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Type of action: Deployment of systemic solutions with the support of local clusters and the development of regional community-based innovation schemes

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Community based innovation scheme, citizen engagement plan & implementation plan for CSS4 - TECH+SOCIAL

Delivery type:	**Report**
Lead beneficiary:	**Veltha**
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Partners

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HISTORY OF CHANGES			
Version	Date	Author/Contributor	Changes
V1. Technical Plan and deliverable structure	05.09.2022	Veltha (Luca Polidori, Nora Åsling)	First draft technical implementation plan (deliverable structure)
V1. Non-technical state of the art: market conditions of CSS4	14.10.2022	UniLodz, OPUS, Parzęczew (authors: Zbigniew Przygodzki, Justyna Trippner-Hrabi, Jacek Chądzyński, Marcin Feltynowski, Pamela Jeziorska-Biel, Ewa Szafrańska, Iwona Jażdżewska, Marcin Podgórski, Aneta Tylman, Dominik Drzazga, Dorota Sikora-Fernandez, Łukasz Waszak, Barbara Kozłowska, **Magdalena Wasiak**)	author's version
V2. Technical Plan	05.12.2022	KFLEX (Kamil Maszczyk, Mateusz Imiela), TUL (Dariusz Bieliński, Krzysztof Jozwik, Krzysztof Sobczak), SIRMAX (Leonardo Bellomo, Nicola Passoni), PROPLAST (Maria Rosa Contardi, Maria Scrivani), PARZĘCZEW (Michal Kowalski),	Technical workshop for co-writing final implementation plan
V2.1 Technical Plan	12.12.2022	NTUA (Chrysa Politi, Antonis Peppas, Sotirios Kottaridis)	Integration of the plan for Task 6.5
Internal Review	12.12.2022	TUL	Update of the non-technical state of the art and overview.
Quality Assurance	13.12.2022	PROPLAST	1 – 1 online session to go through the content.

Disclaimer

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1. Non-technical state of the art: market conditions of CSS4

1.1. Market Analysis

1.1.1. Circular Value Chain Characteristics

The Lodzkie Region is located in the centre of Poland and neighbours six other regions: the Kuyavian-Pomeranian Region, the Mazovia Region, the Silesian Region, the Świętokrzyskie Region, the Opole Region, and the Greater Poland Region (Fig. 1).

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Figure 1 The administrative location of the Lodzkie Region.

Source: own compilation.

The Lodzkie Region has a surface area of 18,219 km^2, which constitutes approx. 6% of the surface area of Poland. The administrative division of the Region includes twenty-four districts, three cities with district rights (Łódź, Skierniewice, and Piotrków Trybunalski), and 177 communes, most of which are rural communes (131). The Lodzkie Region has eighteen urban communes and twenty-eight urban and rural communes.

The Łódź region has 2,426,806 inhabitants, of which 52.4% are women, and 47.6% are men. From 2002-2021, the number of inhabitants decreased by 6.9%. The average age of the inhabitants is 43.3 years, slightly higher than the average age of the entire Polish population. The projected number of inhabitants of Łódź in 2050 is 1,999,131, of which 1,031,519 are women, and 967,612 are men (GUS – Local Data Bank, 2022).

In the Łódź region, a negative natural increase is recorded, amounting to -14 916. This situation corresponds to the natural decrease of -6.09 per 1000 inhabitants of Łódź. In 2020, 20,891 children were born, including 48.9% girls and 51.1% boys. The demographic dynamics index, i.e., the ratio of the number of live births to the number of deaths, is 0.58 and is much lower than the average for the entire country. In 2019, 36.3% of deaths in Łódź were caused by cardiovascular diseases, 25.1% of deaths in Łódź were caused by cancers, and respiratory diseases caused 7.9% of deaths. There are 14.62 deaths per 1000 inhabitants of Łódź. (GUS – Local Data Bank, 2022) It is much more than the average for Poland. In 2020, 19,670 registrations in internal traffic and 21,482 deregistrations were registered; as a result, the balance of internal migrations for the Łódź region was -1,812. In the same year, 445 people checked in from abroad, and 305 deregistrations abroad were registered - this gives the balance of foreign migrations amounting to 140. The structure of people in Łódź voivodeship

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is: 58.3% of the inhabitants of Łódź have a working age, 17.1% have pre-working age, and 24.7% of the inhabitants have post-working age (however, it is necessary to take into account the current changes caused by the war in Ukraine and the significant number of refugees who they also settle in the Łódź region) (GUS – Local Data Bank, 2022).

The Lodzkie Region is relatively well-developed in economic terms, with potential including such elements as(BPPWŁ, 2021):

- A high level of industrialization connected with: the textile and apparel industry, the chemical industry, construction materials, furniture, the electrical machinery industry, the agricultural and food industry, the energy industry, and the pharmaceutical industry;
- A wealth of natural and mineral resources;
- Dynamic development of warehouse and logistic functions;
- Diversification of the industry structure and the growing significance of such industries as the electronic industry, BPO (Business Process Outsourcing), and IT (Information Technology).

It is therefore easy to imagine that in the Lodzkie Region plastic is widely used both in households and in industrial activities. Plastics play a very important role in the economy and it is impossible to image the world without them. However, their non-sustainable, linear use comes at a high price. Environmental pollution with plastics and emissions connected with the growing consumption of primary raw materials are among the most pressing problems of the contemporary world. According to forecasts, by 2040, the amount of plastic manufactured globally will double, while the amount of plastic disposed of in the oceans will triple (Polski Pakiet Plastikowy, 2022).

Today, plastics are used in an infinite number of products and applications, helping to save energy and to reduce CO_2 emissions as well as water and food consumption. It is difficult to imagine the functioning of technologically advanced societies without plastic. In 2018, the demand of European (UE28 + Norway and Switzerland) processors for plastics amounted to approx. 51.1 million Mg. Poland is among six countries with the highest demand for plastics used in manufacturing processes by processing companies. In 2018, it constituted approx. 6.8% (3.6 million Mg) of the European demand (PlasticsEurope, 2019).

Plastics are used in countless products of nearly all industries, such as: packaging production, the construction industry, the automotive industry, electrical and electronic engineering industries, agriculture, and many others. Most of them are used in the production of packaging (39.9% in Europe and 33.5% in Poland) and in the production of construction materials (19.8% in Europe and 25.1% in Poland). In 2018, the volume of plastic packaging waste from households, trade, and industry was approx. 17.8 million Mg, including 7.5 million Mg (42.1%) of recycled waste, 7.0 million Mg (39.3%) of waste reclaimed using energy, and 3.3 million Mg (18.6%) of landfilled waste (IOŚ-PIB, 2021).

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In the past few years, the growth rate of the plastic industry in Poland has exceeded the GDP growth rate. One third of the 3.5 million tons of plastics used by the Polish market are used for the production of packaging (approx. 1.2 million tons). The construction sector and the home appliance industry contribute largely to this. The statistical data show that the use of plastics in the production of packaging in Poland is constantly growing. Only in these years, it has increased by 20%. Also, the amount of waste plastic collected separately per citizen has increased. A high demand for the raw material for processing exceeds the Polish production capacity, which results in large and constantly rising import volumes (PlasticsEurope Polska, 2019).

All plastic products, regardless of whether they are used short-term (or even one-time) or for many years, one day will wear out and become waste. What happens to it has a significant effect on the economy and the environment. Today, it is one of the greatest challenges connected with plastics. Introduction of comprehensive and system solutions for plastic reclamation is a prerequisite for the full use of the potential offered by this material.

Characteristics of Plastic. Plastics cover a wide range of synthetic or semi-synthetic materials (produced by man and not found in nature), with their main component being polymers and additives such as thermal stabilizers, UV stabilizers, flame-retardant agents, antistatic agents, foaming agents, and dyes. They include a wide range of synthetic and semi-synthetic materials. They are organic materials. Natural products, such as petroleum, cellulose, coal, and natural gas are used to produce plastic (Rabek, 2008). Plastics can substitute many of the natural materials, at the same time offering different characteristics and properties. Plastics usually have similar or even better properties of significance for the way the product is used, but their less important properties may be worse (Tab. 1).

Table 1. Advantages and Disadvantages of plastics

Advantages of plastics:	Disadvantages of plastics:
Easy processing,	– A very long decomposition time,
– Low cost of production of large batches of finished products compared with other groups of materials,	– Low resistance to high temperatures and worse mechanical properties (such as hardness, creep-rupture strength) compared with metals or ceramics,
– Perfect secondary raw materials for recycling,	– Creep-rupture sensitivity,
– High calorific value, frequently comparable to coal,	– High tensile strength (sometimes higher than that of metals),
– Resistance to many chemical substances, such as acids, bases etc.,	– Low shape stability, high thermal expansion under high temperature,
– Water resistance,	– Low hardness,
– High tensile strength,	– Low UV resistance,
– Low density,	– Adverse effects of manufacturing processes (resins) on health.
– Good electrical insulating properties,	
– High specific strength (strength-to-weight ratio),	
– Great possibilities for obtaining details with specific colours, textures or surfaces,	

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– A possibility to obtain transparent materials,	
– Relatively long life of materials,	
– A wide range of applications in the industry and everyday life.	

Source: own compilation.

Figure 2 and Table 2 show a list of main polymers produced in Europe, including Poland, and their applications.

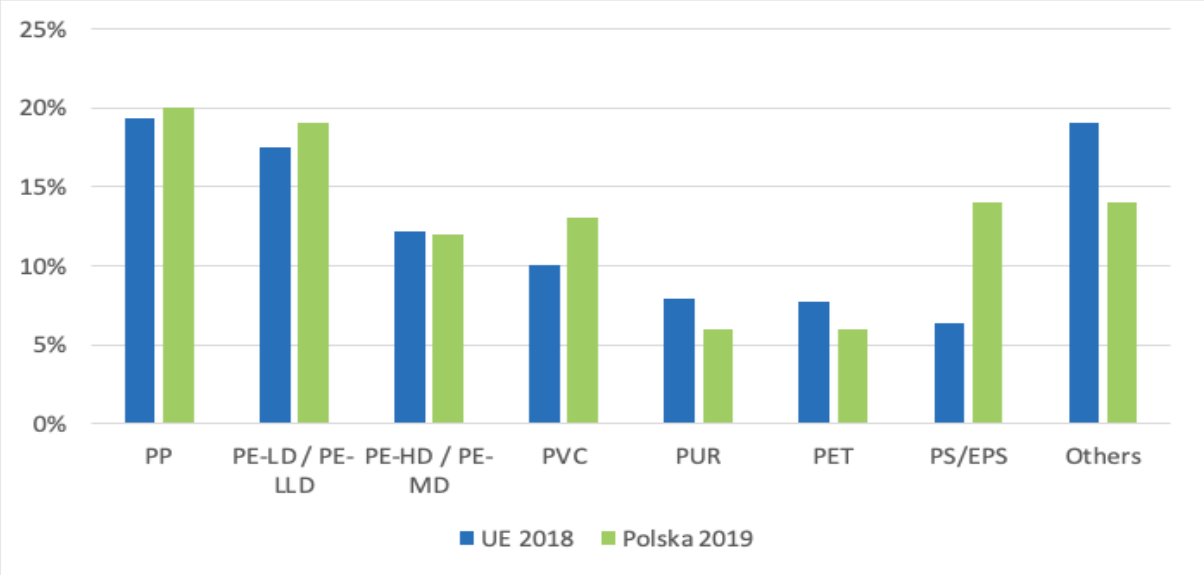

Figure2. Characteristics of the plastics industry in Poland and in the UE [%].
Source: IOS-PIB, 2021

Table 2. A list of main polymers produced in Europe, including Poland, and their applications.

Polymers	Share %		Application
	Europe 2018	Poland 2019	
PP	19.3	20	Food packaging, sweet and snack wrappers, fixed locks, microwave containers, pipes, car parts
PE-LD / PE-LLD	17.5	19	Reusable shopping bags, trays, containers, agricultural foil, foil food wrap
PE-HD / PE-MD	12.2	12	Toys, milk bottles, shampoo bottles, pipes, small household appliances
PVC	10.0	13	Window frames, flooring, wallpapers, pipes, cable insulation, garden hoses, garden pools
PUR	7.9	6	Building insulation, mattresses and pillows, insulation foam for refrigerators
PET	7.7	6	Bottles for water, fizzy drinks, juices
PS/EPS	6.4	14	Food packaging (dairy products, fish), building insulation, E&E equipment, refrigerator internal insulation, eyeglass frames
Others	19.0	14	Car hubcaps (ABS), fibre-optic cables (PBT), spectacle lenses, roofing sheets (PC), touchscreens (PMMA),

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			telecommunications cable covers (PTFE), other materials used in aviation, implantology, surgery, membranes, gaskets, protective coatings, varnishes

Source: IOS-PIB, 2021

Regulations on Plastic Waste Management. The main legislative act of the European Union concerning waste is the Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. The Directive increased the targets for preparing for re-use and recycling of waste by 2025, 2030, and 2035 to 55%, 60%, and 65% respectively.

Another important legislative act regulating the handling of plastic waste is the Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste. And probably the most important legislative act today, directly concerning plastics in the European Union, is the Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment, the so-called Single-Use Plastics (SUP) Directive (32019L0904 – EN – EUR-Lex). The directive reduces the amount of plastic waste from Europe disposed of in the seas, regulating ten types of waste most frequently found on beaches by:

- Prohibiting the placing of certain products on the market;
- Limiting the use of certain products;
- Determining recycling targets;
- Applying requirements to certain products;
- Requiring the use of product marking;
- Determining the scope of the producer responsibility.

The Directive prohibited the placing on the market of:

- Cotton bud sticks, except for medical-type swabs,
- Cutlery (forks, knives, spoons, chopsticks), plastic cups,
- Plastic plates,
- Straws, except for straws used for medical purposes,
- Beverage stirrers,
- Sticks to be attached to and to support balloons, except for balloons for industrial purposes.

The use of food packaging, such as fast-food containers, was limited, except beverage containers, plates, and packets and wrappers containing food.

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Provisions of the Directive extended the restrictions on placing on the market of:

- Single-use lightweight plastic carrier bags, except for those allowed to be placed on the market as the only ones,
- Food containers made of expanded polystyrene (ESP),
- Products made of oxo-degradable plastic (which through oxidation gets fragmented into smaller particles, up to microplastics, and then get deposited in soil for years or can be absorbed by plants and animals).

One should also consider the provisions of the Council Decision of 21 July 2020 concerning the tax on non-recycled plastic packaging waste (confirmed by the Council Regulation (UE, Euratom) 2021/770 of 30 April 2021 on the calculation of the own resource based on plastic packaging waste that is not recycled, on the methods and procedure for making available that own resource, on the measures to meet cash requirements, and on certain aspects of the own resource based on gross national income), which indicate that tax of EUR 0.80 will be collected for each kilogram of non-recycled plastic waste.

In Poland, issues concerning waste including plastic waste are regulated by the Waste Act of 14 December 2012 (uniform text in Journal of Laws of 2022, item 699, as amended), the Act of 13 June 2013 on the management of packaging and packaging waste (uniform text in Journal of Laws of 2020, item 1114), and the Act of 13 September 1996 on maintaining cleanliness and order in communes (Journal of Laws of 2022, item 1297, as amended). According to this Act, communes ensure selective municipal waste collection, including at least paper, metals, plastics, glass, multi-material waste, and bio-waste (Art. 3.2.5).

To determine waste codes correctly, one should refer to the Ordinance of the Minister of Climate of 2 January 2020 on a catalogue of waste (Journal of Laws of 2020, item 10).

Plastic waste has to be collected separately as one of the four basic raw materials for recycling. Pursuant to the Ordinance of the Minister of Climate and Environment of 10 May 2021 on the method for separate collection of selected waste fractions (Journal of Laws of 2021, item 906), waste fractions, (...) including metal waste, with metal packaging waste, plastic waste, with plastic packaging waste, and multi-material packaging waste, are collected in yellow bins or bags labelled “Metals and plastics.” In most cases, this fraction is classified under the code 15 01 06 – mixed packaging.

The management system of packaging waste, including plastic waste, is also influenced by the strategic documents of the European Union, such as: A European Strategy for Plastics in a Circular Economy, European Green Deal, Fit for 55 (legislative package).

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1.1.2. Potential Resources In Communal Waste – Raw-Material Analysis

Plastic waste constitutes a significant part of the municipal waste volume. Table 3 shows types of waste containing plastics.

Table 3. Waste containing plastics collected in Poland in 2018.

Waste code	Waste type	The volume of waste collected, Mg
15 01 02	Plastic packaging	292,098
20 01 39	Plastics	87,876
15 01 06	Mixed packaging waste	519,750
20 01 99	Other fractions collected separately (e.g. the dry fraction)	430,627
20 03 01	Mixed municipal waste	8,427,149

Source: IOŚ-BIP, 2021

Considering lack of detailed data for the Lodzkie Region, the composition of plastic waste in fractions collected separately and in mixed waste is presented based on the data for the Lower Silesian and Greater Poland Regions (IOŚ-BIP, 2021). Table 4 shows the approximate composition of waste collected separately in a stream of mixed packaging waste (15 01 06).

Table 4. The approximate composition of waste collected separately for three urban units from the Upper Silesian and Greater Poland Regions in 2017-2019.

Rodzaj materiału	Big Cities	Small cities	villages	average
	%			
Clear PET	10,8	7,8	8,1	9,3
Blue PET	10,3	9,3	6,6	9,0
Green PET	1,8	2,0	2,7	2,1
PET mix	1,9	5,7	5,8	4,0
HDPE (household chemicals)	3,5	3,5	3,1	3,4
PE-LD and PE-LD foil – transparent and coloured	15,4	14,0	14,3	14,7
PP + PS	10,2	4,5	4,3	,70
Other non-packaging plastic	4,0	4,0	4,0	4,0
Plastics in total	**58,1**	**50,8**	**48,8**	**53,6**
Steel scrap	4,1	5,9	5,3	4,9
Aluminium scrap	2,1	1,8	2,3	2,1
Multi-material packaging (Tetra Pak)	7,8	7,0	7,1	7,4
Others (multi-layered packaging)	2,5	9,5	7,5	5,8
Multi-material waste other than packaging	2,5	0,0	0,0	1,1
Glass	0,0	1,6	1,7	0,9
Others/Pollution	23,0	23,4	27,4	26,5
In total	100,0	100,0	100,00	100,0

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Source: IOŚ-BIP, 202

After sorting, the waste collected in a yellow bin or bag should be assigned correct waste codes. Considering the nature of the waste collected, which allows to separate individual types of waste collected in one bin/bag, it is possible to assign individual types of waste appropriate codes, such as 15 01 02 – plastic packaging, 15 01 04 – metal packaging, or metal and plastic waste classified under the codes 20 01 40 – metals and 20 01 39 – plastics. The average share of plastic waste collected in the stream of the 15 01 06 fraction is from 48.8% in rural areas up to 58.1% in large cities (53.6% on average). Table 5 shows the share of plastic waste in municipal waste divided into administrative unit types.

Table 5. The average amount of plastic in municipal waste and its total amount in 2018.

Parameters	Cities	Towns	Villages	In total	Weighted average
Percentage of plastic waste in municipal waste %	**15.38**	**16.16**	**14.86**		**14.33**
The volume of plastic waste produced	**909,208**	**539,940**	**553,273**	**2,002,421**	

Source: IOS-PIB, 2021

The share of different types of plastic waste in mixed waste (Table 6) ranges from 14.2% in rural areas up to 15.4% in towns (14.3% on average).

Table 6. The share of plastic waste in mixed waste in different administrative areas in Poland in 2017-2019.

