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List of abbreviations

CBT - Circular Benchmark Tool
CE - Circular Economy
CEAP - Circular Economy Action Plan
CPP - Circular Public Procurement
CSS - Circular Systemic Solution
CTC - Circular Territorial Cluster
IS - Industrial Symbiosis
KPI - Key Performance Indicator
EMF - European Monitoring Framework
PPP - Public Private Partnership
RBT - Regional Booster Toolkit



Executive summary

This deliverable focuses on the development of a Circular Economy (CE) monitoring system for the Łódzkie region. It introduces a monitoring framework scheme adapted to the region and it explores and lists in detail Key Performance Indicators (KPIs) for the 4 circular systemic solutions (CSS) developed within the Frontsh1p project. In addition, it gives relevant inputs to create a Public Private Partnership (PPP) and to pursue Circular Public Procurement (CPP).

Łódzkie is known for its dependence on coal mining but since the early 2000s has put efforts to expand its circular economy practices. Current issues important to address specifically involve how a monitor framework for transitioning to the CSSs can be established. The proposed CE monitoring system comprehends 3 main elements, namely territorial characteristics, enabling environment, and assessment of circularity. This framework relies on the updated EU CE Monitoring Framework (EMF), which complies with indicators resulting from the EU project SCREEN (Synergic Circular Economy among European Regions).

The four CSSs answering to the territorial characteristics within this framework include Wood Packaging, Food & Feed, Water & Nutrients, and Plastic & Rubber waste. For every CSS this deliverable provides a specific description of the state of the art and targets that need to be reached. This information is supported by lists of KPIs that cover different scales, categories and sectors; being essential for measuring activities and to quantify the progress made within each CSS.

A PPP is an ideal stakeholders configuration to manage the monitoring activities of the CSSs. This deliverable points out the advantages of PPP as circular hubs and provides input on how to build them, by giving examples of already existing ones and highlighting the essential elements needed for their creation. The concepts of Circular Territorial Cluster (CTC) and Circupuncture support the establishment of Circular Łódzkie, which would facilitate the success of the monitoring system in terms of management and investments. This partnership can be facilitated by a CPP scheme where public authorities clearly identify where to and what to purchase in terms of resources for the region. Inputs on how to monitor and improve CPP are provided by introducing the Circular Benchmark Tool (CBT) and the Regional Booster Toolkit (RBT), where the first one is an assessment tool that was built by regions for regions which can provide inputs for a regional Circular Economy Action Plan through qualitative indicators, the second one is more quantitative by focusing on material flows in terms of inputs and outputs in terms of resources and waste streams.



1.Introduction and background

Cities, regions and territorial clusters can act as potential engines to close waste and material cycles, providing a fertile ground for planning, implementing, demonstrating and replicating innovative circular systemic solutions (CSSs). In this context, monitoring the transition to a circular economy (CE) and its progress becomes crucial, not only to ensure that CSSs actually work, but also to facilitate effective governance by providing access to relevant information, data, measurements, good practices and guidelines to policy-makers. In the Frontsh1p project one of the overall goals is to develop a methodology and toolkits as support for the transition towards a CE within the Łódzkie region in Poland. The Łódzkie Region is located in the centre of the country with a surface area of about 18,219 km², which constitutes 6% of the surface area of Poland, and it is inhabited by 2,416,902 people. Łódzkie is divided into 177 communes and it has forty-eight cities, including three cities with district rights (Łódź, Piotrków Trybunalski, and Skierniewice). The region is located on the border between the North European Plain and the Polish Uplands. The northern part of Łódzkie is crossed by the Warsaw-Berlin proglacial valley. The central part of Łódzkie is a strip of convex landforms, the so- called Łódź Upland. In the northern part of the region, the strip is highest (approx. 260 m) and starts to disappear. This element divides the drainage basin of the Vistula and the Odra, serving as a first-order drainage divide. The highest points are: the natural summit of Fajna Ryba (347 m a.s.l.) in the Przedbórz Commune and the artificial summit of Góra Kamieński (386 m a.s.l.) in the Kamieński Commune. Approximately 19% of the regional land is located in an Environmental protected area, including eighty-seven nature reserves, seventeen protected landscape areas, and seven natural landscape parks. Agricultural land covers approx. 70% of the surface area of the whole region. Łódzkie has the least forest areas of all regions, taking up only 21% of its surface area.

