; risk to loose soil organic carbon; risk to loose nutrients and risk of reduced soil fertility and soil structure when overharvesting forest residues	No effect on the quantity; If no removal leads to increased fertilisation the leaching on N to water may increase.	Negative impact on the environment due to utilization of forests that produce biodiversity and oxygen
Primary forestry production	Stem and crown biomass from early thinnings					
Primary forestry residues	Logging residues from final fellings					
Secondary residues from wood industries	Saw mill residues	Utilization of land that can be potentially used for other purposes	Wood residues are generated from forests – the same applies for the above comment	There are debates that using the wood in panel boards, creates a carbon stock in comparison to combustion of the wood	None	Emissions from plants that utilize the wood residues
Secondary residues from wood industries	Other wood processing industry residues					
Agricultural residues	Straw/stubbles	To achieve sustainable agricultural practices, some of the residues need to be left on the agricultural field. If all the residues are utilized for other purposes, sustainability will not be generated and agricultural fields will be degraded and ruined.	Biodiversity loss when harvesting too many crop residues. This may also have adverse effect on soil biodiversity	Moderate risk to loose soil organic carbon when overharvesting crop residues; risk to loose nutrients when overharvesting	Utilization of agricultural residues may lead to leaching from them to water receivers and have a negative impact on the environment.	Agricultural residues have some elements that are volatile and their utilization can have a negative impact on the climate change and air, due to emissions.
Secondary residues of industry utilising agricultural products	By-products and residues from food and fruit processing industry	Resources utilization to generate secondary residues can have a moderate impact on the environment due to the fact that some land use is specifically oriented towards producing secondary residues.	None	Leaching from residues can have a moderate impact on soil.	Leaching from residues can have a moderate impact on water receivers.	Emissions from plants that utilize secondary residues (e.g. biomass and biogas plants) can have a negative impact on the climate change.
Biodegradable municipal waste	Biodegradable waste	Plants and centres for biodegradable waste utilization can occupy land that can be used for other purposes.	Positive in regions where it avoids landfill	Leaching from residues can have a negative impact on soil.	Leaching from residues can have a negative impact on water receivers.	Emissions from landfills are reduced, no particles existence in the air

Figure 43 Sustainability risks from the exploitation of biomass raw materials for bioeconomy in Croatia (red: high risk; yellow: moderate risk; green: no/ positive impact) ⁵²

⁵² source: information gathered and analyzed during project activities and national workshop

21. VALUE CHAINS FOR THE CROATIAN BIOECONOMY

This section provides facts tailored to 3 value chains in terms of current exploitation of raw materials, future actions that could steer innovative and resource efficient market uptake for biobased products, potential interventions and expected added value. This information has resulted from the consultation with national stakeholders within the duration of the project. While national stakeholders have detected many more value chains, assessment of only three were under the scope of the scientific coordinators. This section includes information on the relevance to the UN Strategic Development Goals (SDGs), selected relevant projects and markets for the biobased products that will derive from each value chain.

▪ **Agriculture**

Main aim of the selected value chains is to:

- Support livestock and crop production; Involvement of rural citizens in rural development
- Exploit high residue potential; Local food processing industries offer opportunities as the negative balance of food export and import is growing

▪ **Forestry**

Main aim of the selected value chains is to:

- Development of rural business activities by mobilising new value chains in the context of circular economy
- New legislation divides State and non-state forests and makes access to funds from state easier (?)
- Research and Innovation activities towards higher added value products from forest biomass and to increase the share of RES

▪ **Waste management**

Main aim of the selected value chains is to:

- Utilize the produced municipal biodegradable waste, instead of sending it to landfills
- Implementation of existing technologies of waste treatment and utilization of valuable nutrients and energy content
- Potential for innovation – production of valuable resource for various industries (bioplastics, pharmaceutical, construction, etc.)