Rodzaj materiału	Large Cities	Small cities	Villages (rural areas)	average
	%			
Clear PET	1,4	1,0	1,0	1,2
Blue PET	1,0	0,7	0,7	0,8
Green PET	0,3	0,2	0,2	0,2
PET mix	0,2	0,2	0,1	0,2
PP+PS	2,4	4,7	4,3	3,5
Packaging of household chemistry	0,5	1,0	0,9	0,8
Folia PE-HD i PE-LD	6,6	6,0	5,5	6,1
Other non-packaging plastic	1,4	1,6	1,5	1,5
Total plastic waste	**13,7**	**15,4**	**14,2**	**14,3**

Source: IOŚ_PIB, 2021

The total amount of plastic waste collected separately and in mixed waste in 2018 can be found in Table 7.

Table 7. The approximate amount of plastic waste in fractions collected separately and in mixed waste in 2018.

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Waste code	Waste type	The volume of waste collected, Mg	The share of plastics in the fraction %	The approximate amount of plastics Mg
15 01 02	Plastic packaging	292,098	90.0	262,888
20 01 39	Plastics	87,876	90.0	79,088
15 01 06	Mixed packaging waste	519,750	53.5	278,325
20 01 99	Other fractions collected separately (e.g. the dry fraction)	430,627	40.6	174,662
20 03 01	Mixed municipal waste	8,427,149	14.3	1,207,443

Source: IOŚ_PIB, 2021

Table 8 shows the total composition of plastic waste in separately collected fractions and in mixed waste.

Table 8. The total composition of plastic waste in fractions collected separately and in mixed waste in Poland.

Waste type	Plastic waste collected separately		Plastic waste in mixed waste		The total amount of plastic waste produced	
	Composition, %	Volume, Mg	Composition, %	Volume, Mg	Composition, %	Volume, Mg
Clear PET	17.3	137,328	8.2	99,211	11.8	236,539
Blue PET	16.8	133,944	5.7	68,327	10.1	202,271
Green PET	3.9	31,042	1.5	18,505	2.5	49,547
PET mix	7.5	59,306	1.2	14,608	3.7	73,914
HDPE (household chemicals)	6.4	50,699	5.4	65,225	5.8	115,923
PE-HD foil	27.5	218,660	42.9	518,508	36.8	737,169
PP + PS + PE	13.1	104,539	24.8	299,830	20.2	404,370
Other non-packaging	7.5	59,460	10.2	123,229	9.1	182,689
In total	100.0	794,979	100.0	1,207,443	100.0	2,002,421

Source: IOŚ-PIB, 2021

Based on the data presented, the largest group in separately collected waste is PET packaging (clear, blue, green, and colourful), constituting a total of 55.5% of all separately collected plastics. The second place is occupied by foil – 27.5%. The dominant materials in mixed waste are foil – 42.9% and PP, PS, and PE packaging (mostly yogurt containers). In the total volume of plastic waste, foil dominates (36.8%), followed by PET packaging (a total of 28.1%) and small packaging (mostly yogurt containers) made of PP, PS, and PE (IOŚ-BIP, 2021).

Table 9 presents the effectiveness of separate collection with regard to the approximate total volume of the plastic waste listed. The data indicates that the highest level of separate collection concerns PET packaging (58.1%-80.2%), while the lowest level concerns small packaging made of PP, PS, and PE (yogurt containers) – 25.9% and foil – 29.7%.

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Table 9. The effectiveness of separate collection with regard to the approximate total volume of the plastic waste listed.

Type of material	Separate collection efficiency %
PET clear	58,1
Blue PET	66,2
Green PET	62,7
PET mix	80,2
HDPE (household chemicals)	43,7
Foli	29,7
PP + PS + PE	25,9
Other non-packaging	32,5
total	39,7

Source: IOŚ- PIB, 2021

In 2019, the municipal waste produced in the Region constituted 9.0% of the total amount of produced waste. The positive trend for reducing the amount of landfilled municipal waste continued. The amount of landfilled mixed waste was 38.8% (the national average – 40.5%), ranking the Lodzkie Region sixth in the country.

Low effectiveness of separate collection systems remains a problem. In the Lodzkie Region, despite an increase in the share of municipal waste collected separately in the total volume of the waste collected to 32.6% in 2019 (the fifth place in the country) and an increase in the share of municipal waste for recycling to 16.4% in 2019 (the national average – 25.0%), these amounts were still low both for a Region and the whole country.

A majority of the total waste produced is industrial waste (91.0%), which is why the share of landfilled industrial waste in the waste produced, along with a decrease in the share of reclaimed waste from 14.7% in 2010 to 5.4% in 2019 (Poland – from 74.3% to 20.4%), is a problem (BPPWŁ, 2021).

Table 10 and Figure 3 show the types and volume of municipal waste containing plastics collected in the communes of the Lodzkie Region in 2017-2021. The data was compiled and made available by the Marshal's Office based on reports from commune heads and mayors on the fulfilment of tasks connected with municipal waste management for the years 2017-2021.

Table 10. The types and volume of municipal waste collected in the communes of the Lodzkie Region in 2017-2021.

No	Cod of waste	Waste type	The volume of waste collected, Mg						
			2015	2016	2017	2018	2019	2020	2021
1.	15 01 02	Plastic packaging	9 467,700	9 112,925	9 481,690	14 740,847	16 657,1733	17 776,9131	22 176,3748

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2.	20 01 39	Plastics	2 269,640	2 031,737	1 226,365	3 626,191	4 467,688	13 336,4355	21 681,945
3.	17 02 03	Plastics	109,880	102,793	98,131	113,930	142,696	162,424	456,437
4.	15 01 06	Mixed packaging waste	52 391,680	45 769,380	46 489,825	43 219,582	29 912,075	49 219,8951	48 537,4558

Source: Marshal's Office Data bases

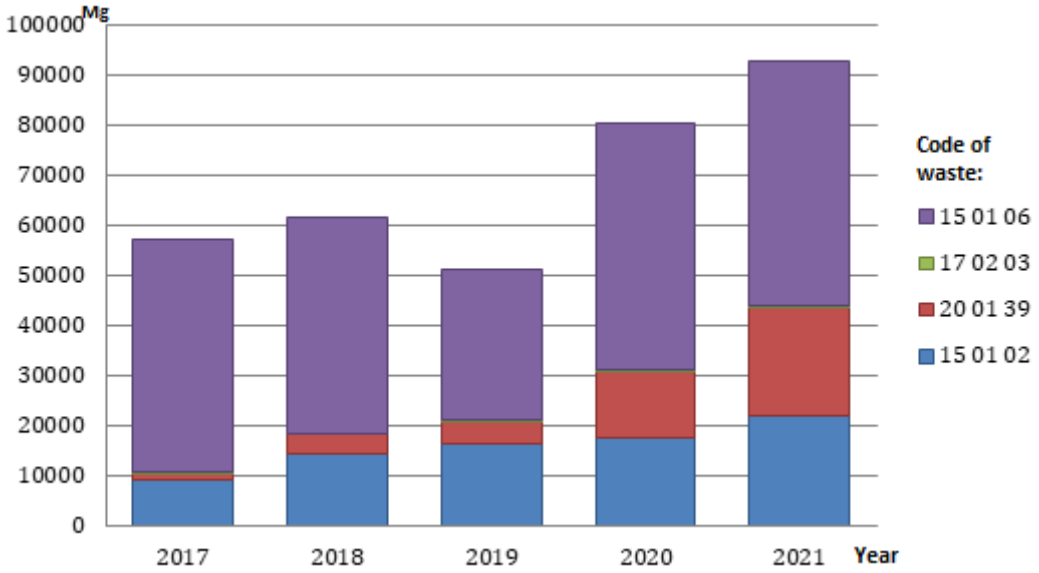

Figure 3. The volume of waste collected in the Lodzkie Region in the years 2017-2021.

Source: Marshal's Office

The years 2017-2021 saw a gradual increase in the amount of waste collected selectively. Figure 4 shows the amount of waste collected selectively in the years 2017-2021 in the districts of the Lodzkie Region.

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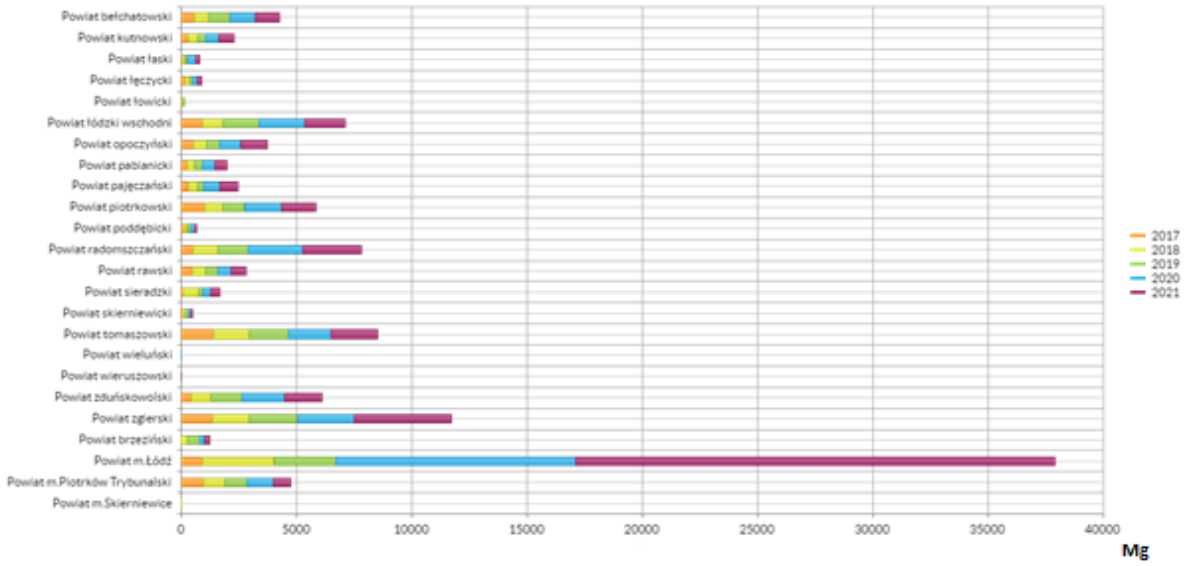

Figure 4. The amount of waste collected selectively in the years 2017-2021 in the districts of the Lodzkie Region.

Source: GUS, Internet 2

In 2021, 13.7 million tons of municipal waste were collected in Poland (an increase by 4.2% compared with 2020). On average, this was 358kg of municipal waste collected per citizen, which meant an increase by 16kg compared with the preceding year (GUS, 2022).

Figure 5 shows the accumulation index of waste from the 15 01 02 group in all communes of the Lodzkie Region, divided into urban, rural and urban, and rural communes.

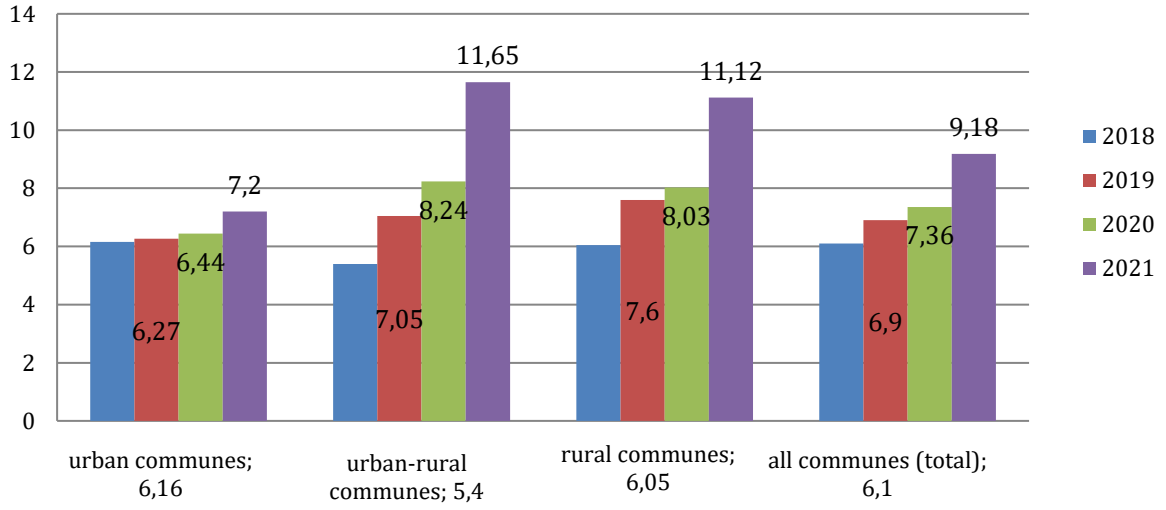

Figure 5. The waste accumulation index for 15 01 02 waste in the communes of the Lodzkie Region.

Source: own compilation

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Today, Poland only recycles plastic waste. According to the Provincial Marshal's report for the years 2014-2016, the capacity of plastic waste recycling facilities in the Lodzkie Region is 300,944 Mg/year, while according to BDO it was 94,829 Mg/year in 2019 (as of 4 May 2021). Analysis of the data from Table 25 leads to a conclusion that preparation of waste for recycling is quite arbitrarily classified as a recycling process. Table 11 shows the list of plastic waste recycling facilities (R3 operation) located in the Lodzkie Region, and the amount of plastic waste recycled in 2019.

Table 11. The list of plastic waste recycling facilities (R3 operation) located in the Lodzkie Region, and the amount of plastic waste recycled in 2019.

No.	Name of plastic waste recycling facilities	Address	Processing capacity Mg/rok	Volume of waste treated in process R3 Mg/year
1	P.P.H.U Export-import Artur Tarczyński	Kutno, Majdany 6, 99-300	9640	3896
2	Piotr Zasada P.P.H.U EKO-RECYKLING	Radomsko, prymasa Wyszyńskiego 142, 97-500	2000	1950
3	SIRMAX POLSKA Sp. z o. o.	Kutno, ul. Holenderska	4000	1537
4	WRB MICHAŁ ŻÓŁTOWSKI	Sieradz, Wojska Polskiego 102, 98-200	4480	896
5	PPHU FOL – POL Jacek Borowski	Kutno, Józefów 22, 99-300	3 464	581
6	EUROPOL HOLDING Sp. z o.o.	Zduńska Wola, Łaska 227B, 98-220	21800	504
7	Eko-Region I Zakład Gosp. Odpadami Przetwórstwa, Utylizacji I Recyklingu Danuta Krysińska	Kadłub 55, 98-300	4025	478
8	PPHU Wtór – Plast Frankiewicz Tomasz	Bedlno, Groszki 14, 99-311	300 300 600	103 103 206
9	"MAWERIK-EKO" Sp. z o.o.	Ozorków, WRÓBLEW 33, 95-035	150	148
10	UPONOR INFRA Sp. z o.o.	Kleszczów, Przemysłowa 5/5, 97-410	2000	103
11	BIOEKO PJ SP.Z O.O. SP.K.	Buczek, Brodnia Dolna 24, 98-113	32000	73
12	BEJA RECYKLING Jarosław Grabarz Zelów,	Miejscowość: Kociszew 52A, 97-425	10000	45
13	PP-U-H "MARPAS" Zgorzelski Władysław	Wieruszów, Marianów 14, 98-400	210	21
14	YETICO SPÓŁKA AKCYJNA	Galewice, Przemysłowa 5, 98-405	100	13
15	ZAKŁAD CHEM "WABA" Waldemar Jęcek, Barbara Jęcek	Dąbrowa nad Czarną 80A/80A, 26-337	360	10
Total:			**95 429**	**10667**

Source: IOŚ-BIP, 2021

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1.1.3. Potential Resources In Industrial Waste – Raw-Material Analysis

Plastic Waste Market. The national materials management in the years 2017-2020 displayed a growing tendency towards the consumption of different materials, with the growth dynamics depending on the material type. The national consumption in these years increased most with regard to plastics (by as much as 30.1%). In 2018, the consumption of plastics in Poland amounted to 3.4 million tons. The largest and the most dynamic segment of the industry includes small and very small companies, which on average employ nineteen people. The largest group are manufacturers of packaging (containers, bottles, boxes, foil), followed by manufacturers of pipes and sections (for the construction industry), and manufacturers of cables (PKO BP, 2021).

The largest customer for plastics is the industry, including construction, with a share of over 90%. Ethylene polymers have the largest share in the structure of plastic consumption, while the second most important group includes polypropylene and copolymers. The analysis covered four most popular plastics: ethylene polymers, polypropylene and copolymers, polyvinyl chloride and copolymers (not mixed with other substances), and styrene polymers – Fig. 6 (GUS, 2021).

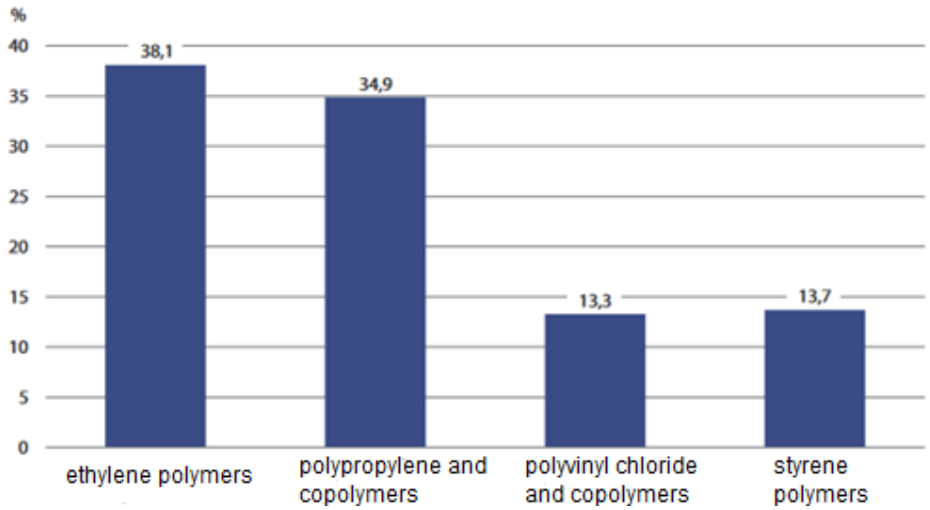

Figure 6. The structure of consumption of selected plastics in the processing industry in 2020.

Source: GUS, 2021

The structure of consumption of plastics in the processing industry is very diverse, depending on the branch (Fig. 7 and 8). Plastics are mostly used to produce rubber and plastic products (as much as 79.6% of the total consumption).