This deliverable focuses on the development of a CE monitoring framework for Łódzkie as well as a Public-Private Partnership (PPP) and Circular Public Procurement (CPP) models to facilitate, guide and support the monitoring system.



1.1 Methodology

With the aim to provide a CE monitoring system for Łódzkie which will also be replicable in other regions, in-depth desk research has been performed. This research includes the review of both academic and policy documents, as well as the analysis of relevant case studies. Such activities were performed to provide a baseline monitoring framework scheme that highlights the territorial characteristics of the region as determined in other deliverables of Frontsh1p (such as Deliverable 2.2), the enabling conditions to monitor circularity within a regional context, general categories and subcategories of indicators belonging to the updated EU Circular Economy Monitoring Framework (EMF) and their compliance with projects focusing on the CE transition within regions (i.e. SCREEN).

Once a baseline is provided, the research then goes more in depth with the establishment of detailed Indicators, by consulting multiple official reports. In this way, many lists of indicators are provided allowing for a proper selection of them, also taking into consideration the proposed governance model of Łódzkie (see Deliverable 2.6) and the possibility to adapt them to other regions.

In addition, research has been performed to identify key elements that suggest how to create an enabling environment for the use of the monitoring system, namely Public Private Partnerships (PPPs) and Circular Public Procurement (CPP). For this part, several case studies have been consulted, in order to highlight good practices from which objectives, strategies, and implementations can represent valuable examples.

In all these steps the contribution of the project partners specified at the beginning of the deliverable has been extremely valuable.



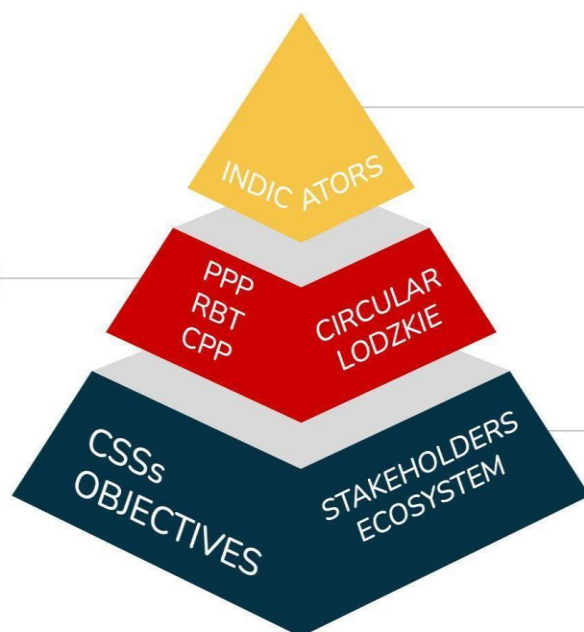
2. Baseline for Łódzkie CE monitoring framework

With the aim to develop a CE monitoring system for Łódzkie, a preliminary scheme is created. The elements constituting this baseline are developed through a place-based approach suitable for delivering a framework that is both effective for a specific region and easily replicable and/or adaptable in others. In order to do this, a monitoring system built upon the *flexible governance model* developed by Gargano et. al, (2023)^[1] that comprehends three dimensions namely *territorial characteristics*, *enabling environment*, and *assessing circularity*, is adapted to the Łódzkie region as shown in **Figure 1**. Territorial characteristics and an enabling environment that is suitable for managing the monitoring activities are considered essential elements. Furthermore, the way how circularity is assessed constitutes the most specific dimension that includes categories of indicators. First general categories of indicators are taken into consideration starting from the updated European Monitoring Framework ^[2] (EMF). The final establishment of specific indicators will be further explained later in this deliverable.