21.1. Poultry meat streams

Value chain	SDGs	Examples of relevant projects
<p>Poultry (meat) side streams:</p> <ul style="list-style-type: none"> ▪ (Slaughterhouse waste) → pet food, taurine production ▪ (feathers) → keratin-based sponge and absorbent materials ▪ (chicken litter) → renewable nitrogen sourcing → AD (biogas / digestate) → protein for chicken feed 		

Current exploitation of biomass raw materials

- Although some producers raise poultry specifically for their feathers (boas, feather fans, masks, costume accessories, etc.), they are often considered a by-product of poultry production (and often a waste by-product). There is no utilisation of the significant poultry waste streams for biobased products
- Low-level of utilisation of chicken litter for biogas and electricity production. Chicken litter is a waste side stream, presenting a problem for the poultry producer, since it requires adequate management. Moreover, chicken litter contains significant amounts of N and P, which can be lost through volatilization of NH₃ or runoff as derivatives of phosphorus. Proper estimation of the nutrients content of chicken litter and proper litter handling are necessary to ensure that application rates minimize emissions from the litter. After extracting the nutrients, the remains can be used in AD process, for biogas production. Digestate, as a by-product of the process, can be utilized for protein production, for chicken feed, since it is depleted from N/P surplus. However, the efficiency and commercial aspect of these processes is questionable, due to requirement for specialising the process to satisfy specific needs of each producer. Additionally, presentation of the new products is also problematic, due to its origin as a waste stream.

Future actions

- Communication with food industry leaders and leaders in pet food production, on possibilities of utilization of products developed this side stream. Utilization of processes that enable use of slaughterhouse waste as a source for pet food production (establishing processes for biorefineries).
- Connecting relevant stakeholders (chemical, construction, materials industry with farmers - feather producers), to increase the collaboration and put the new products on the markets. Implementation of study tours to educate and inform interested stakeholders in existing practices and innovative processes.

Potential interventions

- Climate & Energy Fund: Subsidy schemes for biogas installations
- Standards for agricultural biomass
- Introduce feedstock premiums
- Regulation on agricultural raw materials for biofuels and bioliquids

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Expected added value

- Reduced nitrates in the soil.
- Sustainable energy
- Soil carbon sequestration

Product Group	Market size Europe
Agro-chemicals	1,000 – 10,000 kt
Fertilisers	
Sustainable Energy	>10,000 kt

21.2. Short rotation crops in marginal land

Value chain	SDGs	Examples of relevant projects
Unused lands → lignocellulosic crops (SRC, lignocellulosic grasses, ...) → bioproducts (biobased markets)	 	 http://www.grace-bbi.eu Magic – Marginal Lands for Growing Industrial Crops (magic-h2020.eu)

Current exploitation of biomass raw materials

- No large commercial plantations
- Good experience with rotation forestry plants and perennial grasses

Future actions

- Regulations on SRC and products from biorefineries
- Establishment of bio-based products' market
- Regulation and strategies on utilization of unused lands
- Incentivization of SRC production and utilization of unused lands
- Introduction of innovative technologies and solutions for utilization of unused lands

Potential interventions

- Create tax incentives to support such action and raise the public awareness of the traditional/historical cultivation of hemp in the region, and tout its benefits.

Expected added value

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

- Land will be brought back to use; new industries created; lower carbon-footprint by growing locally; replacement of non-biodegradable products (auto plastic interiors).

Product Group	Market size Europe
Cosmetics	<1,000 kt
Paints & coatings	
Plant based-chemicals	1,000 – 10,000 kt
Fertilisers	
Sustainable Energy	>10,000 kt

21.3. Forest based value chains

Value chain	SDGs	Examples of relevant projects
Secondary wood residues → lignin, hemicellulose, cellulose → bioproducts (advanced biofuels, bioplastics, biopolymers, fibres, chemicals)		 https://www.luke.fi/efforte/ https://www.bioforever.org

Current exploitation of biomass raw materials

- Increased logging (5-6 mill. m3 annually), largely on account of emergency logging due to damaged forest stands (climatic events, pests), emergency logging. 75% of coniferous wood (70% of timber harvested) sold as logs, other pulp & paper, plywood. 56% of deciduous wood used as firewood; From the point of view of the long-term perspective, this is a category that will gain in importance with changes in forest stands (growing share of beech). On the long-run (due to climate change), beech production will increase, bringing additional potential for biorefining processes and the subsequent production of new bio-based materials.
- Low value-added of timber harvested in Croatian forests.
- Fragmented ownership structure, which makes it difficult to establish efficient supply chains; 76% of forests in Croatia are privately owned, 314,000 owners, average size of forest holding is 2.9 hectares.