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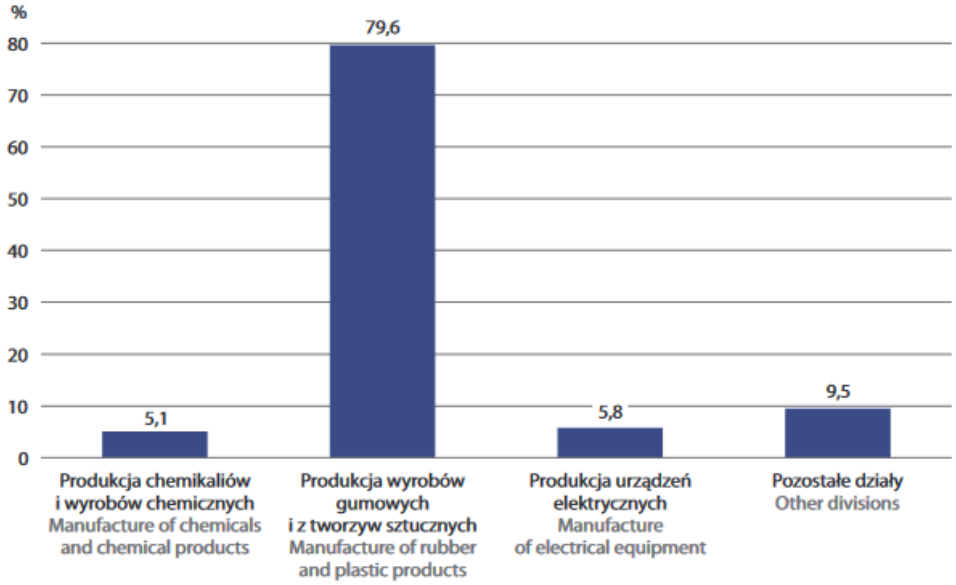

Figure 7. The structure of consumption of plastics (ethylene polymers, polypropylene and copolymers, polyvinyl chloride and copolymers, not mixed with other substances, and styrene polymers) in the processing industry according to selected categories of the Polish Classification of Activity in 2020. Source: GUS, 2021

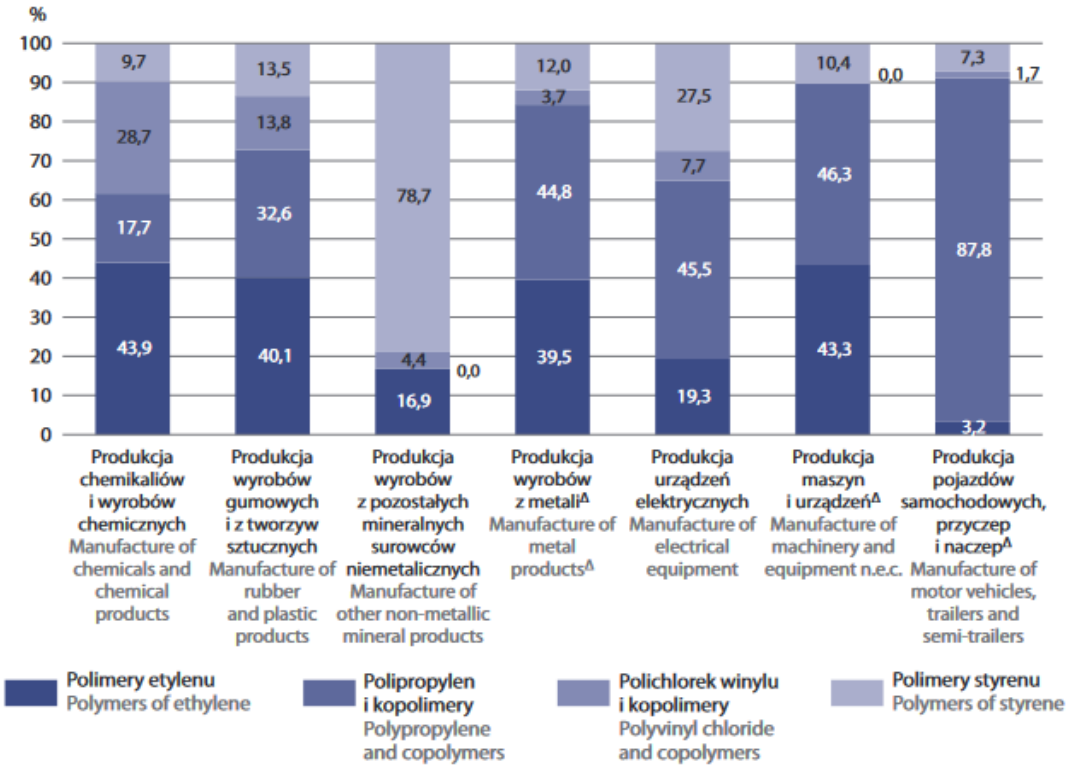

Figure 8. The structure of consumption of selected plastics according to selected categories of the Polish Classification of Activity in 2020.

Source: GUS, 2021

In the group of chemical products, the analysis covered plastics including four most popular materials: ethylene polymers, polypropylene and copolymers, polyvinyl chloride and

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copolymers, and styrene polymers, as well as chemical fibres and synthetic rubber. In 2020, considering all plastics, the largest consumption was identified in the Mazovia Region, accounting for 22.2% of the total consumption, which was a level similar to the preceding year. A share exceeding 10% was also found in the Greater Poland Region (14.3%, an increase in share by 1.4 percentage points and in consumption by 17.9% compared with the preceding year). The Greater Poland Region had the largest consumption of chemical fibres (19.2%, an increase in share by 2.2 percentage points, with a decrease in consumption by 3.9%). A share above 10% was also recorded in the Lower Silesian Region (15.2%, an increase in share by 1.4 percentage points and in consumption by 21.4%), the Lubuskie Region (14.6%, a considerable increase in share by 10.1 percentage points), **the Lodzkie Region (13.8%, an increase in share by 4.1 percentage points and in consumption by 20.2%)**, and the Silesian Region (10.9%, an increase in share by 2.9 percentage points and in consumption by 16.3%) (GUS, 2021). Figure 9 shows the share of selected chemical substances consumed according to Regions in 2020.

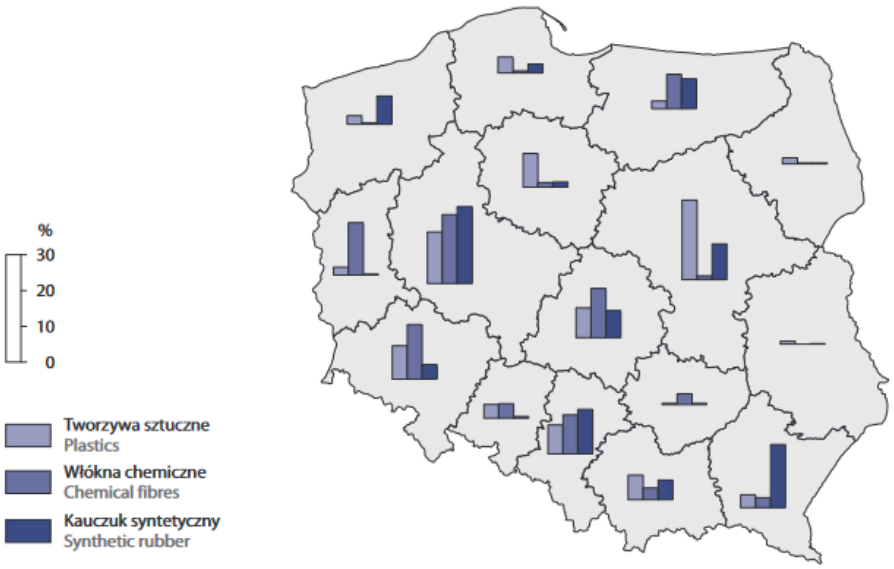

Figure 9. The share of selected chemical substances consumed according to Regions in 2020.

Source: GUS, 2021

The plastics industry in Poland is developing very rapidly at a rate exceeding both the GDP growth rate and the industrial production growth rate. At present, Polish manufacturers do not satisfy the demand for nearly all products, so a considerable part of the plastics consumed has to be imported (PKO BP, 2021).

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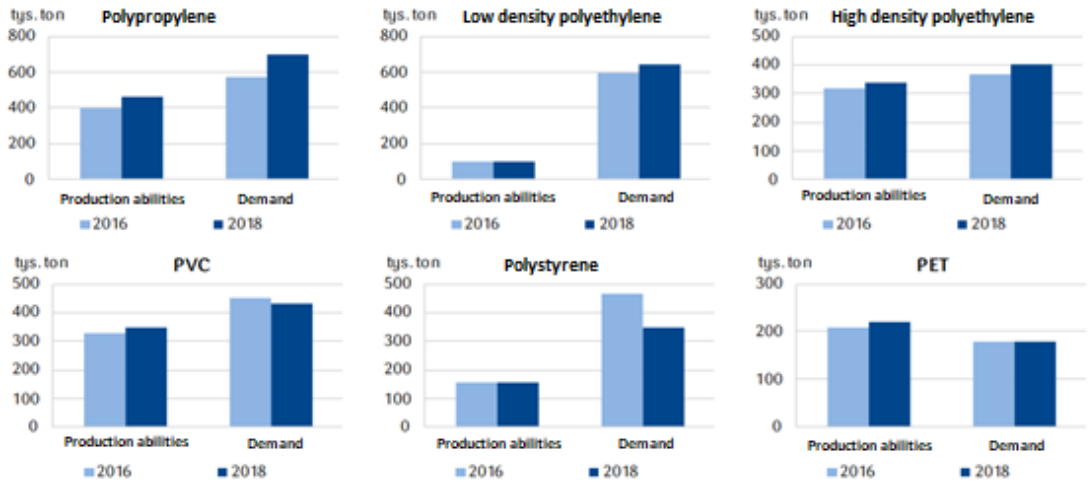

Figure 10. Changes in the capacity and demand for plastics in primary forms in Poland in 2016-2018.

Source: GUS, 2021

In 2020, the share of import in the national consumption of plastics amounted to 83.3%. The share of import of plastics in the national consumption in 2017-2020 was very stable, with differences of 1 percentage point. In 2020, the share of export in the production of plastics was as much as 60.9%.

Table 12 shows a list of the largest manufacturers of plastics in primary forms (PKD 20.16) (GUS, 2021).

Table 12. The largest manufacturers of plastics in primary forms.

	Income [mln PLN]	Market share		Income [mln PLN]	Market share
1 Basell Orlen Polyolefins	3294	26,8%	9 Sirmax Polska	283	2,3%
2 Anwil	2358	19,2%	10 Malborskie Zakłady Chemiczne Organika*	259	2,1%
3 Indorama Ventures Poland	1051	8,6%	11 Eurocast	218	1,8%
4 Solvay Engineering Plastics Poland	668	5,4%	12 Polynt Composites Poland*	168	1,4%
5 Stepan Polska	623	5,1%	13 Minova Ekochem	140	1,1%
6 Lerg S.A.	578	4,7%	14 Purinova	134	1,1%
7 Ciech Pianki	325	2,7%	15 Pureko	121	1,0%
8 Mcns Polyurethanes Europe	301	2,5%	16 Incom Polska	102	0,8%
			Others:	3077	25,1%

Source: GUS, 2021

The sixteen largest manufacturers of primary plastics include a Polish company Sirmax located in Kutno, Lodzkie Region. The SIRMAX POLSKA company started production in its Kutno plant,

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located in the Łódź Special Economic Zone. Among the forty largest manufacturers of boards, sheets, pipes, and sections, there are four companies located in the Lodzkie Region. These are:

- VEKA Polska Sp. z o.o., with its registered office in Skierniewice, manufacturing window and door *sections*;
- *Austrotherm,* with its registered office in Skierniewice, manufacturing foamed polystyrene thermal insulation boards for the construction industry;
- Gamrat S.A., with its registered office in Tuszyn, manufacturing plastic products;
- *Uponor* infra, a leading international provider of plastic piping systems for buildings and the infrastructure, with a production plant in Kleszczów near Bełchatów.

Among the fifty-nine largest manufacturers of packaging, there are six companies from the Lodzkie Region. These are:

- Paccor Packaging Poland Sp. z o.o. from Skierniewice, manufacturing single-use plastic packaging;
- Amcor Flexibles Reflex from Łódź specializing in production using two technologies: rotogravure and flexographic printing;
- Fuji Seal Poland Sp. z o.o., with its registered office in Kutno, operating in the sector of plastic foil and packaging sheet manufacturing;
- Constantia Teich Poland from Rogowiec manufacturing foil packaging;
- HSV-Polska from Łódź designing, manufacturing, and providing goods of EPS, EPP, EPE foamed polystyrene and of other plastics.

Among the thirty largest manufacturers of construction products there are five companies from the Lodzkie Region. These are:

- Alu-plast Krzak Kotynia spółka jawna from Pajęczno introducing modern technologies connected with the manufacturing of doors, windows, and PVC sections;
- A window manufacturer Oknoplast from Pabianice;
- Gealan Polska Sp. z o.o. from Rzgów offering innovative door and window systems;
- Knauf Bauprodukte Polska Sp. z o.o. from Rogowiec;
- Styropmin Sp. z o.o. from Radomsko, which is a foamed polystyrene manufacturer, producing and selling foamed polystyrene boards and insulation used in different industries.

Among the thirty-eight largest manufacturers of other plastic products there are eight from the Lodzkie Region. These are:

- Plastic Omnium Auto from Kleszczów manufacturing car accessories and parts;
- Wirthwein Polska from Łódź, which is a plastic processing company;
- Albea Poland from Łódź manufacturing plastic elements and packaging for the cosmetic, pharmaceutical, and household chemical industries;

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- Rosa Europe Sp. z o.o. from Radomsko manufacturing plastics;
- Coko-Werk Polska from Łódź, which is a plastic processing company;
- Mecalit Polska from Łódź, which is a plastic processing company;
- Plastwil De Bonte from Łódź, which is a plastic processing company;
- Bilplast S.A. from Łódź, which is a company specializing in the production and sale of technologically advanced thermoplastic parts.

The capacity of Polish companies manufacturing plastics (mostly in primary forms) is unable to satisfy the domestic demand, so a considerable part of the plastics consumed has to be imported.

Plastics are irreplaceable due to their strength, low weight, and manufacturing costs. They revolutionized the world in the twentieth century. However, their whole life cycle is connected with greenhouse gas emissions. The extraction and transport of fossil fuels involves CO_2 emissions and high energy consumption. It is similar in the case of manufacturing and processing plastics. The long decomposition time of plastics, even up to 500 years, poses a serious problem. Used plastics end up as waste in seas and oceans, presenting a threat to the marine flora. One should also note the issue of microplastics appearing in water and food. A solution to related problems, such as effective processing of polymeric compound products and waste, should be found as soon as possible.

According to the data of PlasticsEurope, 29.1 million tons of plastic waste were collected in 2018 (including 17.8 million tons of packaging waste), 32% of which (9.4 million tons) were sent for recycling, 43% were sent to energy recovery facilities, and the remaining 25% were landfilled.

To speed up the transformation of Europe towards circular economy, the European Commission decided to launch the so-called Circular Plastics Alliance. Its main objective will be to support the market for recycled plastics in Europe. The European plastics industry supports circular economy principles as companies are aware of the fact that plastics constitute a precious material that can be reused and should not be wasted by landfilling or dumping in the environment, e.g. in forests. This is why companies manufacturing, processing, and recycling plastics develop new technologies, including those connected with recycling, with the aim to remarket plastics.

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1.2. Identification, involvement, needs and expectations from regional stakeholders involved in CSS4

For the proper implementation and development of the circular economy, an adequate and effective legal system is essential, creating a legal framework for the action of the actors involved in this process.

In Poland, laws that consider the norms and regulations under European law control waste management-related issues. The following basic legal procedures apply to waste management (*A complete list of legal acts regulating waste management and trade in packaging waste is included in Appendix 1 at the end of the report*.):

1. The Act of 13 September 1996 on maintenance of cleanliness and order in municipalities (consolidated text: Journal of Laws 2022, item 1297), which regulates the duties of municipalities in the area of municipal waste management, the requirements for carrying out activities in the field of collecting municipal waste from property owners and managing this waste, the requirements for granting permits to entities providing services within the scope regulated by the Act, the obligation.
2. The Act of 14 December 2012 on waste (consolidated text: Journal of Laws 2022, item 699) regulates the responsibilities of municipal waste generators concerning:
   - separate waste collection,
   - the impact of waste generation and management,
   - and lowering the overall impact of resource use and increasing the efficiency of such use,
   - to convert to a closed-loop economy.
3. The Act of 7 May 2009 on Packaged Goods (consolidated text: Journal of Laws 2020, item 1442) which sets forth the rules for the packaging of products to be marketed in packages and the marking of packaged goods with the "e" mark, as well as the rules for the production of measuring bottles and their marking with the "3" (inverted epsilon) mark. In particular, the provisions of the Law also apply to medical devices and medical device equipment.
4. The Act Of 11 May 2001 On Entrepreneurs In Terms Of The Management Of Certain Types Of Waste And The Product Fee (consolidated text: Journal of Laws 2020, item 1903). In order to avoid the development of trash created from goods, decrease their detrimental effects on the environment, and guarantee a high level of recovery and recycling of waste generated from products, the Act specifies 1) the duties of entrepreneurs introducing

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products on the territory of the nation; 2) the principles of dealing with the waste generated from products, and 3) the principles of determining and collecting the product fee.

5. The Act of 13 June 2013 on packaging and packaging waste management (consolidated text: Journal of Laws 2020, item 1114). In order to lessen the amount and environmental harm caused by the materials and substances found in packaging and packaging waste, as well as the amount and environmental harm caused by products, the Act specifies:

   – the requirements to be met by packaging placed on the market;

   – the operating principles of packaging recovery organisations;

   – the handling of packaging and packaging waste; and

   – the principles of determining and collecting a product fee and a recycling fee.

The legislation further outlines the privileges and prohibitions that apply to business owners: 1) organisations that specialise in packaging recovery; 2) companies that supply packaging trash and packaging goods within a community; 3) companies that distribute packaging products; 4) companies that export packaging waste and packaging products; 5) companies that recycle packaging waste; 6) companies that introduce packaging; and 7) companies that introduce packaging products. The legislation also outlines the responsibilities of those who employ dangerous chemicals or plant protection products.

The analysis of the polish legal system of statutory Law and executive acts in the area of waste management and packaging waste turnover leads us to describe the regulation described in detail below. The legal documents have been organised and presented in a specific chronological order, making it simple to locate the Polish legislative framework that now governs the circular economy. A set of rules that show the specifics of the method have been implemented for the most important legal acts. The legislature may overregulate the system through the use of implementation regulations. Implementing practical company endeavours is challenging or impossible due to the systematic structure of the accepted regulations. Business companies pay high organisational and legal expenses. The supreme regulation, which emphasises cleanliness and waste management, demonstrates how the system's methods and operations prevent a sustainable approach. When articulated in this way, the guiding concept of policy toward getting garbage rid is produced by the spirit of legal rules. In the Polish legal system, no rule defines the reuse or maximising value of the raw material. Therefore, excessive control of the system results in a waste management system rather than one that emphasises by products or technology that enable the reuse of raw resources. Similar to how successful recovery is made when priceless value is lost during pyrolysis operations. Regulations lead to a complicated web of legal dependencies and confusing legal assessments of the solutions employed in industrial processes because they do not establish a framework for evaluating economic value and operating to minimise environmental damage.

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The first important element of identifying the involvement, needs and expectations of regional CRC stakeholders was the verification of the perception of legal institutions in the CSS4 area. The diagnosis of formal errors and legal barriers is also information about the reasons for a specific state of involvement. It is also indirectly identifying the expectations of stakeholders towards the legal framework for the functioning of the CSS4 market. Two research methods were used to identify legal and formal barriers: online survey and participant observation.