Enabling environment

Public Private partnership is considered an effective network for the application of the monitoring framework as well as for facilitating investments needed for the development of the CSSs. This partnership could constitute the basis for the creation of the **Circular Lodzkie hub**.

The **Regional Booster Toolkit** comprehends a set of functionalities involving all entities in the region. In addition, the developed solutions will be a replicable solution applicable in other regions of Europe and the world. In addition, **Circular Public Procurement** supports the monitoring activities for the region.



Assessing circularity

This dimension is the most specific as it refers to the **indicators** needed to measure the performances within each CSS from the state of the art to the desired objectives

Territorial characteristics

The monitoring framework is focused on the 4 Circular Systemic Solutions (CSS's) of the Lodzkie region

- Wood Packaging
- Food & feed
- Water & nutrient
- Plastic & Rubber waste

Part of territorial characteristics is also represented by the stakeholders involved in the development of the 4 CSSs

Figure 1. Baseline scheme of the CE monitoring framework for Łódzkie.



The first level (territorial characteristics) has the aim to provide an overview of the main elements that constitute the transition towards a circular economy within the region, in these elements are included the CSSs chosen in Frontsh1p:

- **Wood Packaging.** The aim is to understand how to use wood packaging waste and by-products of wood packaging production and wholesale for boosting regional circular development;
- **Food & feed.** The second CSS aims to develop a CO2 assisted pre-treatment of agro-industrial waste combined with biotechnological treatments;
- **Water & nutrients.** The aim is to understand how to use wastewater and flue gases as feedstock for microalgae biomass for boosting regional circular development;
- **Plastic & Rubber waste.** The fourth CSS aims to optimize a pyrolysis system for chlorinated compounds, to further develop a supercritical CO2 expansion system for insulating biomaterials, and to demonstrate low-cost 3D printing for repairing household appliances.

In the next chapters, the second and third levels of the baseline CE monitoring framework will be further explained. As the work performed on the indicators is more extensive than the rest, the next chapter will actually start from the third level, or rather the work performed to establish general indicators for the regional level, followed by the indicators that monitor the exchanges within the CSSs and finally with Key Performance Indicators (KPIs) of the 4 CSSs with related stakeholders' ecosystems.



3. Indicators for CE monitoring frameworks

The SCREEN project^[3] developed a framework of assessment criteria for the sole purpose of evaluating the circularity of one project with respect to another one and to help evaluators to make a clear and transparent ranking list. Initially, this framework was compared with the EMF of 2018^[4] in order to verify if there was compliance between them (**Figure 2**).





This project

Fig. 2. Compliance between SCREEN and 2018 EMF.

Monitoring Framework - COM(2018) 29 final

No	Name	Relevance	EU levers (examples)
Production and consumption			
1	EU self-sufficiency for raw materials	The circular economy should help to address the supply risks for raw materials, in particular critical raw materials.	Raw Materials Initiative; Resource Efficiency Roadmap
2	Green public procurement*	Public procurement accounts for a large share of consumption and can drive the circular economy.	Public Procurement Strategy; EU support schemes and voluntary criteria for green public procurement
3a-c	Waste generation	In a circular economy waste generation is minimised.	Waste Framework Directive; directives on specific waste streams; Strategy for Plastics
4	Food waste*	Discarding food has negative environmental, climate and economic impacts.	General Food Law Regulation; Waste Framework Directive; various initiatives (e.g. Platform on Food Losses and Food Waste)
Waste management			
5a-b	Overall recycling rates	Increasing recycling is part of the transition to a circular economy.	Waste Framework Directive
6a-f	Recycling rates for specific waste streams	This reflects the progress in recycling key waste streams.	Waste Framework Directive; Landfill Directive; directives on specific waste streams
Secondary raw materials			
7a-b	Contribution of recycled materials to raw materials demand	In a circular economy, secondary raw materials are commonly used to make new products.	Waste Framework Directive; Eco-design Directive; EU Ecolabel; REACH; initiative on the interference between chemicals products and waste policies; Strategy for Plastics; quality standards for secondary raw materials
8	Trade in recyclable raw materials	Trade in recyclables reflects the importance of the internal market and global participation in the circular economy.	Internal Market policy; Waste Shipment Regulation; Trade policy
Competitiveness and innovation			
9a-c	Private investments, jobs and gross value added	This reflects the contribution of the circular economy to the creation of jobs and growth.	Investment Plan for Europe; Structural and Investment Funds; InnovFin; Circular Economy Finance Support Platform; Sustainable Finance Strategy; Green Employment Initiative; New Skills Agenda for Europe; Internal market policy
10	Patents	Innovative technologies related to the circular economy boost the EU's global competitiveness.	Horizon 2020