Future actions

- Increased commercial use of roundwood within Croatia, strengthening technologically more advanced alternatives to the energy use of lower quality wood assortments; optimization of logistics flows, primary processing at the local level and biorefining.

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Potential interventions

- Forest Certification
- Introduce innovation financing for food SMEs and industries
- Regulation on agricultural raw materials for bioeconomy

Expected added value

- Bring lower quality wood to better use than energy use, i.e. bio-based processes (biorefinery)

Product Group	Market size Europe
Cosmetics	S <1,000 kt
Paints & coatings	
Plant based-chemicals	M 1,000 – 10,000 kt
Sustainable Energy	L >10,000 kt

21.4. Biowaste value chains

Value chain	SDGs	Examples of relevant projects
<p>Secondary residues from food processing → electricity and heat (anaerobic digestion process) → digestate → biorefinery → bioplastic, pharmaceutical industry, construction industry</p>		

Current exploitation of biowaste raw materials

In Croatia, waste management is currently one of the largest challenges in the environmental sector and certainly one of the most demanding areas in terms of adjustment to the standards of the European Union. Currently, municipal waste management in Croatia is undergoing a radical transformation from decentralized disposal of non-treated waste on numerous local sub-standard landfills within counties to centralized waste management and Waste Management Centres (WMC) serving the needs of one county or, in some cases, of several counties. The WMC concept has been adopted by the Croatian Government in its National Waste Management Plan (2017).

Future actions

- Acceleration of introduction of end of waste legislation to facilitate utilisation of some of biowastes
- Stimulate the turning of bio-waste, residues, and discards into valuable resources

This project received funding from the BBi JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