The survey addressed to selected local government units. The questionnaire was addressed to the municipalities that are part of the Inter-Communal Association of Bzura and neighbours in close proximity - potential members of the developing CRC. A total of 15 responses were obtained. The study was conducted in the period from 01/03/2022 to 03/03/2022. The questionnaire was carried out online. The results show that among the main difficulties of effective involvement of the municipality in selective collected waste are:

- Low level of circular market development and sector diversification,
- The lack of appropriate skills among officers, citizens, scientist and entrepreneurs in building circular market,
- Lack of cooperation between local government units in area of waste management - lack of gaining scale effect,
- Limited access to databases with information about waste and raw materials collected on regional level,
- Lack of databases with market information addressed to companies and society,
- The unusability of waste management databases,
- Lack of cooperation and integrated activities between companies, society, local non-government organisations and academy,
- Lack of regional networks exchange of good practice in scope of waste management,
- Limited access to sources financing CE for local government,
- Limited knowledge of innovative technologies in field of implementing CE,
- Few companies on regional market of waste management (oligopoly market)

To sum up, important issue is local law (i.e. act on order and cleanliness in the municipality) regulating waste management. Those acts are created separately in every municipality. The better solution will be preparing one act for many municipalities. It lets to build the legal framework for Circular Regional Cluster. Creating one act for group of municipalities is allowed by Polish law. In practise the interpretation of this law is different. National entities that control the activities of municipalities (provincial office) impose nationwide, standard, simplified solutions in this regard (separated local acts and limited flexibility of local governments). The following detailed conclusions regarding the research carried out have been formulated:

- Vaguely defined municipalities' responsibilities for waste management and the organization responsible for waste management;

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- Low diversification of the municipality revenue sources in the municipal and industrial waste management system;
- Circular economy regulations are scattered in many legal acts;
- The environmental impact of products and services is not included in the sales price;
- The problem with the enforcement of penalties.

These conclusions are strongly connected with circular economy elements based on all materials: packaging, **plastics**, food, water and nutrients analysed in FrontSh1p project.

An inadequate legal system is not the only barrier limiting the possibility of implementing the circular economy. Each market's development faces various constraints in the form of market failures appearing on it. The most common categories of market failures are public goods, externalities, imperfect competition, incompleteness of the market, and asymmetrical information (Randall, 1983, Stiglitz, 2004, Moreau, 2004, Jackson, Jabbie, 2019). Others also add incomplete property rights to this list (i.e., Perman et al., 2003; Acheson, 2006). A different approach was presented in the evolutionary economy, where the market is perceived as dynamic, chaotic, and constantly changing, rather than tending to a state of equilibrium (Nelson, Winter, 2002, Nelson, 2008, Schmidt, 2018). From this point of view, market failures typical for a neoclassic economy are not failures.

In this report, we looked at the market failure from the circular economy perspective. In a circular economy, it is more often to identify the barriers which derail or slow down the transition towards a CE (Kirchherr et al., 2018). The most common categories of barriers are: technological, economic, institutional and social. De Jesus and Mendonça (2018, p. 77) introduced an additional classification for the above barriers. They divided them into hard ones and soft ones. Hard barriers are related to techno-economic, and soft ones, have to do with regulatory and social issues.

The economy of the Lodz Region is still in process of transition to CE. That is why, we decided to identify “classical” market failures, which are universal for all areas and entities operating within the circular economy. Our research aimed to identify market failures in the circular economy and to assess the level of their occurrence in the Lodz Region. The research was conducted among four groups: business, government, academia and society, who we consider as main actors in the market. To achieve the aim, we conducted two-stage research:

1. Quantitative stage: Survey – online survey conducted among representatives of four mentioned groups. A separate survey sheet was prepared for each group.
2. Qualitative stage: Focus Group Interview (FGI), conducted among representatives of mentioned groups, with the same respondents. FGI research allowed verification of survey results and their interpretation.

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As already mentioned, in the case of CSS 4 “Plastic”, we can identify five main market failure categories: public goods, externalities, imperfect competition, incompleteness of the market, and asymmetrical information.

To be successful in creating a circular economy and in creating a circular economy cluster using plastic as a secondary raw material, good, long-term and stable legal regulations, which market actors will respect, are needed (market failures - public goods). In addition, there is a need to be aware of the benefits and risks of operating on the principles of circular economy (externalities) and willingness to cooperate both on the part of entrepreneurs and other potential cluster participants (imperfect competition) ([https://biznes.newseria.pl [access: 19.08.2022]). In these areas, the largest and most common market failures occur in the Lodz Region, but they are typical for Poland.

Considering the individual groups of participants of the circular economy, the main market failures characteristic of these groups can be identified, which most hinder their participation in the circular economy market. For entrepreneurs, the biggest problem is the quality of the regulations related to the activities of plastic market actors (public goods). The second one is the cost-effectiveness of using secondary raw materials in production processes (externalities). The production of plastics is usually more profitable than their reuse. Another barrier is the insufficient number of measures to stimulate the market for recycled plastics (incompleteness of the market). When looking at society as actors of the circular economy market, a large barrier is the incompleteness of information on the waste collection system (information asymmetry) and lack of awareness of being a link in the value chain of industrial symbiosis (imperfect competition). For a large part of society, the interest in the further fate of the plastic waste produced ends when it is placed in the right container. For the authorities and entrepreneurs, the main barrier is low-quality legal regulations (public goods). Too lenient regulations do not force producers to change and often allow entrepreneurs and society to bypass the regulations. The authorities point to the lack of universal and extended responsibility of producers for the further fate of the plastic products they use, e.g., packaging (externalities). Barriers to better use of the secondary raw material are also incompleteness of information on the waste collection and reuse system (information asymmetry). In turn, the academic community must deal with the problem of crowding out of private finance by public funds (public goods). Another barrier for academics is the insufficient absorption of the proposed solutions in the Regional market - R & D's projects related to CE in the region (incompleteness of the market).

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1.3. Requirements and success criteria to satisfy the implementation of non-technological solutions required in CSS4

The requirements and success criteria to satisfy the implementation of the required non-technological solutions relate to various areas, including in particular:

- the scope and appropriateness of applying incentives,
- identification of areas requiring intensification of the integration processes of regional stakeholders' activities,
- the availability and interoperability of databases related to CSS4 activities.

To be successful in implementing the non-technological solutions necessary for CSS4, a set of appropriate **incentives** is required. Given that CE has such a wide variety of stakeholder groups involved, we assumed that circular economy incentives encourage all relevant stakeholders to implement circular economy into action.

In conducting the need of this task research, the qualitative method was used with three different research techniques. The first was the technique of overt participant observation. The role of the total observer was assumed (Babbie, 2004, p. 309; Marshall, Rossman, 1995, p. 60). Secondly, individual interviews with a standardized list of information searched for (IDI (Individual In-Depth Interview) were conducted. The research tool was scientific and research dispositions, i.e. a list of information sought. It should be noted that the respondents were treated as experts on the subject under study and were selected in a targeted method.

The study also used consisted of the value of observations made through the use of participatory observation, content analysis of the materials collected, and qualitative interviews conducted, as well as analysis of the literature on the subject (scientific articles, reports, EU studies), which indicated the current system of incentives within the implementation of the circular economy in the Lodz region and beyond.

The purpose of the study was to show the regularity of the phenomenon through the typical characteristics of qualitative data analysis: frequency, intensity, structure, processes, causes, and consequences of the process (Lofland, 1995, pp. 127-145).

Being more precise, the process of incentivizing (to implement the objectives of CE), i.e. sending and receiving incentives can be presented by means of the model of communication functioning (Griffin, 2000 p. 554; Dobek, 2002, p. 13; Drzazga, 2004, p.13). The stakeholders of change and therefore the subjects of the process of incentivizing will be Sender (Source)

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and Recipient (Audience). The message will be equivalent to a specific incentive. The research conducted reveals six types of incentive (communication) process models:

1. One-way and two-way communication model: one Sender, one Incentive, one Recipient
2. Mass communication model: one Sender, one Incentive, several Recipients
3. Sector Communication Model: One Sender, One Incentive, Recipient Sectors
4. Multiple Sender Communication Model: multiple Senders, one Incentive, One Recipient
5. The communication model of the plurality of Senders and Incentives: multiple Senders, multiple Incentives, one Recipient
6. The Communication model of the plurality of Incentives: One Sender, multiple Incentives, one Recipient .

The sender formulating the incentives will be first of all the Government, but also in a few cases, the other CE market actors: Society, Company and Academy. The recipient of the incentive, on the other hand, will be mainly the company and Society, and marginally Government and Academy.

The incentive system to support the implementation of CE can be considered for specific groups of waste:

a. Plastics and Rubber
b. Water and Nutrients
c. Food and Feed
d. Wood Packaging

Incentives can be dedicated directly to entrepreneurs and other entities operating in industries specific to a considered waste group, as well as be universal and independent of waste type. As part of the survey, respondents diagnosed two kinds of incentives, claiming that very few are dedicated, and most are universal incentives for waste (raw materials) in general. An example of such a universal incentive is, for example, the system of grants and loans from the National Environmental Protection and Water Management Fund (NFOŚiGW) and WFOŚiGW for the implementation of tasks in the field of environmental protection, including those aimed at implementing CE, provided that the specific task is included in the priorities set for the given year in a resolution of the Board of Directors of the respective Fund. Individuals, entrepreneurs, social organizations, local government, and state budgetary units can apply for these funds.

The main problem with plastic and rubber waste is their multicomponent and the inability to separate the different fractions. The undertaken activities should aim to encourage

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(mainly entrepreneurs) to reduce the production of such waste as much as possible. According to the experts surveyed, the segregation of polystyrene foam as a separate fraction could also be done. With regard to this type of waste, the incentive is therefore a (planned) deposit system. The deposit system is an example of a mass communication model. The sender is one and here is the Legislator, the incentive is the deposit, and the recipients are many. They are, for example, companies, as well as individual residents. In this case, it is also important to build the right habits and change the thinking about plastic packaging as a valuable element of the whole goods. Return to the deposit system, which had already existed in Poland before 1989, has not only an economic dimension but also a socio-cultural one. In the case of plastic packaging, social incentives to reduce this type of waste and/or its proper storage play a major role. Functioning for example bottle machines, having their own reusable cups/bottles. Shaping the desired behaviour is also done through systematic education of children and young people. Incentives are thus aimed at a mass recipient, there may be present also a lot of senders. Here, therefore, model 5 is intertwined with models 2 and 3. Considering plastic packaging, the Act of 13 June 2013 on packaging and packaging waste management (consolidated text Journal of Law 2020, item 1114) imposes an obligation on marketers of such packaging to design and manufacture it in such a way that it can be reused and later recycled (or otherwise reused). In this case, we are dealing with model No. 2, when the Legislator directs an incentive to multiple recipients (entrepreneurs) or sectors. However, it is not a direct incentive, but an indirect type. This is because it results from a statutory obligation and conditionality.

In order to reduce the amount of plastic and rubber waste, it is important to expand the network of incinerators. Currently, in the Lodz region, there are only three incinerators. This is an activity aimed at energy recovery more favourable than landfilling. It should be mentioned that the building of incineration is regulated by precise laws. However, the presence of incineration as an incentive itself fits the basic model of incentive No. 1, where the sender is the legislator and the recipient is a local government. An analogous situation applies to the next incentive, the inclusion of a clause in the Provincial Waste Management Plan about the need for waste processing facilities and recycling points. Such a provision in the future provides the basis for applying for the financing of the project.

Moving on to the problem of identifying the areas requiring the intensification of the integration processes of regional stakeholders' activities, attention should be paid to the specific type of network organization to be created. The crucial element for the existence and development of a circular economy at a regional level can be the presence of clusters operating according to circular economy principles. Clusters have a chance to develop in a territory that has specific characteristics. Contrary to expectations, the territory, i.e. formal and informal institutions, social capital, explicit and tacit knowledge, and specific resources, determines whether a particular environment has produced a proper ecosystem. This ecosystem must be ready to build network relationships based on trust, cooperation and competition

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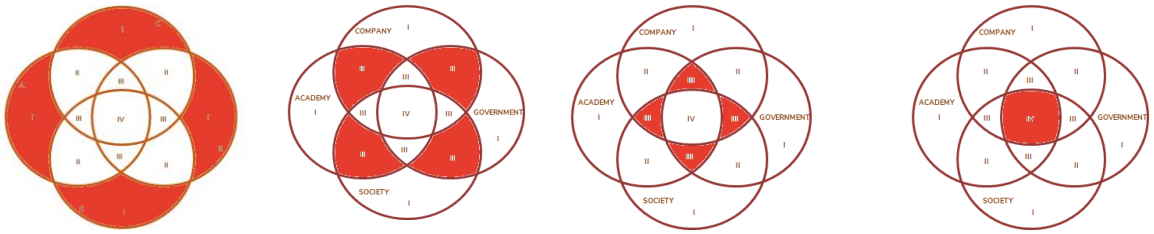
simultaneously. In the case of circular clusters, on the other hand, this environment must have solid environmental awareness. It is a crucial factor because ecological maturity allows or does not allow different stakeholders to build cross-sector business relationships (allows circular chain value creation). Therefore, one of the important studies carried out in the Lodzkie Region CRC area was to identify the degree of integration of activities of stakeholders potentially interested in building CRCs.

The implementation of the circular economy requires the involvement of all four groups of partners responsible for creating CRC: company, academy, society and government. This involvement requires monitoring and coordination. Such coordination should be the domain of public authorities at both the local and regional levels. Integration of activities induces synergy processes and is therefore a function of the speed of change and the dynamics of regional development processes. This element is particularly important when talking about systemic changes - the evolution of a free market economy operating under a linear production model into a circular economy. However, it should be highlighted that integration of activities on a regional scale (CRC) does not necessarily mean direct cooperation between partners. It is most important that the activities of individual partners affect the resolution of the challenges of the other partners to the greatest extent possible. Hence the importance of the study, which aims to identify the scope of impact of the projects implemented by individual CRC stakeholders on the realization of the challenges and objectives of the projects of the other regional partners.

The Leopold Matrix method was used to achieve this goal. The method makes it possible to assess the level of relations between regional partners as measured by the degree of the synergy of their projects. In Frontsh1p, this method was modified to identify the levels of integration between 4 sets of partners: company, academy, society and government. The study analyzed: 187 projects.

The research allowed to identify four types of impacts: intra-sectoral interaction (specific impact), cross-sectoral interaction (between two sets of partners), cross-sectoral interaction (between three sets of partners) Integration (simultaneous integration between all collections of partners) (Fig. 11).

Figure 11. Types of interactions between projects and indicators



[I] intra-sectoral interaction (specific impact)	[II] cross-sectoral interaction (2.level)	[III] cross-sectoral interaction (3.level)	[IV] Integration

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Source: own compilation.

Analysis of the synergy of aims and results of CRC stakeholder activities in the Lodz Region at the beginning allows concluding that projects have been identified in each group that strengthens CE building. However, the sum of such projects is small: 187 projects, implemented in the period 2014-2021 (Company and Academy) and 2019-2021 (Society, Governance). Thus, one can speak of a low level of project involvement of CRC stakeholders in Lodz Region in strengthening CE.

The number of projects that strengthen CE building varies due to the availability of information in the databases and the size of the projects. Nevertheless, it can be noted that in the Company (28) and Academy (28) groups, the selected projects directly relate to activities involving green technologies and are related to environmental protection in various aspects. On the other hand, in the Society (99) and Governance (32) groups, the majority of projects involve activities indirectly related to strengthening CE. Most often, these are projects that strengthen the sense of responsibility, level of participation and social activation, sharing of things, services or reduction of consumption. Less often, these projects involve processes related to recycling and reusing things. The three times higher number of projects in the Society group is due to their fragmentation and small scale of activities. Nevertheless, projects of this type are characteristic of activities undertaken by residents and local community groups. To sum up, projects undertaken directly by local authorities (Governance) and the local community (Society) are rarely about empowerment or inclusion in the Circular Value Chain.

Analysing the findings on the interactions between the regional partners' project activities, it is important to note the relatively large variation in the average ratings for each impact category (Figure 12).

Figure 12. Average ratings of synergistic interactions between stakeholder groups

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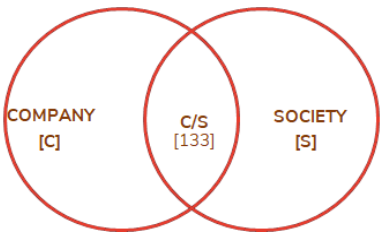
Source: own compilation.

The vast majority of implemented projects by CRT stakeholders are sectoral (2563). These projects do not affect the achievement of results by other partners. They are important from the point of view of strengthening the sector's internal competitiveness, but their synergistic effects on the local and regional environment are marginal. Optimally, the quantities identifying the different levels of impact should be high and balanced. The lack of this level of sustainability is especially underscored by the fact that the assessment of interaction impacts is five times lower (577.25), concerning partnership relations between two groups of stakeholders.

It is difficult to speak of a sustainable level, nevertheless, it is worth noting that there were cross-sectoral projects in the region that effectively achieved their goals and contributed to the achievement of results in three groups (1,381) or all stakeholder groups (1,507).

The most important image illustrating the scope and needs for coordination of integration activities is given by the analysis at the detailed level (Figure 13). This diagnosis indicates the weaknesses and strengths of particular partnerships between regional stakeholders. It is also important to remember that it is not the existence of formal partnerships. Often, in this case, the strength of synergistic effects depends on the level of awareness and tacit knowledge in the CRC.

Figure 13. Scope and levels of synergistic effects among CRC stakeholders in Lodz Region



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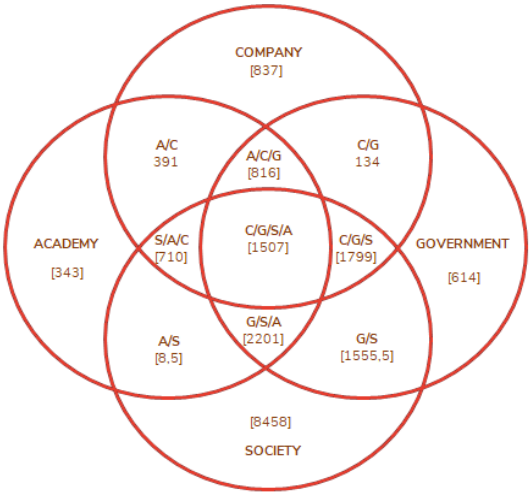

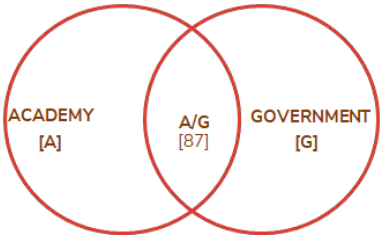

Source: own compilation.

In intra-sectoral interaction, the highest level of self-management of development processes within the sector is observed in the Society group (8458). On the one hand, this is good information. On the other hand, the height of this indicator can be interpreted as a closure of the sector to interactions with other sectors. This conclusion is supported, in particular, by the values of second-level interactions between Society and Company (133) and Society and Academy (8.5), which are practically non-existent. The convergence of the Society sector's internal goals is mainly due to the effect of copying the ideas of neighbours and the specificity and monoculture of non-governmental institutions at the local level. In the Government and Company sectors, the ratios are significantly lower, respectively: 614, 837. Nevertheless, it can be considered that these values are at the average level. In this case, the interaction between the objectives of the projects was determined primarily by the availability of project funding sources. It is about the orientation of the subject matter of the projects by the terms of the grants. The lowest value of the intra-sectoral interaction index is identified in the Academy sector (343). This is related, on the one hand, to the low budget 0for R&D in Poland, sectoral closure and individualism determined by the low degree of territorialization of academic sector entities in the Lodz Region. Sectoral closure usually means the implementation of partnership projects but based on industry similarity of partners, rarely spatial proximity.

The situation at the second level interaction is also a challenge. There is a lack of cross-sectoral sustainability. On the one hand, four areas of neglect can be identified: Academy/Society (8.5), Academy/Government (87), Company/Society (133) and Company/Government (134). The processes of synergistic effects between these areas hardly occur. On the other hand, one can see a positive picture of project relations between the Academy/Company sectors (391). This is not an indicator of a particularly high value, but nevertheless, this scope of cooperation is particularly desirable and difficult in Polish conditions, so it is worth highlighting. On the other hand, the value of the indicator of relations

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between sectors is high: Government/Society (1555.5). This means that local authorities influence the behaviour of residents to a large extent and can carry out coordination activities with great effectiveness.