1	2	3	4
N.	Description		Explanation
1	Mass of waste resources recovered and re-introduced in the own production cycle	or	Waste recovered is re-used in the same location as a secondary raw material
2	Industrial symbiosis: Mass of waste resources recovered and introduced in another production cycle	or	Waste recovered is re-used in another location as a secondary raw material
3	Increase in the recyclability of waste generated	or	Waste recovered is put on the market as a secondary raw material
4	Avoidance of waste generation	or	The new process generates less waste
5	"Net Energy balance respect to the previous system" or "Amount of energy recovered"	or	The new process consumes less energy or same energy of the new process is recovered
6	Reduction of emissions	or	The new process has less emissions respect to the old one
7	Net balance of jobs	or	Number of new jobs created by the circular economy project, minus the number of jobs lost in the previous linear process
8	Increase of economic value (life cycle)	or	Ratio of economic value of the new process respect to the previous one
9	Project promoting waste recycling	or	
10	Implementation of "green procurement" in the project	or	
11	Inclusion of relevant stakeholders education on circular economy	or	

among 1, 2, 3 and 4)

Indirect projects

Social criterion

Criterion

The assessment criteria of SCREEN has been thus validated and its compliance has also been verified with the 10 sub-categories of indicators described in the updated 2023 EMF (**Figure 3**), which includes a new dimension on global sustainability and resilience that adds to the already existing four dimensions of the previous monitoring framework.