Potential interventions

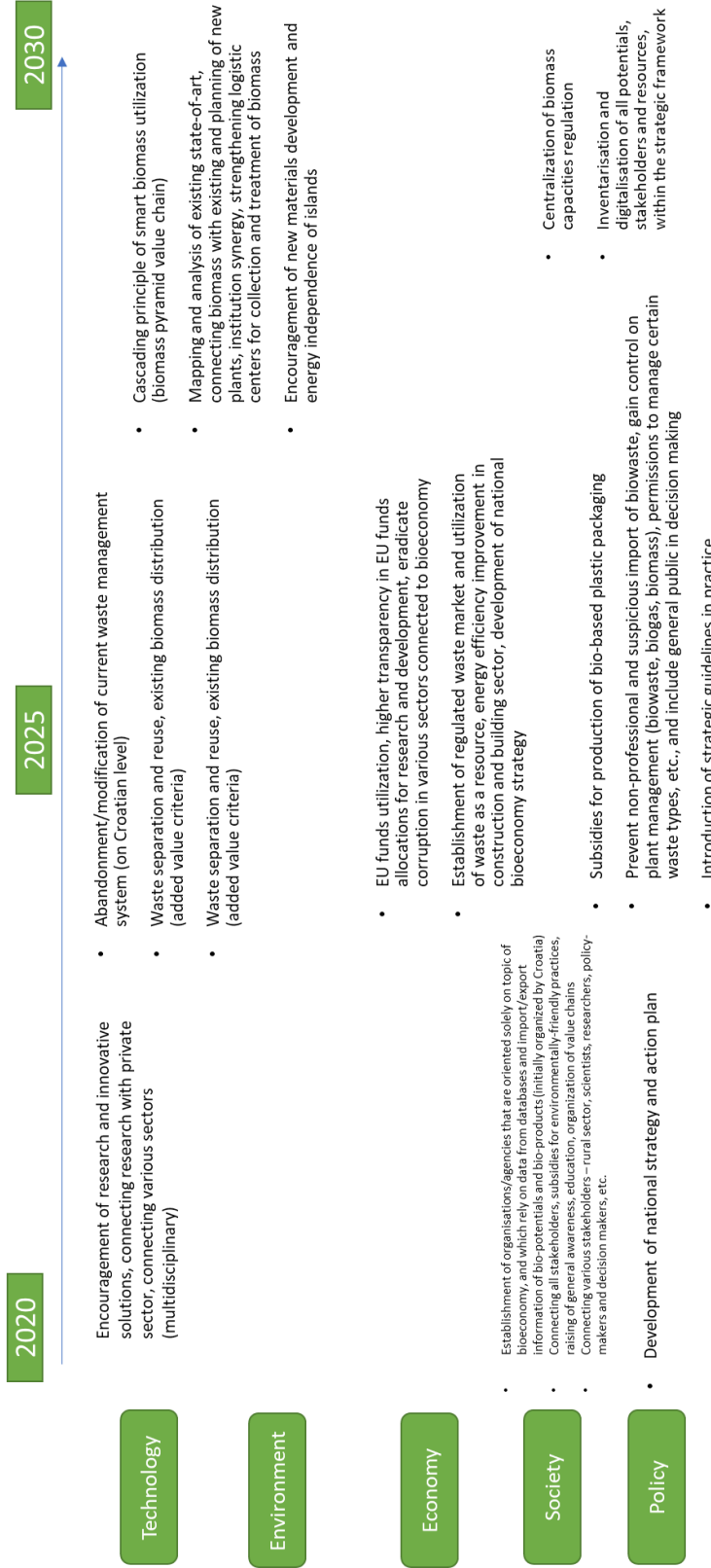
- Incentives for the use of waste for biogas production (subsidies) and fostering the development of clean and renewable energy production. This could include penalties and rewards for energy production, depending on their environmental impact.
- National wide recycling and waste separation campaign and implementation of this type of education in schools.

Expected added value

- Increased use of urban/municipal waste, cleaner energy, reduced environmental impact, potential to improve revenue of all stakeholders
- Efficient system of urban waste collection, improvements possible in higher share of energy utilisation (biogas)
- New opportunities for eco-construction options in integration of renewable energy

Product Group	Market size Europe
Bioplastics	 <1,000 kt
Construction materials	
Plant based-chemicals	 1,000 – 10,000 kt
Sustainable Energy	 >10,000 kt

22. IMPLEMENTATION PLAN






Actors and funding opportunities

Action ⁵³	Actors involved	Funding instruments
Encouragement of research and innovative solutions, connecting research with private sector, connecting various sectors (multidisciplinary) (T)		National financing Horizon Europe, LIFE, Cohesion fund, ERDF, ESIF, RFCS
Establishment of organisations/agencies that are oriented solely on topic of bioeconomy, and which rely on data from databases and import/export information of bio-potentials and bio-products (initially organized by Croatia) (S)		National funds, Horizon Europe LIFE, BBI JU, LIFE
Connecting all stakeholders, subsidies for environmentally-friendly practices, raising of general awareness, education, organization of value chains (S)		National financing Cohesion fund, LIFE Action Plan on financing sustainable growth
Connecting various stakeholders – rural sector, scientists, researchers, policy-makers and decision makers, etc. (S)		Action plan on sector development Cohesion Fund
Development of national strategy and action plan (P)		National co-financing, Horizon Europe, Cohesion Fund
Abandonment/modification of current waste management system (on Croatian level) (T)		Cohesion Fund, Action plan on waste management
Waste separation and reuse, existing biomass distribution (added value criteria) (T)		Cohesion Fund, national co-financing
EU funds utilization, higher transparency in EU funds allocations for research and development, eradicate corruption in various sectors connected to bioeconomy (Econ)		Cohesion Fund, National Bioeconomy Strategy and Action Plan
Establishment of regulated waste market and utilization of waste as a resource, energy efficiency improvement in construction and building sector, development of national bioeconomy strategy (Econ)		Bioeconomy Action Plan, Cohesion Fund, national co-financing
Subsidies for production of bio-based plastic packaging (P)		National co-financing, Environmental Protection and Energy Efficiency Fund, Bioeconomy Action Plan
Prevent non-professional and suspicious import of biowaste, gain control on plant management (biowaste, biogas, biomass), permissions to manage certain waste types, etc., and include general public in decision making (P)		Environmental Protection and Energy Efficiency Fund, national funds
Introduction of strategic guidelines in practice (P)		Bioeconomy Strategy and Action Plan, Environmental Protection and Energy Efficiency Fund, national and private financing
Cascading principle of smart biomass utilization (biomass pyramid value chain) (T)		National and private financing, EU funds (LIFE, Horizon Europe, ERDF, etc.)
Mapping and analysis of existing state-of-art, connecting biomass with existing and planning of new plants, institution synergy, strengthening		National and private financing, EU funds (LIFE, Horizon Europe, ERDF, etc.)