Particular attention should be paid to the Third level of interaction and integrated impacts. It can be seen that in projects implemented in a group of Government or realizing its goals, the interaction has a balanced and relatively high level (from 1507 to 2201). In another case, for example, in the sets: Society/Academy/Company (710) the value is less than half. We can conclude that the goals of projects that coincide with local or regional development policies have a significantly higher potential for synergistic effects. This also means that an extremely important role has to be played by local and regional Government in the transformation of the traditional economy to a circular economy in the Lodz Region.

In Lodz Region in particular in the CRC, care should be taken to strengthen the synergies obtained through public, private and social investments. Projects undertaken by all regional partners, above all, should be implemented far more often in scopes related to the formation of CE. This effect can be achieved not only by increasing investment budgets but, above all, by targeting resources more precisely to the goals of CE implementation. In this regard, it is also worth emphasizing the importance of Green Public Procurement, which is used to a minimal extent. In contrast, the potential of targeted public spending is high.

Another area that requires intervention is data availability and **database interoperability**. Data interoperability is essential for an effective system of implementing the circular economy assumptions, including implementing solutions required in CSS4. Data interoperability cannot be equated with data integration, which aims to synthesize data from different, independent sources into a unified schema. Data interoperability requires the implementation of both data integration and exchange, so the stakeholders must have access to databases. Interoperability is not a purely technical matter. It is connected with: the organizational level, semantic level and technical level (Pagano et al., 2013; Masud, 2020). The technical level is the most important because it allows for developing the remaining interoperability components.

The methodology of research concerning databases is based on the desk research method. The aim of the study was: the identification of databases containing information related to the circular economy in the region, in particular in the area of Circular Systemic Solutions of the project; identification of gaps in database characteristics; and identification of the level of database interoperability at the technical level.

The desk research allowed us to identify ten databases with information connected to Fronsh1p project. These databases owners were: Statistics Poland (three databases), the marshal's office in Lodz (2 databases), the Ministry of Climate and Environment (two databases), the Head Office of Geodesy and Cartography (one database), the Ministry for

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Education and Science (one database) and the Patent Office of the Republic of Poland (one database).

In the case of CSS4, statistical databases will allow the identification of communes which are the leaders in producing plastic waste. It is connected with the area and the number of inhabitants in it. The limited information about plastic waste in the business sector is available in the databases of Database on Products, Packaging and Waste Management. The gap in this database is the data, to the full extent, are available at the central level. The way to change it is to build the geosystem, which allows for real-time interaction between the chain elements and creates different types of databases, both spatial and statistical. The Marshal Office is potentially an integrator of different types of databases and the information available.

2. Technical Implementation Plan

5.1 T6.2 3D Printer

A. **Project Rationale:**

1. **Project objectives**

- The main objective is to produce a Filament Polymer as a feedstock for a 3D printer.
- 3D printing implementation in repairing schemes and activities in the community.
- To create new job opportunities where the community can learn how to use a 3D printer to repair household materials.

2. **Identify and define a circular economic strategy**

- Provide job opportunities in the community.
- Increase the shelf life of household appliances and furniture.

3. **Formulate measurable targets**

- Decrease plastic waste in the community.
- Less carbon footprint.
- Supports the circular economy

4. **Standard monitoring methods**

1. **Quality control for Feedstock.**
    1. **Homogenous**
        - Feedstock must have only one phase and must have consistency.
    2. **Characterized by type of polymer**

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- Polymeric materials are characterized as elastomers, plastics, or rigid polymers depending on their mechanical properties.

3. With agglomerated phase
   - Agglomerates are loosely held together by physical and chemical forces, depending on the method or process used for adhesion.
4. Low moisture content
   - Moisture impacts the processability of almost all plastics. Feedstock must have low moisture content.
5. Purity
   - In the case of recycled feedstock it is important to check the purity and assess the amount of pollutants (other polymers or black specs). The selection of Recycled grades have to be done on the dimensions of the filter used in the compounding phase (normally film grades or fibre grades are fine).

f. Rheology
   - Is also an important parameter. Rheological test in rotational or capillary rheometer equipment will be done to assess polymer fluidity and stability under shear condition.

2. Quality control for Filament Polymer
   1. High-glass transition temperature
      - polymers with higher glass transitions go through more shrinkage after extrusion.
   2. Melting properties
      - The melt viscosity of a polymer at a given temperature is a measure of the rate at which chains can move relative to each other.
   3. Melt Flow Index
      - A method of measuring the flow properties of melted plastics.
      - A high value MFI means that the polymer is easier to be pushed through the 3D printer nozzle.
      - Low value MFI is also helpful to obtain better mechanical properties (strength and impact resistance) of the final product.

d. Optical Characterization / Visual Appearance
   - Filament Polymers were optically characterised in the range from the UV up to the IR wavelengths, in order to test their possible employment for probe construction in DO applications. To this purpose, measurements with Near Infrared Spectroscopy and Diffuse Correlation Spectroscopy techniques were considered. The results obtained show how the material employed for probe construction can negatively affect the quality of DO measurements.

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3. Records and Data of Plastic Waste

- All plastic waste is collected in a yellow bag or container labelled “Metals & Plastics”. The company collecting municipal waste is obliged to inform the municipality about the lack of or incorrect segregation of waste. It is also obliged to keep quantitative and qualitative records of waste, provide the municipality with monthly reports and waste transfer cards on the type and weight of waste collected. Plastic waste is collected and transferred by the waste collection company to a municipal installation or sorting plant for selectively collected waste, where it is sorted.

5. Legal & Environmental Aspects

1. Legal Aspects
    - Important issues of protecting third-party intellectual rights. If third-party intellectual property was used in creating a 3D model, then both the use and the distribution of the 3D models themselves and the printing of objects on a 3D printer in most cases will infringe third-party rights.

2. Environmental Aspects
    - 3D printing can have a positive impact on the environment, it reduces manufacturing of waste, lowers the carbon footprint and supports the circular economy.
    - An environmental benefit of 3D printing is the ability to print items from anywhere, even in a store or in your home. This theoretically could significantly reduce the need to transport items and therefore lowers the emissions associated with that transportation.
    - 3D-printed products can also be up to 50 percent lighter than those produced with standard methods by using “sparse interior structures” that are impossible to produce using alternative manufacturing methods. This means these 3D printed parts would require less energy to transport.
    - The benefit of decreased distribution is currently limited by the fact that 3D printing isn’t widely used for mass-production, so the emission decreases happen on a smaller scale. That could change, however, as 3D printing technology improves and usage becomes more widespread.

6. Project Location

- Pilot activities will be carried out in the municipality of Parzęczew - a model of a social enterprise creating jobs for people at risk of social exclusion will be developed for the municipality. Educational activities will be piloted in the municipality of Parzęczew.

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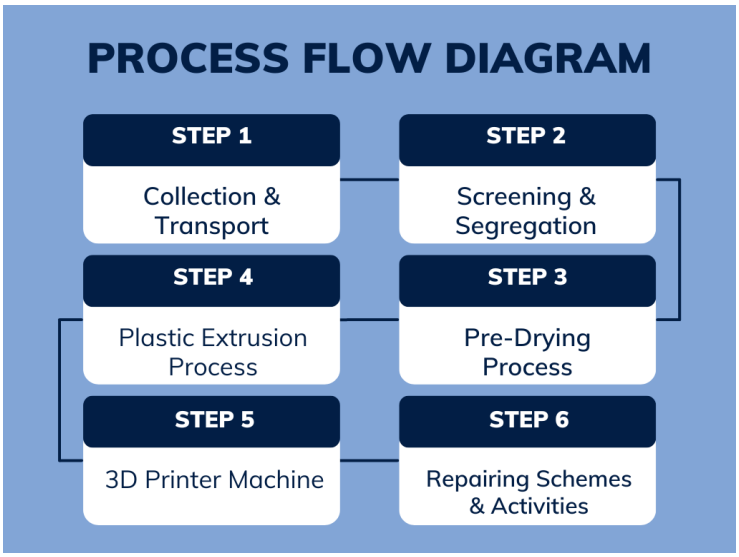
- These activities shall be implemented in Gmina Parzęczew and member communes of the Bzura Intercommunal Association.

B. Process Flow:

C. Process Description:

1. Plastic Waste Collection & Transport:
    - Plastic wastes from different sectors in the community are being collected and transported to the recycling facility. Proper coordination between the community and the hauler company is imperative. The collection rate and quantity of plastic waste must be monitored and recorded.



(to be carried out by PARZECZEW and K-FLEX)

2. Screening & Segregation:
    - Upon the arrival of the plastic waste in the recycling facility, it undergoes a proper screening process to separate the plastic materials according to its classification. It passes through a manual or automated separation process. Plastic waste is identified and categorised before the pre-Drying process. It is being monitored and proper quality control is strictly implemented to ensure the quality of the plastic before feeding it to the Extruder Machine. For post-consumed incoming plastic material some preliminary steps have to be foreseen: cutting, washing to assure the reduction of biological risk. And drying. The team must take into consideration that if the waste does not officially become a product during this stage, it will not be possible to bring the material to the next steps.

(to be carried out by CERTH & TUL)

3. Pre-Drying Process:
    - In this stage, plastic waste as feedstock undergoes a pre-drying process to minimize the moisture content of the plastic polymer. Because hygroscopic polymers attract and absorb water molecules from the atmosphere, they must

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be dried prior to processing to achieve consistent production results regardless of changes in the ambient temperature and humidity conditions that occur throughout the year.

(to be carried out by LP)

4. Extrusion of Filament:
    - After characterization of plastic waste and pre-drying process, when a good quality of feedstock is obtained, plastic polymer is being fed into an extruder machine to produce pellets. In the extrusion step an appropriate screen (i.e. 120 microns) is used to take out impurities and produce a good quality material. First tests will be done using commercial post-consumed polymer grades produced by Sirmax. The 3D filaments will be then produced by proplast and will be the feedstock to the 3D printer machine located in the Lodzkie region. If material modifications are needed, Proplast can help Sirmax in polymer formulation and little scale lab trials to develop materials with enhanced functionality according to the targets that the final application requires. (PROPLAST & SIRMAX)

5. Quality Control / Assurance:
    - Filament Polymer standard monitoring will be implemented to ensure that this product is capable or achieves the desired characteristic as a feedstock for a 3D printer. Testing for its parameters like density, stress, tensile strength, durability, etc. must be continuously conducted.

(TUL will conduct quality control)

6. 3D Printer:
    - It is a machine for designing and building a 3D object. Also known as additive manufacturing, or a method of creating a three-dimensional object layer-by-layer using a computer-created design.

(The 3D printer will be provided by LEDA POLYMER)

7. Repairing Schemes / Activities:

- The market analysis will be preceded by a technological analysis of the use of plastic waste and its use in the creation of 3D printing products and other technologies for the use of plastic waste from the municipal waste fraction (activity conducted with Leda Polymer). Initial planned products for analysis are the possibility of producing filament for 3D printers' spare parts for use in 3D printing products produced by other technology from plastic waste possible for use in: farms, horticulture e.g. flower pots, composters local authority cleaning and landscaping businesses, e.g. flowerbeds,

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urban furniture.

- Activities engaging the local community will includes educational and informational activities within WP6 concerning the use of 3 D printing (activities implemented in Parzęczew commune and member communes of the Bzura Intercommunal Association) mainly in educational institutions information and promotion activities carried out within the framework of WP 7 as campaigns on recycling plastic waste creation of a model social enterprise operating in the area of plastic waste recycling and the use of the above mentioned technology. **(OPUS will engage in this area.)**

D. **Project Timeline:**
The empty cells are to be defined during the task due to its uncertainty level at this stage in research.

Descriptions	Start Date	Milestone	Target Impact	Completion Date
Collection & Transport	Ongoing (M1)	Couple of Tons ready – M13	None	Will keep ongoing
Screening & Segregation				
Pre-Drying Process	M10 – Testing K-FLEX Materials	M13 – Confirmation suitability of materials		End of deliverable
Extrusion Process	M13 – K-FLEX will send standard scrap to Proplast. Sirmax will provide different post consumed PE and PP grades filtered at different screen mesh (different purity level	Filament needed. for right material in the market Identification of waste material with right purity. + How many different filaments?	From K-FLEX Find the conditions to make the extrusion possible to reach the right dimension of filament. + X filaments sent to Poland.	End of deliverable

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Quality Control / Assurance	To be understood (previous step)	//	//	End of deliverable
3D Printer Machine	Evaluation of the right 3d printer	Machine installed in the social enterprise	Support given and material printed	End of deliverable
Repairing Scheme / Activities				

E. Equipment & Machines:

1. Equipment Technical Specifications:

- Pre-Dryer - the common types of plastic dryer machine include rotary wheel dryers, vacuum dryers, compressed air dryers, and dehumidifying dryers. With a Centrifugal Dryer, single screw rubbing drying machine can separate mud/dust, and dry material efficiently, making the product 3% under moisture.

- Extruder - We have a 3Devo system for filament production. Handles temperatures up to 450 °C and Diameter Range 0.5 – 3mm, with an automated control system in principle we can use all type of polymers.

- 3D Printer - We can perform also 3D printing tests using 3NTR industrial Open-source 3D printer having volume of 295x156x200 mm; Triple extruder technology (up to 410 °C); Heated build plate (up to 135°C); Heated chamber (up to 70°C). The quality of the final products will be checked through mechanical tests and morphological tests (optical microscope, SEM) to assess layers adhesion, Thermal analysis.

F. Compliance Documents:

1. Quality Management System Plan
    - A quality management system is a collection of business processes focused on consistently meeting customer requirements and enhancing their satisfaction. It is aligned with an organisation's purpose and strategic direction.

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- A quality management system is a set of policies, processes and procedures required for planning and execution in the core business area of an organisation.
- All activities must adhere to QMS plan and ISO certifications.

2. Environmental Management Plan
   - An Environmental Management System (EMS) is a set of processes and practices that enable an organisation to reduce its environmental impacts and increase its operating efficiency.
   - A system and database which integrates procedures and processes for training of personnel, monitoring, summarising, and reporting of specialised environmental performance information to internal and external stakeholders of a firm.

3. Emergency Response Contingency Plan
   - The purpose of the Emergency Response Contingency Plan (ERCP) is to establish a process to respond to emergency cases during the business operation. This plan would include, but not limited to the following action plans: Implementation plan based on personnel safety. Evacuation plan and posting in all major corridors.
   - The purpose for contingency planning is to better enable a business or organisation to mitigate disruption to the enterprise.

G. Conclusion:

In order to implement a project successfully, it is very imperative that all key stakeholders actively engage during the entire project implementation period. They will be interested in participating in the project when they understand it well. Therefore, there is a need to communicate all project aspects to internal and external key stakeholders.

5.2 T6.3 Insulating Bio-Materials

A. Project Rationale:

1. Project objectives
   - Produce insulating biomaterials from PU, Rub
   - ber, PE, HDPE, and other plastic materials.
   - Overall process must comply with a systematic legal and environmental approach.
   - Determine the reusability of bio-char, bio-gas & bio-oil.

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2. Identify and define a circular economic strategy
   - Increase local resilience with biomaterials
   - Uptake of low-cost and low-impact biomaterials for insulation

3. Formulate measurable targets
   - Decrease plastic waste in the community.
   - Less carbon footprint.
   - Selling of bio-char, bio-gas & bio-oil to the market.

4. Standard monitoring methods

4.1 Quality control for Feedstock

a. Mechanical properties
   - describe the material's reaction to an applied force, such as tension, compression, and impact. The most common type of specimen for testing plastics in tension is commonly referred to as a dog bone because of its tabbed ends and reduced cross sectional area.

b. Chemical properties
   - determine the chemical properties such as permeability, solubility and combustibility. The interaction of chemicals with plastics can take place in different ways, adversely affecting their useful properties at varying rates and to varying degrees.

c. Physical properties
   - ocular and visual inspection of plastic feedstock. Tests to determine the physical properties of plastics: chemical resistance, water and/or moisture absorption and density of a body.

d. Chlorine Content
   - determine the chlorine content of plastic waste to simply classify them according to chlorine content prior to de-chlorination process.

2. Quality control for By-Products
   1. Bio-Oil
      - The bio-oil has higher carbon contents and lower oxygen content than the original raw material and accordingly have higher heating values when compared with higher heating value of the raw material.

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2. Bio-Char
    - Biochar obtained at optimum operating condition is characterised by various physicochemical and analytical methods. Comparing the C, H, O, and N content of biochar and its red algal biomass, it seems that biochar becomes carbonaceous, since the carbon content in biochar is higher than that in red algal biomass.

c. Bio-gas
    - pyrolysis gas contains the basic components of syngas (carbon monoxide, carbon dioxide, and hydrogen), it can be determined thru gas-chromatography and mass spectrometry.

3. Quality control for Product Polymer from Pyrolysis

- Strength: measure of the resistance of a material to external stress.
- Stiffness: measure of the resistance of a material to deformation.
- Hardness: measure of the resistance of a material to deformation under concentrated compressive load.

4. Records and Data of Plastic Waste

- In the Parzęczew municipality, plastic waste is collected in yellow-coloured containers or bags marked "Metals and plastics". Metal waste, including metal packaging waste, plastic waste, including plastic packaging waste, and multi-material packaging waste are collected together in one container/bag. This fraction is qualified under code 15 01 06 - Mixed packaging waste. Part of the plastic waste is collected as part of a separate stream of plastic packaging under code 15 01 02 and plastics, under code 20 01 39. Therefore, we do not have detailed data for plastics and are unable to determine the detailed content of plastic waste collected under fraction 15 01 06 (the contents of the so-called yellow bag).

5. Legal & Environmental Aspects

1. Legal Aspects
    - In disputes over the use and possession of the insulating biomaterials, there has been a marked reliance on property law concepts. Judges frequently resort to the language of "ownership", "gifts", "donations", "trusts" and so on, in order to resolve disputes over the use of insulating biomaterials. When this happens, however, we observe certain recurring mistakes. Judges and academics writing in this area have sometimes misunderstood the basic rules governing the creation and operation of property rights. We do not seek to take a stance on the normative matters at stake. Our aim is to provide an accurate account of how

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property law could operate when applied in the context of the biomaterials use.

2. Environmental Aspects

- Thermal insulation in construction plays an important role in the minimization of operational energy consumption. Currently, insulation is performed via mineral and fossil-derived materials, which require high manufacturing energy. For this reason, attention has been paid to finding clean and energy-efficient alternatives. Subsequently, biomass-based insulation materials have been identified as low- embodied energy materials that reduce energy use and greenhouse gas emissions. These green and sustainable insulation materials fall in line transition in towards low- carbon and positive-energy buildings. In this respect, research works have mostly focused on renewable biomass resources and wastes, the design and production of insulation materials, the testing of their properties and their installation in buildings; however, experts have reviewed their durability and end-of-life management. To fit more in the circular bioeconomy concept, light has been shed in this project on the end-of-life of these biomaterials to avoid their landfilling.

6. Project Location

- Pilot activities will be carried out in the municipality of Parzęczew - a model of a social enterprise creating jobs for people at risk of social exclusion will be developed for the municipality. Educational activities will be piloted in the municipality of Parzęczew.

- These activities shall be implemented in Gmina Parzęczew and member communes of the Bzura Intercommunal Association.