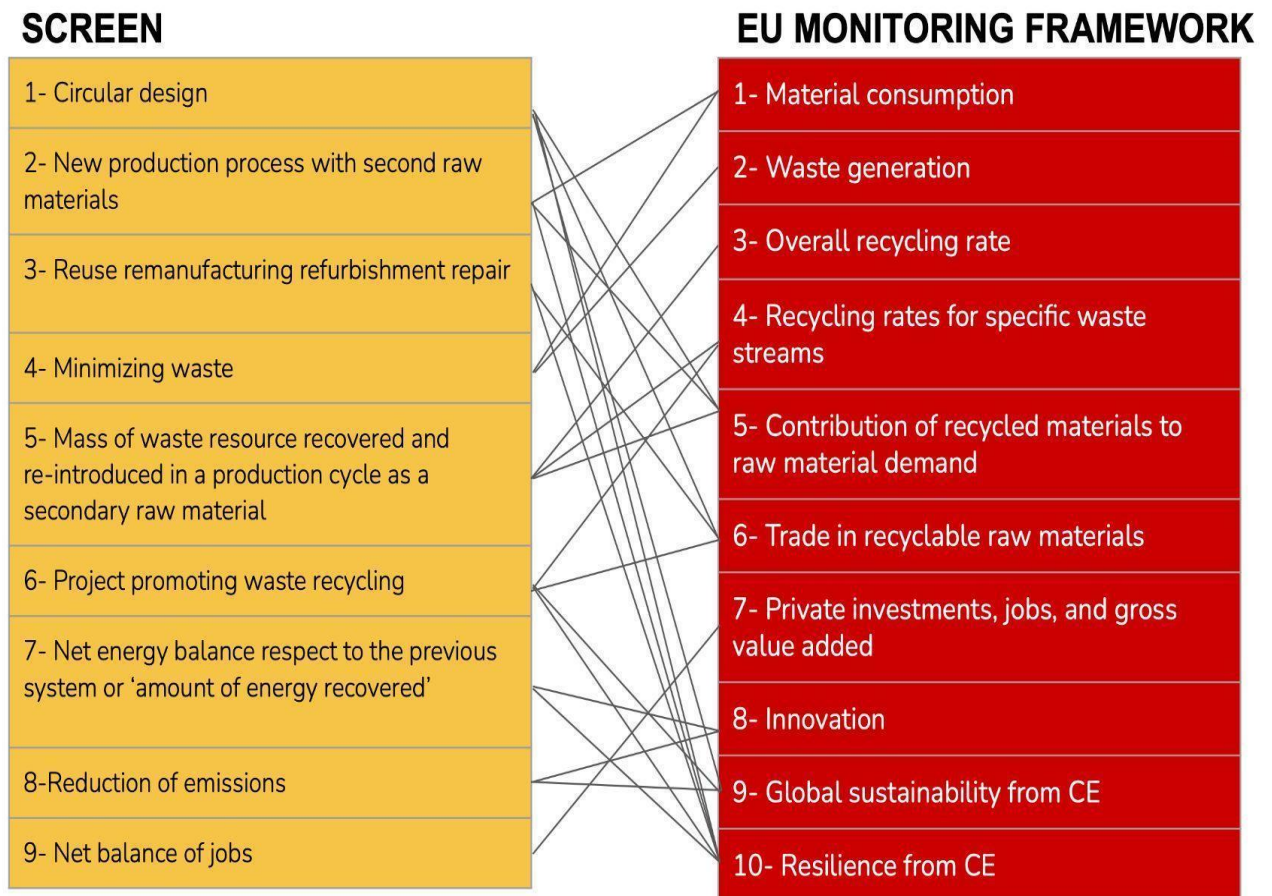


Figure 3. Compliance between SCREEN and 2023 EMF.

The SCREEN assessment criteria were built on a bottom-up approach basis, which included several discussions between the 17 regions involved in the project and a wide stakeholders' consultation. After the verification of its compliance with the EMF the final version ^[5] (**Table 1**) shows 9 categories of indicators with related description, metrics, parameters, and weights.

Table 1. The 9 final indicators in the SCREEN methodology [5].

Table of Assessment Criteria for Circular Economy Projects Rev. 4.0

		A	B	C	D	E	F
PRODUCTION	N	Criterion	Description	Metrics	Additional Parameters	Assessment Indicator	Suggested Weight
	1	Circular Design	Re-shaping the first stage of an industrial process (Product design) in order to reduce the waste generated AND/OR increase the life of the final product	Kg/year of virgin material avoided through the new process AND/OR by the prolongation of the product's life	Economic value of virgin material (€/kg)	Metrics x additional parameter (€/year)	10 for products NOT falling into the Directive 2009/125/EC. Otherwise the suggested weight is 5
	2	New production process accepting "secondary raw material"	Replacement, total or partial, of virgin material with "secondary raw material"	Kg/year of virgin material avoided through the new process	Economic value of the virgin material (€/kg)	Metrics x additional parameter (€/year)	8

CONSUMPTION	3	RE-Use, Re-Manufacturing, Refurbishment, Repair	Prolongation of the life of a certain product that otherwise will be disposed	Kg/year of virgin material avoided by the prolongation of the product's life	Economic value of virgin material (€/kg)	Metrics x additional parameter (€/year)	8
	4	Waste reduction	The new process generates less waste	Kg/year	Cost of disposal (€/kg)	Metrics x additional parameter (€/year)	10
DISPOSAL	5	Industrial symbiosis: mass of resources provided and re-introduced in a production cycle as secondary raw material	The new process generates waste that can be re-used in the same process or in another production process	Kg/year	Economic value of the secondary raw material (€/kg) minus cost of its transport to the production site (€/kg) (*)	Metrics x additional parameter (€/year)	8 (*)
	6	Project promoting waste recycling	Promotional campaign with a specific target producing a specific waste	Waste collected by the target Kg/year	Cost of disposal (€/Kg)	Metrics x additional parameter (€/year)	6
CLIMATE	7	"Net energy balance respect to the previous system" or "Amount of energy recovered"	Energy (kWh) used in the process <u>per unit of product</u> divided by energy used in the old process per unit of product	Number that can be lower or higher than 1	--	Metrics (the number in column C)	1 if the assessment indicator is "per €" or weight