⁵³ T: Technology; Env: Environment; Econ: Economy; S: Society; P: Policy

This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

logistic centers for collection and treatment of biomass (T)		
Encouragement of new materials development and energy independence of islands (T)		Cohesion funds, National Development Strategy
Centralization of biomass capacities regulation (P)		National and private financing, Cohesion fund, Environmental Protection and Energy Efficiency Fund
Inventarisation and digitalisation of all potentials, stakeholders and resources, within the strategic framework (P)		National and private financing, Cohesion fund, Environmental Protection and Energy Efficiency Fund



This project received funding from the BBI JU under the EU Horizon 2020 research and innovation programme under grant agreement No.838087

REFERENCES AND TABLES

23. REFERENCES

- Anić et al.: "The competitiveness cluster in Croatia", *Economic Review*, 2018, vol. 69, no. 5, pp. 571-593
- Božičević et al.: "Evaluation of the Croatian Transport System". In B. Hernavs & P. Meše (Eds.), *Proceeding of the 16th International Symposium on Electronics in Traffic (ISEP) in Ljubljana, 2008*, pp. 1–10)
- Broz and Švaljek: "Mikrokozmos zadružnog gospodarstva: gdje i kako posluju hrvatske zadruga?", *Sociologija i proctor*, vol. 57, no. 2 (214), 2019, pp. 107-138
- Camia et al.: "Biomass production, supply, uses and flows in the European Union (First results from an integrated assessment)", 2018
- Dyjakon and D. Garcia-Galindo: "Implementing Agricultural Pruning to Energy in Europe: Technical, Economic and Implementation Potentials". *Energies*, 2019, vol. 12, pp. 1513
- Karagiannidis et al.: "Evaluation of sewage sludge production and utilization in Greece in the frame of integrated energy recovery". *Desalination and water treatment*, 2011, vol. 33, issue 1-3, pp. 185-193.
- AEBIOM: *Statistical Report: Pellet Market Overview 2017*. European Pellets Council.
- Čosić et al.: "Geographic distribution of economy potential of agricultural and forest biomass residual for energy use: Case study Croatia". *Energy*, 2011, vol. 36, pp. 2017-2027
- Elbersen et al.: "Outlook of spatial biomass value chains in EU28". *Biomass Policies* project, 2016
- Kulišić et al.: "National biogas market development study", *Horizon 2020 Biogas Action* project, No 691755, 2018
- Bilandžija et al.: "Energy potential of fruit tree pruned biomass in Croatia". *Spanish Journal of Agricultural Research*, 2012 10(2), 292-298
- Croatian Agency for Environment and Nature (CAEN), *Report on municipal waste*, Zagreb, 2017
- Croatian Bureau of Statistics (a), *Statistical Yearbook of the Republic of Croatia 2018*, Zagreb, 2018
- Croatian Bureau of Statistics (b), *Indices of Agricultural Production*, Zagreb, 2018
- Croatian Bureau of Statistics (c), *Early estimates of some important early crops*, Zagreb, 2018
- Croatian Bureau of Statistics, *Croatia in Figures*, Zagreb, 2019
- Croatian Chamber of Economy, *The Republic of Croatia 2017*, Zagreb, 2017
- Croatian Forests Ltd., *Annual Report*, Zagreb, 2019