B. Process Flow:

C. Process Description:

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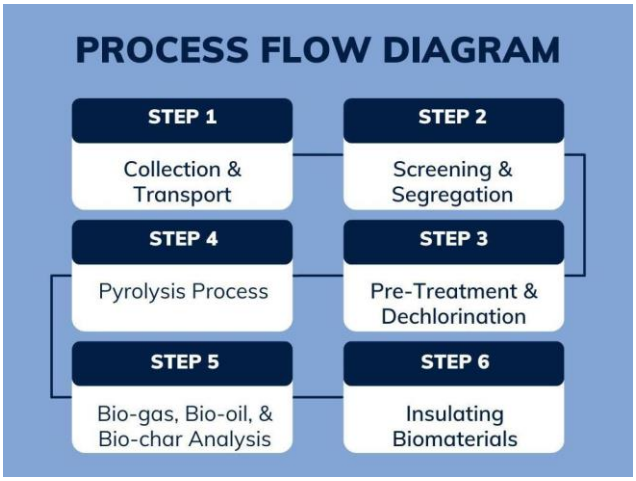
1. Plastic Waste Collection & Transport
    - Plastic waste is collected and transferred by the waste collection company to a municipal facility or sorting plant for selectively collected waste. The waste collection company is required to keep quantitative and qualitative records of waste, provide the municipality with monthly reports and waste transfer cards on the type and weight of waste collected.



(to be carried out by PARZECZEW by K-FLEX)

2. Screening & Segregation
    - Upon the arrival of the plastic waste in the recycling facility, it undergoes a proper screening process to separate the plastic materials according to its classification. It passes through a manual or automated separation process. Plastic waste is identified and categorised before feeding it to the reactor according to its material composition. It is being monitored and proper quality control is strictly implemented to ensure the quality of the plastic before feeding it to the Reactor.

(Can this be carried out by K-FLEX or Waste4Me?)

3. Pre-treatment/Dechlorination Process
    - Once the Plastic wastes have been classified or categorised, it will now undergo a pre-treatment process. Pre-heating and/or dechlorination is a step before being fed to the Pyrolysis Reactor. This is a densification of the plastic material through a compression module to remove gas and other foam-like materials. It will also change its chemical composition and remove all hazardous contents. This enables and optimises feeding rate and improves reaction rates within the reactor.

(to be monitored by K-FLEX & Waste4Me)

4. Pyrolysis Reactor
    - In this stage, pre-heated plastic waste as feedstock undergoes a chemical reaction to change its physical and chemical properties to produce a new form

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of plastic as a final product. This process also produces a by-product which is biochar, biogas & bio-oil. **(to be supplied by Waste4Me)**

5. By-Products
    - By-products from the reactor such as biochar, biogas & bio oil will undergo Quality Control/Assurance. Experiments and laboratory tests are being conducted to determine the reusability and disposability of these by-products. The goal is to extract further energy from these by-products before disposing in landfills. **(QC testing by CERTH and TUL)**

6. Quality Control / Assurance
    - Product Polymers are monitored and tested based on quality to produce bio insulating materials with similar specification but lower in density.

(QC testing by CERTH and TUL and National Technical University of Athens (NTUA) for LCA)

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7. Insulating Biomaterials
    - These final polymers can be used as insulating biomaterials in any type of industry. It is also known in the market because it is a low-cost and low-impact biomaterial for energy efficiency. (K-FLEX)

D. Project Timelines:
The empty cells are to be defined during the task due to its uncertainty level at this stage in research.

Descriptions	Start Date	Milestone	Target Impact	Completion Date
Collection & Transport	Start deliverable			
Screening & Segregation				
Pre-treatment & Dechlorination	M10	Knowledge of the molecular composition of foam.	Possibility of Pyrolysis without breaking the machine.	Pre-condition for Pyrolysis reactor.
Pyrolysis Reactor	At the end of the previous step.		gas and oil to be sent to K-FLEX	End of the deliverable
Quality Control / Assurance				
Insulating Biomaterials				

E. Equipment & Machines:

1. Equipment Technical Specifications
    - Pre-Treatment / Dechlorination - The dechlorination of chlorine containing hydrocarbons in pyrolysis vapour is poorly understood. In order to shed new light on the dechlorination mechanism, a model mixture composed of iso-octane doped with 2-chlorobutane, 2-chloroethylbenzene, and chlorobenzene was used to study the dechlorination of chlorinated hydrocarbons by alkali adsorption. These three chlorinated hydrocarbons were selected as they can be typically produced from the pyrolysis of mixed plastic waste containing polyvinyl chloride (PVC). The mixture is pumped continuously through a

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Na2CO3 or CaCO3/alumina bed, and GC-MS is used to identify the dechlorination products and to follow the dechlorination reactions.

- Pyrolysis Reactor - Pyrolysis is the thermal decomposition of organic compounds in the absence of air/oxygen, starting at temperatures between 350-550oC up to 700-800oC. The long hydrocarbon chains in the biomass break down into smaller molecules in the form of gases, condensable vapours (tars and oils) and solid charcoal. Solids flow down a vertical shaft and contact a counter-current upward moving product gas stream. Made of firebricks, steel or concrete with a fuel feeding unit, ash removal unit and gas exit. Operating parameters include high carbon conversion, long solid residence time, low gas velocity and low ash carry over. Simple & reliable technology for fuels uniform in size with low content of fines. For small scale heat and power applications.

2. Operations & Maintenance Manual
    - This manual will be provided by the equipment and machine supplier who is assigned to produce the task including its technical specifications.

1. Quality Management System Plan
    - A quality management system is a collection of business processes focused on consistently meeting customer requirements and enhancing their satisfaction. It is aligned with an organisation's purpose and strategic direction.
    - A quality management system is a set of policies, processes and procedures required for planning and execution in the core business area of an organisation.
    - All activities must adhere to QMS plan and ISO certifications.

2. Environmental Management Plan
    - An Environmental Management System (EMS) is a set of processes and practices that enable an organisation to reduce its environmental impacts and increase its operating efficiency.
    - A system and database which integrates procedures and processes for training of personnel, monitoring, summarising, and reporting of specialised environmental performance information to internal and external stakeholders of a firm.

3. Emergency Response Contingency Plan

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- The purpose of the Emergency Response Contingency Plan (ERCP) is to establish a process to respond to emergency cases during the business operation. This plan would include, but not limited to the following action plans: Implementation plan based on personnel safety. Evacuation plan and posting in all major corridors.
- The purpose for contingency planning is to better enable a business or organization to mitigate disruption to the enterprise.

G. **Conclusion:**

In order to implement a project successfully, it is very imperative to get all key stakeholders to actively engage during the entire project implementation period. They will be interested in involving in the project when they understand it well. Therefore, there is a need to communicate all project aspects to internal and external key stakeholders.

5.3 T6.4 Foaming with supercritical CO_2

A. **Project Rationale:**

1. **Objectives.**
   - Capture and use of **CO_2** as a building block.
   - Produce PE, rubber, polyurethane and non-isocyanate polyurethane foam expanded with supercritical CO_2 or a mix of $scCO_2$ and isobutane.

2. **Circular economic strategies.**
   - Application of CO_2-based expansion process into new industries in the region.
   - Considering the opportunity of valorising CO_2 even at a lower purity level.

3. **Measurable targets.**
   - Reduction of the use of chemical blowing agents such as azodicarbonamide
   - Injecting of supercritical **CO_2** as foaming agent (also as a replacement of iso-butane)

4. **Standard monitoring methods.**
   1. **Quality control for Feedstock.**
      1. **Homogenous**
         - Feedstock must have only one phase and must have consistency.
      2. **Characterised by type of polymer**
         - Polymeric materials are characterised as elastomers, plastics, or rigid polymers depending on their mechanical properties.
      3. **Low moisture content**

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- Moisture impacts the processability of almost all plastics. Feedstock must have low moisture content.

2. Quality control for Foam Materials.
    1. Strength
        - Foam materials are generally featured by high strength to weight ratio as well as excellent acoustic and thermal insulation properties compared with other engineering materials.
    2. Vulcanization
        - A testing methodology is developed for the characterization of the vulcanization and foaming processes of a polymer/rubber and for establishing the relationship of its physical and mechanical property evolution with vulcanization and foaming process temperature. To establish this relationship, the vulcanization and foaming reaction kinetics and their coupling have been determined, as well as important parameters in the behaviour of the material, such as conductivity, specific heat capacity and coefficients of expansion and foaming. This aforementioned strategy allows the setting of a material model that can be implemented into finite-element (FE) codes to reproduce the material changes during the vulcanization and foaming processes. The material model developed reproduces with enough accuracy the coupling of chemical kinetics of vulcanization and foaming reactions.
    3. Rheology
        - In case of rubber foaming a strategy for proper feeding of material into the extrusion line is assessed. Also, the ideal conditions in terms of mixing and shearing for CO_2 dissolution in the polymer melt are targeted. Finally, the influence of various parameters on foam density and quality is assessed. The most important parameters are: the material rheology (also in presence of CO_2), the expansion ratio, crosslinking time, additives needed to optimise cell structure.

    4. Mixing Components
        - Ratio of components of the foam, mixing temperature, viscosity of raw components, Thermal stability of raw components.

e. For foaming with supercritical CO_2
    - Temperature, operating pressure, time of saturating the polyethylene / rubber / polyurethane compound with $scCO_2$, decompression rate.

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4. Market Research
    - The research conducted in the field will allow for the development of new knowledge which will be published to extend the impact of the project. The knowledge will contribute to the development of technologies of this kind, with special care devoted to direct application in the technology implemented in the K-FLEX installation by Promix.

5. Legal & Environmental Aspects.
    1. Legal Aspects
        - There are still no specific and dedicated laws that protect the consumer with regards to the quality of materials, nor are the producer's responsibilities defined. All the materials must be considered, from the structure to the foam used. Focusing on the foam, the minimum quality standards must be ensured, in order for the foam to maintain its characteristics (such as density, hardness, resilience, recovery) over time. Consumer rights state that the quality of goods and services must be fit for the purposes for which they are intended and produce the effects attributed to them. In fact, there is no law that protects the consumer and effectively guarantees that the characteristics in a foam material are those claimed by the seller or, more importantly, are best suited for the product.
    2. Environmental Aspects
        - The actual environmental impact of the manufacturing of foam is minimal. There are no combustible gases produced. It is actually quite a clean process. The only significant impact on the environment is the energy required to run the foaming line. The same applies for polyethylene foam and rubber. So apart from the aspect of ensuring that the chemicals are stored safely and securely, manufacturing of the foam itself doesn't have much of an impact on the environment at all. What does, is that foam is not biodegradable.

6. Project Location
    - Preliminary rubber foaming trials are done at Proplast in Italy with Promix foaming equipment.
    - Trials with TPE foamed materials are done at Propoplast, same with the polyurethane.
    - PE foaming with reduced use of iso-butane blowing agents will be carried out at K-FLEX facility in Uniejow. Part of the iso-butane will be replaced by $scCO_2$ using Promix foaming equipment.

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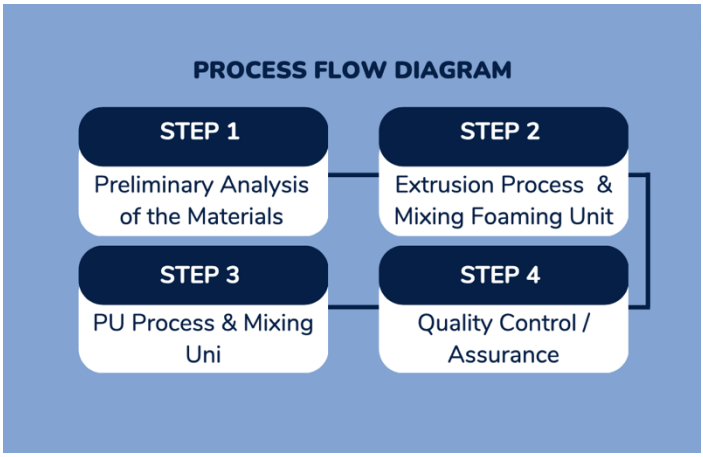
B. Process Flow:

C. Process Description:

Three different foaming processes will be developed according to the three different incoming materials: vulcanised rubber, Thermoplastic (PE and TPE) and Polyurethanes. To such extent a deep testing campaign will be performed by the use of the PROMX deep knowledge on the mixing process. Within the project, mixing processes will be applied in two fields: Once in the field of polyethylene (PE) and rubber foaming and once in the field of polyurethane (PU) and non-isocyanated polyurethane (NIPU)



All the Materials are coming from SIRMAX or K-FLEX, LEDA POLYMER to PROPOLAST.

2. Preliminary Analysis of the Materials

Materials respond in different ways to process change, and every adjustment needs to be made with a solid understanding that a part's dimensions, aesthetics and even function can either be improved or degraded as variables are changed. This enables and optimises feeding rate and improves reaction rates within the CO_2 injection process. It takes a strong and knowledgeable approach toward process setup when adjustments are being made to a process. (to be monitored by K-FLEX & SIRMAX & LEDA & PROPLAST)

3. Extrusion Process + Mixing Foaming Unit

Extrusion is a continuous form of polymers processing that takes place in a grouping of equipment called an extrusion line. Unlike injection moulding or similar processes that rely on repeated “cycles” of mould-filling and part-extraction, extrusion is a process that is ideal for the continuous production of high-quality boards, sheets, profiles, pipes, etc. at very high volumes. In the extrusion process, a resin is molten, compacted and pushed forward using a rotating screw. To homogenise and cool the melt flow exiting the screw, special static mixing equipment from Promix can be installed. The melt is finally exiting the extruder through a die which will give the product its final dimensions.

In case of thermoplastic TPE rubbers, a deep study on nucleating agents, thermal conditions to control CO2 solubility and diffusion, cell dimension will be studied to adapt processing

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conditions to the different polymer formulations produced by SIRMAX. Evaluation of process robustness. Bio-based foam materials that comply with technical, legal, and environmental aspects will be produced. Less CO2 emissions. Less Carbon Footprint. It will be useful to the market. A collaboration between Proplast, SIRMAX and Promix will target the development of TPE foaming using CO2. **(PROPLAST, SIRMAX and PROMIX)**

For physical foaming of PE and rubber, a precise amount of blowing agent ($scCO_2$), partly replacing the currently used isobutane, is injected at high pressure into the extruder using a Promix gas dosing unit. After injection, the gas needs to be solved in the polymer melt. This can be done by using a combination of dynamic mixing inside the extruder barrel (screw) and a Promix melt cooler and static mixer after the screw. **(K-FLEX and PROMIX)**

4. PU process + Mixing Uni

- This is the process for the stabilisation of PU and NIPU. If foaming can be avoided, the mixing process will run smoother, resulting in shortened production times. Whenever powders, solids or other substances are added to a liquid, there is a chance of air-entrapment. This could happen, for example, by the powder, a solid or substance being dumped or absorbed into the liquid. As soon as a mixing element faces these conditions, there is a chance a layer of foam starts forming. Depending on the type of foam, this could massively disrupt the process. Thus, preventing foaming is strongly preferred. A tight collaboration on foaming process parameter study for PU foaming will be held.

LP is studying the best formulation for NIPU production in order to apply the supercritical CO2 technology in this foam production. LP after scouting technology has identified the best raw material in the EU market in order to reach an industrial test in foaming machines. In a first phase LP will evaluate the best reactive conditions on lab scale in order to optimise reactivity, density, viscosity at industrial scale in collaboration with PROPLAST and PROMIX. **(to be supplied by LEDA POLYMER & PROMIX at PROPLAST facility)**

5. Quality Control / Assurance

  - Process adjustment is a delicate process as each change can potentially have a knock-on effect and create additional problems. This is where the skill and expertise of the production team is required to know not only what should be tweaked but how to adjust other variables to avoid unwanted product changes or additional defects. **(SIRMAX, K-FLEX, and PROPLAST will conduct their own quality tests)**

- TUL will conduct a set of numerical studies aiming at assisting the development of the technology with research activities related to the process of rubber extrusion and, in a longer perspective, in the evaluation of the potential key factors influencing the

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foaming process, including SCO2 foaming. Computational Fluid Dynamics simulations (named CFD henceforth) are a powerful research technique allowing predictions of fluid flow processes. The research challenge of this task is to push the limits of knowledge in this field to describe not only the extrusion process but also the foaming process with higher details than the resources available worldwide. They need to be conducted in parallel with experimental tests which deliver all necessary input data and allow for validation of the developed model. When validated, the CFD model can give insight into the details of the processes and assist in their development without the need to perform numerous experimental tests. In case of unsuccessful foaming model formulation, a different strategy will be proposed, such as the combination of numerical simulation with analytical analyses or the application of semi-empirical models. The results of scheduled activities are expected to be supporting the development of technology CSS4. It is also expected that part of results will be disseminated in the form of scientific papers and conference presentations.

Project Timelines:
The empty cells are to be defined during the task due to its uncertainty level at this stage in research.

Descriptions	Start Date	Milestone	Target Impact	Completion Date
PE Extrusion/foaming Process	M12	PE	Remove chemical solvents	
Vulcanized rubber extrusion/foaming process			Remove chemical solvents	
TPE Extrusion/foaming Process			Remove chemical solvents	
PU+ Mixing Foaming Unit			@promix @Leda	
Bio-Based Foam Materials			Sirmax is this the same of TPE?	

D. Equipment & Machines:
1. Equipment Technical Specifications

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- Plastic Extruder + foaming system - One foaming line for thermoplastic materials composed of a single screw extruder equipped with a Promix melt cooler and static mixer for scCO2 injection and an extrusion head for sheets and tubes production. The gas will be dosed using a Promix gas dosing unit. In the scope of replacing part of the currently used isobutane by scCO2 in the foaming of PE, a Promix gas dosing unit and further necessary equipment (melt cooler, static mixer, nucleation additive) are delivered to K-FLEX facility in Uniejow for installation on an industrial scale extrusion line. Two different extruders will be used depending on the temperature needed for the incoming material.

- Low Pressure Mixing foaming unit - For PU, a new low pressure PU foaming unit will be rented by Proplast. a PROMIX static mixer will be added to the lyne in which LEDA polymer will produce the NIPU foams. The mixing will be performed with a low-pressure polyurethane foaming unit. The machine has the output capacity of 22-100 kg/min and the ratio of components A to B of the polyurethane formulation goes in the range of 1:5 - 5:1. The unit is equipped with two tanks where the raw ingredients are provided. The ingredients are then transferred to a mixing head that is able to dose them together in the mass ratio selected previously by the operator on the control panel. The operator can also select the temperature to which each of the components is heated, to ensure obtaining a homogenous mixture. Then the NIPU will be dosed to the pressure vessel where the foaming will be performed using $scCO_2$.

- Computational Fluid Dynamics - CFD simulations of the extrusion and foaming processes are challenging and the state-of-the-art research indicates numerous limitations in their practical implementation. This kind of study requires numerous tests and solutions of the flow problems for complex geometry and specific fluid properties, with complicated fluid-solid and multi-phase interactions. Therefore, in the beginning, TUL will conduct a series of studies of rubber extrusion assuring a good choice of numerical code employed. ANSYS Fluent and POLYFLOW are considered initially. Studies with these codes will be run in parallel to explore the strengths of each software as the flow model becomes more and more complicated. The necessary experimental test will be carried out in TUL to deliver all necessary input data for the model (e.g. fluid viscosity characteristics) and to validate it. Afterwards, the experimental setting will be proposed to explore the basic physics of the foaming and the possibility of including this multi-phase process in CFD simulations. In the case of successful model development, the simulations of combining the extrusion and foaming processes will be performed. Besides the CFD software, high-performance workstations will be dedicated to run simulations.