- Đurđević et al.: "Energy Recovery from Sewage Sludge: The Case Study of Croatia". *Energies*, 2019, vol. 12, pp. 1927-1946
- Ijkić, et al.: "Stanje i perspektiva proizvodnje žitarica i uljarica u Republici Hrvatskoj". *Glasnik Zaštite Bilja*, 2019, Vol. 42 No. 3, pp. 62–71
- EIHP (Vuk et al.): "Energy in Croatia 2017", annual energy report. Ministry of Environmental Protection and Energy of the Republic of Croatia, 2018
- EIHP (Vuk et al.): "Energy in Croatia 2018", annual energy report. Ministry of Environmental Protection and Energy of the Republic of Croatia, 2019
- Govt. of Republic of Croatia, *Waste Management Plan for Republic of Croatia for period 2017-2022*, Zagreb, 2017
- J. Božičević: "Evaluation of the Croatian Transport System", *ISEP*, 2008
- M. Zrakić et al.: "Tendencije proizvodnje kukuruza u svijetu, Hrvatskoj i Sloveniji". *Glasnik Zaštite Bilja*, 2017, vol. 40 no. 6, pp. 78-85
- Ministry of Agriculture, *Annual report on agriculture status in 2019*, Zagreb, 2020
- Ministry of Agriculture, Directorate for Rural Development, *Rural Development Programme of the Republic of Croatia for the Period 2014-2020*, Zagreb, 2013
- Ministry of Economy, *Industrial Strategy of the Republic of Croatia 2014.-2020.*, 2014
- Ministry of Environment and Energy, *Energy Development Strategy for the Republic of Croatia for 2030 with a view to 2050 – White book*, Zagreb, 2019
- Ministry of Environment and Energy, *National Forestry Accounting Plan for the Republic of Croatia (General Forest Management Plan)*, Zagreb, 2017
- Ministry of Transport, the Republic of Croatia: *Major transportation routes in Croatia*
- P. Gurría Albusac et al.: "Biomass uses and flows". European Commission, Joint Research Centre (JRC), 2017
- Y. Valleyo Sarmiento et al.: "Transport and logistics in Croatia", 2016
- Z. Nikolić and D. Zorić: "Razvoj start-up kulture u hrvatskoj u funkciji razvoja gospodarstva". *Praktični management*, 2014, vol. 5, pp. 100
- Eurostat most recent statistical data sources (Accessed August/September 2019) (<https://ec.europa.eu/eurostat/data/database>) and statistical factsheets (https://ec.europa.eu/agriculture/statistics/factsheets_en). (n.d.).
- <https://ec.europa.eu/eurostat/data/database>
- https://ec.europa.eu/agriculture/statistics/factsheets_en
- <https://datam.jrc.ec.europa.eu/datam/public/pages/index.xhtml>
- https://www.dzs.hr/default_e.htm
- https://files.hrote.hr/files/PDF/OIEIK/GI_%202019_HROTE_OIEIK%2020200224_final.pdf

- Posavec S., Šašek M., Beljan K. (2011): The structure and potential of small scale forests in the North-west of Croatia. IUFRO SMALL-SCALE FORESTRY CONFERENCE SYNERGIES AND CONFLICTS IN SOCIAL, ECOLOGICAL AND ECONOMIC INTERACTIONS, Delnice.
- Šporčić M., Martinić I. (2004): Uslužni izvoditelji šumskih radova u Hrvatskoj (Forest contractors in Croatia). Šumski list, no. 11-12, pp. 633-648.
- Požgaj Đ., Puntarić E., Kušević-Vukšić M., Kufrin J. (2019): Izveštje o komunalnom otpadu za 2018. godinu (Report on municipal waste for 2018). Ministry of Environment and Energy

24. TABLE OF ILLUSTRATIONS

FIGURES

Figure 1 Major transportation routes in Croatia (source: Ministry of Transport, Republic of Croatia)	14
Figure 2 Position of Croatia in the Trans-European Transportation Network	14
Figure 3 Biomass flows in Croatia (net trade), JRC Sanky Diagrams of biomass flows (Albusac et al., 2017: https://datam.jrc.ec.europa.eu/datam/public/pages/index.xhtml)	15
Figure 4 Production of solid, gaseous and liquid biofuels in Croatia (EIHP, 2017)	16
Figure 5 Timeline of bio-based sectors' turnover in Croatia (source: JRC, 2020)	17
Figure 6 The structure of turnover from Croatian bio-based sector, 2017 (source: JRC, 2020)	17
Figure 7 Agricultural land, by the type of cultivation in 2018 (Ministry of Agriculture, 2019)	18
Figure 8 Economic production (top pane) from the main crop groups per member state, expressed in Mt of dry matter per year; and the shares at national level (bottom pane). Average values over the reference period 2006-2015. (Camia et al., 2018)	22
Figure 9 Outlines of the potential future biogas market in Croatia (Kulisic et al., 2018)	33
Figure 10 Forest cover in Croatia (source: EIHP based on CORINE 2018)	39
Figure 11 Share of woodland in municipalities/towns (Source: Wisdom)	40
Figure 12 Forest growing stock origin in forested areas (ha) (Source: General FMAP, 2017)	42
Figure 13 Comparison of forestland area and forest growing stock in different forest categories by purpose	42
Figure 14 Area of forestland affected by forest fires (Croatian bureau of Statistics, 2018a)	44
Figure 15 Prescribed harvest (felling) in 2018 in state-owned forests managed by Croatian Forests Ltd. (75% of total growing stock of all forests)	47
Figure 16 Distribution of wood processing subjects and furniture industry (Source: Strategy for wood processing and furniture production development, with action plan 2017-2020)	51
Figure 17 Produced and landfilled biodegradable municipal waste in period from 1997 to 2015, in relation to prescribed goals (Government of Republic of Croatia, 2017)	58
Figure 18 Estimated composition of mixed municipal waste in the Republic of Croatia in 2015	61
Figure 19 Spatial arrangement of agglomerations in Croatia (Đurđević et al., 2019)	63
Figure 20 An overview of composting and biogas facilities in Croatia, 2016 (Govt of Republic of Croatia, 2017)	66
Figure 21 Position and capacity of planned WMCs according to the Waste Management Plan, according to the current status of realisation (Government of Republic of Croatia, 2017)	67
Figure 22 Quantities of produced, separately collected and recovered biowaste from municipal waste in Republic of Croatia, in the period from 2012 to 2015 (Government of Republic of Croatia, 2017)	69
Figure 23 Value chains in GRACE project	79
Figure 24 Maritime transport statistics in Croatia (Božičević et al., 2008)	82
Figure 25 River transport on main Croatian inland waterways (Valleyo Saarmiento et al., 2016)	82

Figure 26 Map of Croatian industrial hubs	83
Figure 27 Railway network map with stations and stops in Croatia	84
Figure 28 Pan-European corridors in Croatia (Božičević, 2008)	85
Figure 29 Status of EU projects on modernizing the railway structure in Croatia	86
Figure 30 Road Network Map (Valleyo et al., 2016)	88
Figure 31 Croatian transmission network	89
Figure 32 Primary energy production in Croatia (EIHP, 2018)	90
Figure 33 Energy import in Croatia (EIHP, 2018)	90
Figure 34 Unemployment by activities in Croatia for 2019 (Croatian Bureau of Statistics, 2018a)	95
Figure 35 Average registered unemployed persons by age and sex, 2018 (Croatian Bureau of Statistics, 2019)	96
Figure 36 Registered vacancies in 2019 (Source: Statistics of Croatian Employment Service)	96
Figure 37 List of PPP in Croatia (Source: Centre for Monitoring Business Activities in the Energy Sector and Investments (CEI))	105
Figure 38 Total budget by theme	115
Figure 39 Jobs and wealth in the Croatian bioeconomy in 2017 (source: JRC and nova-Institute)	185
Figure 40 Employment and value added in the bioeconomy by sectors in Croatia in 2017 (source: JRC and nova-Institute)	185
Figure 41 Biorefineries in Croatia	198
Figure 42: Share of woodland in municipalities/towns (Source: Wisdom)(LEFT) & Distribution of wood processing subjects and furniture industry (Source: Strategy for wood processing and furniture production development, with action plan 2017-2020)(RIGHT)	200
Figure 43 Sustainability risks from the exploitation of biomass raw materials for bioeconomy in Croatia (red: high risk; yellow: moderate risk; green: no/ positive impact)	203