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E. Compliance Documents:

1. Quality Management System Plan
    - A quality management system is a collection of business processes focused on consistently meeting customer requirements and enhancing their satisfaction. It is aligned with an organisation's purpose and strategic direction.
    - A quality management system is a set of policies, processes and procedures required for planning and execution in the core business area of an organisation.
    - All activities must adhere to QMS plan and ISO certifications.

2. Environmental Management Plan
    - An Environmental Management System (EMS) is a set of processes and practices that enable an organisation to reduce its environmental impacts and increase its operating efficiency.
    - A system and database which integrates procedures and processes for training of personnel, monitoring, summarising, and reporting of specialised environmental performance information to internal and external stakeholders of a firm.

3. Emergency Response Contingency Plan
    - The purpose of the Emergency Response Contingency Plan (ERCP) is to establish a process to respond to emergency cases during the business operation. This plan would include, but not limited to the following action plans: An implementation plan based on personnel safety. An Evacuation plan and posting in all major corridors.
    - The purpose for contingency planning is to better enable a business or organisation to mitigate disruption to the enterprise.

F. Conclusion:

In order to implement a project successfully, it is very imperative to get all key stakeholders to actively engage during the entire project implementation period. They will be interested in involving in the project when they understand it well. Therefore, there is a need to communicate all project aspects to internal and external key stakeholders.

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I.T6.5 Ecodesign and circular economy business models of the Systemic solution 4

A. Project Rationale:

1. Framework and Objectives

- In T6.5 NTUA will perform a Life Cycle Assessment (LCA), Social Life Cycle Assessment (S-LCA) and Life Cycle Cost (LCC) study over CSS4. A sensitivity analysis will be conducted, to identify environmental hotspots of CSS4 technological pathway. The results will serve as a basis for proposing configurations to the solution's value chain to minimize the environmental impact.
- The LCA/S-LCA and LCC will be performed in accordance with the 14040:2006 - Environmental Management - Life Cycle Assessment - Principles and Framework and 14044:2006/A1:2018 - Environmental Management – Life Cycle Assessment — Requirements and Guidelines (based on ISO 14044:2006/Amd 1:2017) and the International Life Cycle Data (ILCD) Handbook. The ILCD Handbook further specifies the provisions of ISO 14040 and 14044 standards on environmental LCA.
- The study's objective is identifying potential and existing value chains for CSS4, using the EU-17 procedure.

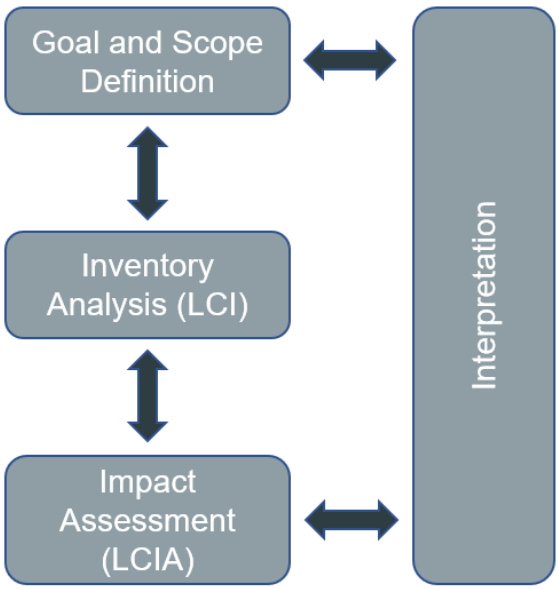

Figure 14. Life cycle assessment framework

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B. Process Description:

1. Goal and Scope Definition

- The goal of the study is the evaluation and communication of potential impacts for the proposed CSS4.
- The first step of the LCA implementation is the definition of the product system and system boundaries. NTUA will review the outcomes of WP6 to establish a baseline scenario.
- The second step is defining the Functional Unit (FU) to which the environmental, societal and economic impact will be connected to.
- Cut-off criteria will be applied, to decide the inputs considered in the assessment, such as mass, energy and environmental significance, simplifying the system while maintaining the result's quality.
- The next step of implementation is the allocation procedure, in accordance with the ISO 14044:2006 for multi-functional systems with many products delivered by the system.
- After defining the LCA's goal and scope, the impact categories under consideration will be defined, such as Global Warming Potential (GWP 100 years).

2. Life Cycle Inventory (LCI) construction

- Following the definition of the impact categories to be examined, LCI data will be collected to perform the impact assessment. Such data will concern:
    - Material inputs, including major and auxiliary materials
    - Water inputs
    - Energy inputs, including all fossil fuels, non-fossil fuels, electricity, and purchased thermal energy
    - Product, intermediate product and by-product outputs
    - Environmental releases such as air, water and solid waste releases
    - Waste treatment mechanism (e.g., treated, non-treated, recycled, landfilled, etc.)
    - Processes description at the various production stages included in the system
    - Information for the Plant

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- Source of major and auxiliary materials
- Information on the transportation inside the system boundaries (e.g., type of transportation, distances, energy type and consumption, etc.)

- LCI data will be gathered by measurements from the pilot sites, to ensure a technologically representative database. To this end, NTUA will construct an LCI data collection questionnaire to be distributed among the involved project partners. In case of insufficient data, information will be drawn by other sources.
- Integrated databases in GaBi for raw materials, wastes, products and processes (Ecoinvent, ELCD of EC-Joint Research Center and others) will complement the data acquired by the questionnaire. The datasets of GaBi will be assessed for the applicability in the particular study and used accordingly.

3. System and LCI database modelling and developing

- The GaBi commercial software package will be used for modelling and developing the system and LCI database. The final LCI data will be a mixture of measured, calculated or estimated data, from real stream analysis, GaBi database and the actual performance of the demo plant (power consumption, mass and energy balances etc.) relying strongly on the data collected from the questionnaires.
- NTUA will provide a detailed time plan for remote interviews and meetings with partners for the collection of data. This action will allow for the construction of a concrete LCI database, collecting previously missing information and ensuring the data is up to date.
- After data collection, a thorough review of the all the info related to CSS4 will be conducted in terms of quality and sufficiency.

4. LCIA results interpretation and exploitation

- After system and LCI database construction, the LCIA results will be calculated, evaluated and finally interpretated, identifying the significant issues and environmental “hotspots of the system to assess its viability as the final product of the study.

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- During the implementation period, a minimum of two meetings with WP partners will take place concerning the preliminary actions for the LCA/S-LCA and LCC and reviewing the final implementation decisions.
- An internal report will also be conducted and updated on a six month basis, concerning the approach and methods, to enable the actions and process tracking, moving towards the final report.
- The LCA/S-LCA and LCC analysis results will serve as the basis for proposing a circular model economy, suited for the specific needs and expectations of the involved stakeholders, concerning environmental impact, economic viability etc.

C. Project Timeline

Descriptions	Start Date	Milestone	Target Impact	Completion Date
Data Collection	M1	LCI questionnaire finalization, data collection roadmap definition		M12
Data Collection	M1	Data collection and review of available info related to CSS4		M12
LCA/S-LCA/LCC goal and scope	M12	Review of WP outcomes, establishment of baseline, LCA/S-LCA and LCC framework definition		M14
Data Collection	M12	Remote interviews and meetings with partners for data collection		M14
Data Collection/Impact Assessment	M1	A minimum of two meeting with WP partners related to preliminary actions for LCA and final decisions-review		M18
Impact Assessment	M1	Internal Report - LCA approach and methods -to be updated every 6 months		M24
Impact Assessment/ Interpretation	M12	LCA/S-LCA/LCC final report		M48

D. Conclusions

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To implement the LCA/ s-LCA and LCC analysis successfully, communication with all related partners is key. Through efficient communication, as well as remote interviews and meeting, a concrete and up-to-date database can be constructed, for a most representative simulation of the system and its processes, facilitating the generation of high accuracy results. These results will serve as the basis for the evaluation and optimisation of the CSS4 technological pathway towards the most beneficial adaptation.

6. Plan for citizens engagement in activities carried out under the Circular Systemic Solution (CSS) 4 “Plastics”

The report's final section will present a road map of diagnostic research and implementation activities to engage citizens in the activities implemented under CSS4.

2.1.1. Characteristics of social involvement in circular economy and its indicators in EU literature and documents

The study is based on the literature.

Title: “Indicators of social commitment to the circular economy”.

Implementation methods: descriptive analysis of desk research literature.

Schedule: December 2021 – March 2022.

2.1.2. Definition of citizens engagement in a circular economy (CE)

The study made on the basis of literature. Will be interactively modified in the course of implementation of the activities provided for in this plan.

Methods of implementation: descriptive analysis of *desk research* type literature and expert discussion.

Schedule: implemented in March – April 2022 (version 1);

June – September 2022 (version 2).

In the course of further work, the wording of the definition might be updated (according to the identified problems, in particular with regard to the forms of citizen involvement and the possibility of supporting them).

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Content of the definition (abbreviated):

Citizens' engagement in the circular economy refers to the involvement of the public (households and communities) in activities (processes) for the implementation of the solutions that make up the circular economy system (CES), otherwise known as the circular economy (CE) or closed-loop economy (CLE). This concept means, first of all, involvement in real processes related to management (processes from the real sphere), that is, undertaking specific practices, i.e. those that bring material effects consisting in increasing the degree of circulation of natural resources in the socio-economic system, and, consequently, in reducing the anthropogenic impact on the natural environment, first of all, from generation and accumulation in it of various types of waste, mainly the post-consumption waste, i.e. the waste accompanying consumption (therefore, this refers mainly to the so-called municipal waste).

The practices of households in the field of CE may be initiated and supported by various types of activities (instruments) undertaken (applied) by public entities, non-governmental organizations, etc. These supporting activities should also be analysed as part of research on social involvement in CE.

Social involvement in a closed loop economy, in a broader sense, may also refer to regulatory processes related to management (processes from the regulatory sphere), i.e. those that are related to designing of organisational solutions aimed at increasing the degree of natural resources circulation in the socio-economic system, and thus reducing the anthropogenic impact on the natural environment, mainly from generation and accumulation of various types of waste, mainly post-consumption waste, i.e. waste that accompanies consumption (thus mainly municipal waste).

We define the activities of citizens (households) for the circular economy as real (and not only declarative) involvement in the following practices and processes:

- refusing (e.g. not necessary consumption of goods; elimination of unnecessary / harmful consumption),
- reducing (consumption of goods in order to lower the physical flow of matter in economic processes),
- reusing (the multiplication of the use of material goods for their current purpose),
- refurbishing (renewal of material goods in order to restore the original functionality and extend the life time),
- repairing (fixing of broken or damage material goods),
- repurposing (finding new applications and functionalities for material objects already used up for their original purpose),

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- recycling (processing material goods into new, secondary raw material),

as well as activities not directly related to CE, but supporting such practices:

- sharing (using one item / material good together with other households in order to increase the intensity and efficiency of use),
- leasing (rental systems of material goods),
- and segregation and selective collection in the local waste management system.

Analysing (researching) activities supporting the involvement of citizens (households) in the above-mentioned practices for the benefit of circular economy will consist in assessing the effects of initiatives undertaken by public institutions, non-governmental organizations, or other entities, such as:

a) activities increasing awareness and knowledge of issues related to the circular economy (soft activities),

b) action modifying the behaviour of citizens (households) in the sphere of managing material resources, in an institutionalized manner, i.e. as a result of the application of legal and administrative coercion, as well as through a system of incentives and / or negative incentives – respectively: forcing, stimulating or discouraging to specific activities (practices) (hard actions of a command-control nature, regulations and economic instruments);

c) activities involving citizens in the process of creating system and regulatory solutions in the field of circular economy (activities such as: regulations by reaching an agreement and co-creating policies and participation in decision-making processes);

d) activities encouraging citizens (households) to behave and practice consistent with the concept of circular economy, introduced by private entities on the basis of self-regulation (voluntary regulation).

Ad. (a) awareness-raising and awareness-raising activities are targeted at citizens as audiences and include, inter alia:

- information activities,
- educational activities,
- promotional activities (e.g. targeting the creation of new social trends in the field of CE),
- advisory activities.

Awareness and knowledge-raising activities can be carried out by very different entities, i.e.:

- national (central), regional and local authorities,

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- non-governmental / social organizations, social partners (?),
- private and public enterprises,
- educational and educational institutions.

Ad. b) actions modifying the behaviour of citizens (households) in the field of managing material resources, in an institutionalized way, they include legal regulations and economic / financial solutions that can be introduced by local, regional and central authorities to persuade, force, encourage or punish a citizen for application or non-compliance with specific practices in the field of circular economy, and which are of interest to public policy (public interest sphere). These activities include, for example:

- introducing an obligation to segregate and separate waste collection,
- introducing a system of fees (e.g. for products, recycling) and penalties, as well as subsidies by national / local government authorities,
- introducing an obligatory deposit system when using specific packaging by producers,
- other.

Ad. c) activities involving the process of creating systemic solutions, including in particular regulatory ones, in accordance with the principle of co-management (governance by co-governance) – they include the involvement of citizens as participants and stakeholders in the processes related to the organization of the material resource management system itself (in particular waste management) on levels: strategic, operational and related to the creation of draft legislative solutions to support circular economy. These activities can be implemented on various scales: local / regional / national and may include, for example:

- participation of citizens in consultation processes and co-creation of various types of public documents (concepts, policies, strategies, plans, programs) describing the directions of activities relating directly or indirectly to the issues of circular economy,
- participation of citizens in legislative initiatives (e.g. legislative initiative),
- participation of citizens in advocacy and lobbying activities (including, for example, petitions to the authorities),
- activities undertaken by citizens within the so-called non-statutory planning,
- other.

Ad. d) activities encouraging citizens (households) to behave and practice consistent with the concept of circular economy, introduced by private entities (e.g. commercial establishments, service entities) on the basis of self-regulation (voluntary regulation). This includes activities such as:

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- voluntary introduction of deposit systems, e.g. for the return of certain types of packaging,
- introducing free collection services for used tangible goods when purchasing a new one,
- others.

2.1.3. Comments on the social acceptance of the circular economy

The study is based on the literature.

Implementation methods: descriptive analysis of desk research literature and expert discussion.

Schedule: March 2022.

6.2 Scope and areas of citizens (households) engagement under CSS 4 "Plastic"

6.2.1 Identification of the expected citizen (household) involvement for a given CSS

As part of this section, an assessment will be made of the feasibility of applying circular economy activities at the household level, which, as a result of the previous analysis, included the following practices:

- refusing,
- reducing,
- reusing,
- refurbishing (renewal),
- repairing (fixing),
- repurposing,
- recycling (processing),

as well as activities not directly related to CE, but supporting such practices:

sharing,

- leasing (rental).
- and segregation and selective collection in the local waste management system.

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The starting point for performing such an assessment is a technical report. The assessment is to demonstrate to what extent an action (practice) from the group is necessary for the introduction in the local/regional circular economy system of the designed technical solutions for CSS 4 Plastic.

Table 13. Analysis/assessment chart of the feasibility of household practices for implementing solutions in each CSS

Practice name (practice categories)	CSS Plastic
Refusing	
Reducing	
Reusing	
refurbishing (renewal)	
repairing (fixing)	
Repurposing	
recycling (processing)	
segregation and selective collection in the local waste management system	
Sharing	
leasing (rental)	

NOTE: the table is used to initially identify the link between a given practice type and the activities anticipated under a given CSS type, using the following designations:

- practices needed to implement CSS (PN),
- practices to support CSS implementation (PS),
- general practices - i.e., directly unrelated to the implementation of CSS (to increase citizens engagement in circular economy solutions in general (GP),
- lack of practices adequate for the activities envisioned in a given CSS (LP).
-

Source: own study.

Methods of implementation: surveys with the participation of leaders of individual CSS and WP activities and also descriptive analysis of the survey as well as expert discussion.
Schedule: November 2022 – January 2023.

6.2.2 Characteristics of the specifics of the expected household practices identified for CSS 4

For each category of practice identified for a given CSS, a subject (essential) description will then be made of the activities that households are expected to undertake. This description will provide a characterization of the expected households engagement in activities in a given CSS. In the summary of the description, a breakdown of the activities can be made:

- indispensable – i.e., conditioning the ability to implement the technological activities envisaged in the project;
- supportive – i.e., enhancing the effectiveness of the implementation of technological activities envisaged in the project, but not necessary for its implementation;

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– general – i.e., raising the general level of public awareness of the need to take action for the circular economy on the issues addressed in a given CSS.

Conducting the analysis indicated in Table 1 and then performing the above description will further allow us to determine whether there are any areas of common practice for each CSS, which can then be standardized at the regional/local implementation level (Table 13A).

Table 13A. Assessment of the feasibility of direct household practices for implementing solutions in each CSS – summary table

Practice name (practice categories)	CSS type / name			
	CSS 1	CSS 2	CSS 3	CSS 4
refusing				
reducing				
reusing				
refurbishing (renewal)				
repairing (fixing)				
repurposing				
recycling (processing)				
segregation and selective collection in the local waste management system				
Sharing				
leasing (rental)				

NOTE: the table is used to initially identify the link between the type of practice and the activities envisaged under the type of CSS, using the following designations:

- **practices needed** to implement CSS (PN),
- **practices to support** CSS implementation (PS),
- **general practices** – i.e., directly unrelated to the implementation of CSS (to increase citizens engagement in circular economy solutions in general (GP),
- **lack of practices** adequate for the activities envisioned in a given CSS (LP).

Source: own study.

Methods of implementation: Descriptive analysis of the survey, comparative analysis and expert discussion.

Schedule: February – April 2023.

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6.3 Types of activities dedicated to supporting social engagement in CSS 4 (analysis of conditions and selection of instruments)

6.3.1 Identification of the determinants of social involvement of citizens (households) and the possibility of undertaking practices for activities in a given CSS

The activity will identify the determinants that influence households to undertake the practices identified in 5.2.1 and 5.2.2 for CSS. The logic diagram for such identification is presented in Table 14. This analysis will be carried out separately for each CSS.

Table 14. Diagram for identifying / analysing / assessing the determinants of the application of household practices for the implementation of solutions in the framework of CSS 4 "Plastic"

Determinants of social commitment / citizens (households) engagement in CE (CSS)	Name of practice (practice categories)									
	refusing	reducing	reusing	refurbishing (renewal)	repairing (fixing)	repurposing	recycling (processing)	segregation and selective collection in the local waste	sharing	leasing (rental)
Technology (increasing accessibility)										
Awareness and knowledge (improvement through education)										
Coercion (creation of legal and administrative solutions with an enforcement mechanism)										
Stimulus: stimulant / destimulant (creation of economic and financial solutions)										
Best practice (dissemination, popularization)										
Cultural pattern										

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(creation and dissemination)										

NOTE: the table is used to identify the determinants of social engagement of households in undertaking practices for the implementation of activities/solutions envisioned in a given CSS. Identification using scale:

- very important / key condition (conditioning the effectiveness of CSS activities - essential),
- essential condition (supporting the effectiveness of CSS activities),
- conditionality generally supportive of public commitment to CE,
- no relationship or marginal importance of a given determinant for undertaking practices in a particular area (no or insignificant impact on the implementation of activities under a given CSS).

Source: own study.

Methods of implementation: Matrix analysis of conditions based on information / data received from local government partners (local communities & authorities, union of municipalities) participating in the project. Expert discussion using the Delphi method.
Schedule: the months of May – June 2023.

6.3.2 Analysis/ assessment of the importance of the various identified determinants of citizens engagement of households in undertaking practices for activities in a given CSS

In this activity, a descriptive analysis (assessment) of the relevance of the various identified determinants that affect households' uptake of the practices identified in Section 5.2.1 and 5.2.2 for CSS will be made. The analysis will be used to develop a summary that identifies key determinants of the effectiveness of households' undertaking practices relevant to the implementation of CSS activities. Recognition of these conditions, and determinants will be necessary for the identification and, finally, programming (on a local / regional scale) of activities supporting households in their involvement in CSS 4 and the selection of instruments for this purpose (Section 5.3.3).

Methods of implementation: Expert discussion. Descriptive analysis of the study.
Schedule: May – June 2023.

6.3.3 Identification of instruments (tools) to support household practices in their commitment to activities within framework of CSS 4 "Plastics"

The activity will include the initial identification, review and mapping of instruments that can potentially influence households to undertake the practices for implementation of CSS 4 identified in Section 5.2.1 and 5.2.2. The starting point for the selection of instruments is the

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analysis performed in Section 5.2.2. The logic diagram for such identification is presented in Table 15. This analysis will be performed separately for each CSS.

Table 15. Flowchart for identifying / analysing / evaluating instruments to support household practices for implementing solutions for each CSS (separately)

Instruments / tools to promote social engagement	Name of practice (practice categories)									
	refusing	reducing	reusing	refurbishing (renewal)	repairing (fixing)	repurposing	recycling (processing)	segregation and selective collection in the local waste management	sharing	leasing (rental)
Promotional activities/ initiatives										
Educational activities/ initiatives										
Information and consultancy activities/ initiatives										
Financial incentives (positive and negative)										
Legal and administrative regulations										
Co-creating solutions (consultations, workshops, forums, referenda)										
Self-regulation (voluntary regulation)										
Other										

NOTE: the table is used to identify instruments to promote social engagement of households in undertaking practices for implementation of activities/solutions envisioned in a given CSS. Identification using scale:

- very important / key instruments (conditioning the effectiveness of CSS activities - essential),
- essential instruments (to support the effectiveness of CSS activities),
- Instruments generally supporting social commitment to CE,
- no relationship or marginal importance of a given instrument for undertaking practices in a particular area (no or insignificant impact on the implementation of activities under a given CSS).

Source: own study.

Methods of implementation: Matrix analysis based on the literature review and previous work provided for in this plan. Expert discussion using the Delphi method.
Schedule: June – August 2023.

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6.3.4 Description of recommended instruments (tools) to support household practices in their commitment to activities within the framework of CSS 4

The activity will carry out a descriptive conceptualization of the instruments that should be used at the level of the local/regional territorial system for supporting household practices (identified in Section 5.2.1 and 5.2.2), the undertaking of which will contribute to the implementation of the activities envisaged under the given CSS and increase community engagement in the CE in general. The starting point for the detailed characterization of the instruments is their preliminary overview made in Section 5.3.3. The description of the instruments should include their assignment to following subjects:

- municipal / community local governments,
- county local governments,
- regional local governments,
- non-governmental organizations (NGO's),
- scientific and research entities, academic institutions,
- private entrepreneurs,
- public entrepreneurs,
- households,
- others (?).

Methods of implementation: Expert discussion. Descriptive analysis on the basis of literature review and previously performed work provided for in this plan.
Schedule: months of August – September 2023.

6.3.5 WP-specific activities implemented under the framework of CSS 4

Within the framework of WP 6 T.6.2 activity, activities related to the conduct and dissemination of 3D printing technology in local communities covered by project activities are envisaged. The activities described in sections 5.3.2 and 5.3.3 will include informational and educational activities on the use of 3D printing in households.
Under Measure 5.3.5, the following will be conducted:

- analysis of the possibility of household engagement in the needs of using 3 D printing in everyday life,
- analyse the technological feasibility of using waste to create filament and involve the local community in the operation,
- information and education activities on the use of 3 D printing.

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Methods of implementation: focus research in the local community on the needs for the use of 3D printing, technological analysis, expert discussion
Schedule: months November 2022 – October 2025.

6.4 Schedule of activities for citizens engagement in the implementation of activities within the framework of CSS 4 "Plastic"

Below (Table 16) is an overview of planned CSS4 activities related to citizens engagement in the form of a goal – implementation matrix.

Table 16. Activities planned for citizens engagement in the implementation of CSS 4 "Plastic"

Objective of activities	Planned activities	Lead time	Contractor/ leader	Place of implementation
Identification of needs regarding the scope of social involvement of citizens (households) within a given CSS (4)	[5.2.1] Identification of the expected citizen (household) involvement for a given CSS	November 2022 – January 2023	OPUS	All technical partners under CSS 4
	[5.2.2] Characteristics of the specifics of the expected household practices identified for CSS 4	February – April 2023	OPUS	All technical partners under CSS 4
Identification and analysis of conditions and selection of instruments to support the social involvement of citizens within the CSS (4)	[5.3.1] Identification of the determinants of social involvement of citizens (households) and the possibility of undertaking practices for activities in a given CSS	May – June 2023	OPUS	Activities planned for use in the region of Lodz and the municipality of Parzeczew and on the territory of the Bzura Intercommunal Union
	[5.3.2] Analysis/ assessment of the importance of the various identified determinants of citizens engagement of households in undertaking practices for activities in a given CSS	May – June 2023	OPUS	

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	[5.3.3] Identification of instruments (tools) to support household practices in their commitment to activities within framework of CSS 4 "Plastics"	June – August 2023	OPUS	
	[5.3.4] Description of recommended instruments (tools) to support household practices in their commitment to activities within the framework of CSS 4	August – September 2023	OPUS	
Increase knowledge of the use of 3D printing in local communities	[5.3.5] WP-specific activities implemented under the framework of CSS 4 – use of 3D printing a) educational activities for the local community	November 2022 – October 2025	LEDAPOLYMER /OPUS	Activities planned to be carried out in the municipality of Parzeczew and on the territory of the Bzura Intercommunal Union

Source: own compilation.

The action plan for CSS 4 is linked to activities under WP 7 where individual activities will be implemented in the form of community testing.
The complementary catalogue of activities which are going to be launched under WP 7 framework are presented in Table 17.

Table 17. Catalog of complementary activities to be launched under WP 7 framework

Objective of activities	Planned activities	Lead time	Contractor/Leader	Implementation sites
Increase the knowledge of the region's residents concerning activities within the framework of CSS 4	Outreach activities: a) information campaigns on CSS 4, e.g., through traditional information channels (local media, social media); b) preparation of informational materials for residents in print and electronic form on CSS4 solutions (e.g. posters, podcasts, educational videos); c) creation/ establishing of a dedicated fan page on the local		Veltha	Activities planned for use in the region of Lodz and the municipality of Parzeczew and on the territory of the Bzura Intercommunal Union

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	community social media platform regarding all CSS; d) participation in local cultural events that will present the assumptions of the circular economy. circular economy.			
	Educational activities a) hybrid thematic seminars (online and onsite) on the use of, for example, 3 D printing b) training on the implementation of circular economy goals and design objectives - applicable to all CSS, c) educational activities for kindergartens, schools, including competitions for children in the area of CSS4		Veltha OPUS /Ledapolymer under CSS4	Activities planned for use in the region of Lodz and the municipality of Parzęczew and on the territory of the Bzura Intercommunal Union
Increase engagement of residents in the activities within the framework of CSS 4	a) local micro-grant programs for residents to promote closed-loop economy solutions including those dedicated to CSS 4		OPUS /municipality of Parzeczew/ ZMB	Activities planned for use in the region of Lodz and the municipality of Parzęczew and on the territory of the Bzura Intercommunal Union

Source: own compilation.

6.5 Social enterprise co-creation model developed for CSS 4

6.5.1 Analysis of examples of how social enterprises operate within the circular economy

As part of the activity, an analysis of examples of social entrepreneurship development in the CE area operating in the world and Poland was conducted. The report was developed with a particular focus on the areas of activity covered by the framework of CSS's, included in this project.

Methods of implementation: descriptive analysis of desk research type literature outline & review and expert discussion.

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Schedule: implemented in August – September 2022.

6.5.2 Identification and analysis of conditions/opportunities for the development of a social enterprise using CSS 4 solutions

The activity will identify and analyse the conditions/opportunities for the development of a social enterprise using the solutions within a given CSS. The starting point will be:

a) technological analysis of the feasibility of using the solutions in the framework designed under CSS 4,
b) technological analysis of the possibility of using plastic waste in solutions for the production of products such as public utilities (urban furniture),
c) the analysis of market conditions will be done using the Business Model Canvas template, i.e. broken down into elements such as:
   - customer segmentation,
   - value proposition,
   - distribution channels,
   - customer relationships,
   - revenue structure & streams,
   - key resources,
   - key activities,
   - key partners,
   - cost structure.

Methods of implementation: Expert discussions. Workshops. Descriptive analysis.
Schedule: November 2022 – January 2024.

6.5.3 Business plan for a social enterprise focusing on CE

As part of the measure, a business plan for a social enterprise will be created, taking into account local conditions for the area of the Parzeczew municipality and the Association, taking into account the possibility of creating jobs for people at risk of social exclusion.

Business plan schedule includes:

1. company characteristics:
   - business object,
   - social and economic goals,
   - enterprise values,
   - social capital,
   - SWOT analysis of the company;
2. marketing plan:
   - product/service description,

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- market analysis,
- promotion;

3. financial analysis:
   - revenue and cost analysis,
   - investment plan.

Methods of implementation: Expert discussions. Workshops. Descriptive analysis.
Schedule: June February – December 2024.

6.5.4 Description of the social enterprise project using the solutions within the framework of given CSS

The activity will describe a project for the development of a social enterprise using CE solutions within a given CSS. The starting point will be the analysis of the conditions for the development of such an enterprise made in general in section 5.5.1 and – especially – in Section 5.5.2 as well as 5.5.3.
The description scheme is presented in the table 18.

Table 18. Template for the description of a social enterprise project (so-called "fiche") taking into account the spatial dimension of the planned activities

Project title	
Description of the project (justification of the need for the project, characteristics of the project)	
Linking the project to the goal tree (of citizens engagement in CSS)	
Components of the project	
The spatial dimension of the project	
Expected results	
Project stakeholders	
Stages of project implementation	
Project indicator (output and result)	
Anticipated budget and source of funding for the project	

Source: own elaboration based on Markowski (ed.), 2015.

Methods of implementation: Expert discussion. Workshop. Descriptive analysis.

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Appendix

Appendix 1. The list of legal acts regulating waste management and trade in packaging waste

Waste management	
Main legal act	The Act of 14 December 2012 on waste (consolidated text: Dz. U.* 2022, item 699)
Implementing acts	– Resolution No. 57 of the Council of Ministers of May 6, 2021 amending the Resolution on the National Waste Management Plan 2022 (M. P.** of 2021, item 509) – Decree of the Minister of Climate and Environment of December 23, 2021 on the determination of specific conditions for the loss of waste status for waste asphalt destruct (M.P. of 2021, item 2468) – Regulation of the Minister of Climate and Environment of November 26, 2021 on the disposal and storage of medical waste and veterinary waste (Dz. U. 2021, item 2245) – Decree of the Minister of Climate and Environment of March 19, 2021, amending the decree on landfills (Dz. U. 2021, item 673) – Ordinance of the Minister of Climate and Environment of September 11, 2020 on detailed requirements for waste storage (Dz. U. 2020, item 1742) – Regulation of the Minister of Climate of June 10, 2020 on the operation of the Database on Products and Packaging and Waste Management (Dz. U. 2020, item 1071) – Regulation of the Minister of Internal Affairs and Administration of February 19, 2020 on fire protection requirements to be met by construction facilities or parts thereof and other places intended for collection, storage or processing of waste (Dz. U. 2020, item 296) – Regulation of the Minister of Climate of January 2, 2020 on the waste catalogue (OJ*** 2020, item 10) – Regulation of the Minister of Climate of December 24, 2019 on the conditions for recognizing waste as having infectious properties and the manner of determining these properties (OJ. 2020, item 3) – Decree of the Minister of Climate of December 23, 2019 on types of waste and quantities of waste for which there is no obligation to keep waste records (Dz. U. 2019, item 2531) – Ordinance of the Minister of the Environment of August 29, 2019, on a vision control system for the storage or dumping of waste (Dz. U. 2019, item 1755) – Regulation of the Minister of the Environment of December 13, 2018 on the model form of the report on packaged products, packaging and packaging waste management for 2018 (Dz. U. 2018, item 2526) – Regulation of the Minister of the Environment of December 3, 2018 on model forms of reports on electrical and electronic equipment and waste equipment for 2018 Regulation of the Minister of the Environment of September 13, 2018 on the manner of assigning a registration number to entities entered in the register kept under BDO (Dz. U. 2018, item 1807) – Regulation of the Minister of the Environment dated January 19, 2018 on the rates of the registration fee and the annual fee (Dz. U. 2018, item 184) – Ordinance of the Minister of Health of October 5, 2017 on detailed handling of medical waste (Dz. U. 2017, item 1975) – Regulation of the Minister of the Environment of October 7, 2016 on detailed requirements for waste transport (Dz. U. 2016, item 1742)

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	– Regulation of the Minister of the Environment of June 8, 2016 on technical conditions for qualifying the portion of energy recovered from thermal waste conversion (Dz. U. 2016, item 847) – Ordinance of the Minister of Development of January 21, 2016 on the requirements for carrying out the process of thermal transformation of waste and methods of dealing with waste generated as a result of this process (Dz. U. 2016, item 108) – (s) Regulation of the Minister of Environment of November 10, 2015 on the list of types of waste that individuals or organizational units that are not entrepreneurs may subject to recovery for their own use, and permissible methods of their recovery (Dz. U. 2016, item 93) – Regulation of the Minister of Economy of October 5, 2015 on the detailed method of handling waste oils (Dz. U. 2015, item 1694) – Regulation of the Minister of Economy of July 16, 2015 on allowing waste to be stored in landfills (Dz. U. 2015, item 1277) – Regulation of the Minister of Health of July 24, 2015 on the types of medical waste and veterinary waste whose recovery is permissible (Dz. U. 2015, item 1116) – Regulation of the Minister of the Environment of July 1, 2015 on the manner and form of drawing up a provincial waste management plan and the model of an investment plan (Dz. U. 2015, item 1016) – Regulation of the Minister of the Environment of May 11, 2015 on the recovery of waste outside installations and facilities (Dz. U. 2015, item 796) – Regulation of the Minister of the Environment of January 20, 2015 on the recovery process R10 (Dz. U. 2015, item 132) – Regulation of the Minister of the Environment of January 19, 2015 on waste from titanium dioxide production processes and from the processing of such waste, which cannot be disposed of by landfilling (Dz. U. 2015, item 125) – Regulation of the Minister of Economy of January 16, 2015 on the types of waste that can be disposed of in a landfill in a non-selective manner (Dz. U. 2015, item 110) – Regulation of the Minister of the Environment of January 7, 2015 on landfills and storage sites for waste from titanium dioxide production processes and the processing of such waste (Dz. U. 2015, item 74) – Regulation of the Minister of Environment of January 13, 2014 on the document confirming the disposal of infectious medical waste or infectious veterinary waste (Dz. U. 2014, item 107) – Regulation of the Minister of the Environment of December 9, 2013 on the model form for acceptance of metal waste (OJ 2013, item 1607) – Ordinance of the Minister of Environment of September 13, 2013 on establishing qualifications in waste management (Dz. U. 2013, item 1186) – Regulation of the Minister of Environment of April 30, 2013 on landfills (Dz.U. 2013 item 523)
Main legal act	The Act of 13 September 1996 on maintenance of cleanliness and order in municipalities (consolidated text: Dz. U. of 2022, item 1297)
Main legal act	The Act of 7 May 2009 on Packaged Goods (consolidated text: Dz. U. 2020, item 1442)
Implementing acts	– Ordinance of the Minister of Economy of October 7, 2009 on carrying out control of the correctness of the system of internal control of the quantity of packaged goods (Dz. U. 2009, No. 178, item 1376)

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	– Regulation of the Minister of Economy of October 7, 2009 on conducting inspections of measuring bottles (Dz. U. 2009, 178, item 1377) – Regulation of the Minister of Economy of July 20, 2009 on detailed requirements for the labelling of prepackaged goods (Dz. U. 2021, item 481) – Ordinance of the Council of Ministers of June 5, 2020 on legal units of measurement (Dz. U. 2020, item 1024) – Ordinance of the Minister of Finance of October 14, 2009, amending the Ordinance on the list of sanction fees (Dz. U. 2009, No. 183, item 1428)
Main legal act	The Act of 11 May 2001 On Entrepreneurs In Terms Of The Management Of Certain Types Of Waste And The Product Fee (consolidated text: Dz. U. 2020, item 1903)
Implementing acts	– Regulation of the Minister of Climate, dated December 19, 2019, on detailed rates of product fees for individual products (Dz. U. 2019, item 2485)
Main legal act	The Act of 20 July 1991 on the Environmental Protection Inspection (consolidated text: Dz. U. 2021, item 1070)
Main legal act	The Act of 3 October 2008 on providing information on the environment and its protection, public participation in environmental protection and environmental impact assessments (consolidated text: Dz. U. 2022, item 1029)
Main legal act	The Law of June 29, 2007 on international shipments of waste (consolidated text: Dz. U. of 2020, item 1792)
Trade in packaging waste	
Main legal act	Implementing acts
The Act of 13 June 2013 on packaging and packaging waste management (consolidated text: Dz. U. 2020, item 1114)	– Regulation of the Minister of Climate and Environment of December 19, 2021 on the annual levels of recycling of packaging waste in individual years until 2030 (Dz. U. 2021, item 2375) – Regulation of the Minister of Climate and Environment of December 17, 2021 on detailed conditions for counting the mass of packaging waste as recycled (Dz. U. 2021, item 2365) – Ordinance of the Minister of Climate and Environment of July 29, 2020 on the template of the report (Dz. U. 2020, item 1457) – Regulation of the Minister of Environment of August 27, 2019 on the rate of recycling fee (Dz. U. 2019, item 1639) – Regulation of the Minister of the Environment of December 3, 2018 on the minimum annual levels of recovery and recycling for multi-material packaging and for packaging of hazardous agents, below which levels cannot be set in the agreement concluded with the provincial marshal (Dz. U. 2018, item 2310) – Regulation of the Minister of the Environment of December 3, 2018 on annual recycling levels for household packaging waste (Dz. U. 2018, item 2306) – Regulation of the Minister of the Environment of December 21, 2015 on the annual external audit of entrepreneurs issuing DPO, DPR, EDPO or EDPR documents (Dz. U. 2015, item 2264) – Regulation of the Minister of the Environment of January 21, 2015 on how to determine the sum of lead, cadmium, mercury and hexavalent chromium content in packaging (OJ 2015, item 170) – Regulation of the Minister of the Environment of January 21, 2015 on packaging to which the requirements for the content of lead, cadmium, mercury and hexavalent chromium in packaging do not apply (Dz. U. 2015, item 137)

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	– Regulation of the Minister of the Environment of December 16, 2014 on the rates of product fees for specific types of packaging (Dz. U. 2014, item 1972) – Ordinance of the Minister of the Environment of September 3, 2014 on the patterns of packaging labelling (Dz. U. 2014, item 1298) – Regulation of the Minister of the Environment of October 22, 2013 on the sample list of products that are or are not considered packaging (OJ 2013, item 1274)

NOTE: * Dz. U. - Journal of Laws; ** M.P. - The Official Journal of the Republic of Poland "Monitor Polski"; *** OJ – Office Journal of the European Communities.

Source: own study based on binding legal acts.

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