TABLES

Table 1 Population, land surface, GDP and trade characteristics of Croatia benchmarked against EU average	13
Table 2 Key characteristics for the agricultural sector in Croatia	19
Table 3 Availability of primary residual biomass from cereals and grain maize (tonne d.m.) in Croatia	28
Table 4 Residual biomass potentials from arable crops 2020 in tonne d.m. (=S2BIOM UD1 potential)	30
Table 5 Technical potential of biomass	32
Table 6 Overall energy potential	32
Table 7 Biogas potential in Croatia by different beneficiaries (source: Horizon 2020 Biogas Action, 2019)	33
Table 8 Biomass potentials from agrifood processing industries 2020 in Tonnes d.m.	36
Table 9 Roadside cost levels (€/tonne d.m.) for agricultural biomass sources based on S2BIOM cost calculations	37
Table 10 SWOT analysis for agriculture sector	38
Table 11 Structure of forests & forest land in Croatia by ownership and purpose (Source: General FMAP, 2017)	41
Table 12 Overview of main characteristics of forestry sector in Croatia	43
Table 13 Planned and achieved cut in 2006-2015 and prescribed harvest for 2016-2025 (General FMAP, 2017)	45
Table 14 The structure of forest wood assortments production in 2016- 2018 (HR bureau of Statistics, 2018a)	46
Table 15 2010, 2020 and 2030 EFI-GTM harvest levels expressed as % of yearly average biomass increment level in forests. (Elbersen et al., 2016; Biomass Policies project)	49
Table 16 Availability of biomass for energy from primary forestry (EIHP, 2019)	49
Table 17 Structure of industrial products from forestry (Croatian Bureau of Statistics, 2018a)	52
Table 18 Availability of secondary biomass from forestry (Ministry of Environment and Energy, 2019)	52

Table 19 Reported amounts of wood industry processing residues in 2017	53
Table 20 SWOT analysis for forestry sector.....	56
Table 21 Amount of total municipal waste generated in period 2010-2017	59
Table 22 Municipal biodegradable waste amounts produced in Croatia in period 2010-2017	60
Table 23 Biodegradable waste potentials for Croatia (Ktonnes d.m.) as assessed in S2BIOM	62
Table 24 Industrial waste amounts produced in Croatia in period 2012-2017	64
Table 25 Composting plants and their capacities in Croatia in period 2012-2017	65
Table 26 Waste amounts of treated waste (municipal and industrial) in Croatia for period 2010-2017	68
Table 27 Waste amounts with potential for energy and/or material recovery (municipal&industrial) 2010-2017	69
Table 28 SWOT analysis for waste sector.....	71
Table 29 SWOT analysis of bio-based products, industries and markets	80
Table 30 Maritime transport statistics in Croatia	81
Table 31 Transport of Goods on Inland Waterways in Croatia in tonnes	83
Table 32 SWOT analysis of the infrastructure, logistics and energy sector in Croatia	93
Table 33 SWOT analysis of educational, innovation and skills sector in Croatia	106
Table 34 SWOT analysis of the Croatian policy framework	113
Table 35 SWOT analysis of the Croatian financing sector	116