	8	Reduction of emissions	Emissions of CO2 (**) generated by the old process <u>per unit of product</u> , divided by emissions used in the new process for the same unit of product	Number (that can be lower or higher than 1)	--	Metrics (the number in column C)	
EMPLOYMENT	9	Net balance of jobs	Number of new jobs created by the circular economy project, minus the number of jobs lost in the previous linear process	N = Number of full time NEW working units in the new process; it is negative in case of reduction of personnel	P = Number of full time working units in the old process	$1 + N \div P$	1 if the assessment indicator is "per €" or weight
Applicants may select only		Implementation of "circular procurement" (***) in the project (tick the box if relevant)	The suggested weight of the related project is increased by 20%				
		Educational projects targeted to relevant stakeholders (tick this box if relevant)	The suggested weight of the related project is increased by 10%				

(*) In case the secondary raw material does not have a final destination but is "put on the market", the weight is reduced from 8 to 7.

(**) As in case of other pollutants, a table of equivalence should be used to convert them into CO2 equivalent emissions:
<https://climatechangeconnection.org/emissions/co2-equivalent/>

(***) For the definition, see: https://ec.europa.eu/environment/gpp/circular_procurement_en.htm

This table represents a general baseline for the development of specific categories of indicators for the Łódzkie CE Monitoring Framework that will be further "customised" for each of the 4 CSS, and provides



an overview of relevant performances needed for the transition towards a circular economy. This baseline helps to dive into more detailed indicators which refer to specific targets and actions of the CSSs in Łódzkie.

Multiple scales and categories of indicators were therefore consulted to be assigned to specific actions and targets of each CSS. Firstly, in order to understand their dimension in terms of spatial scale of impact, indicators can be divided into 3 levels, namely macro, meso, and micro indicators.

The Summa Circular Economy Policy Research Centre classified indicators in their short term assignment *Indicators for a circular economy*^[6] available in the CE European Stakeholders Platform. Taking as an example material flow indicators or rather those indicators that measure the material inputs or outputs for a certain system, it is easily understandable that they can flow within a global system (e.g. between countries) or within a local system (e.g. between factories located in the same municipality). It is important to mention that even in this case there can be overlaps and the boundaries between scales are not well defined as different scales can intertwine with each other. However, it is possible to assign 3 different scales to indicators to facilitate their categorization:

- **Macro level indicators** can support areas such as economic, trade and environmental policy integration, sustainable development strategies and action plans, and national waste management and resource conservation policies. At this level the main emphasis is on material exchange between the economy and the environment. Macro indicators usually describe national characteristics and their comparison with other countries and with the rest of the world through trade flows.
- **Meso level indicators** can already distinguish categories of material and information can be more specific. They can describe trade flows within an economy by distinguishing industries, producers and consumers. The focus on the industry implies the detection of waste materials, polluting factors and opportunities for producers and consumers. Meso indicators describe performances of a region or an industry.
- **Micro level indicators** describe flows within a local scale, for example at a business level. They describe specific performance of a city, a product or a company by supporting the implementation of policies and decisions in areas such as product policies, energy efficiency, and integrated waste management.

The OECD inventory of circular economy indicators^[7] provides a good categorization of indicators that can be used for national, regional, and urban CE monitoring, as for the specific cases of Łódzkie. It firstly



distinguish 5 domains of indicators highlighting their percentages (e.g. most indicators are related to the environmental domain):

- Environment (39%)
- Governance (34%)
- Economic and business (14%)
- Infrastructure and technology (8%)
- Social (5%)

Each of these domains is divided into subcategories as shown in **Table 2**.

Table 2. Domains and sub categories of the OECD CE indicators inventory [7].

Category	Sub-Category
Economic and business	Added value
	Business
	Economic efficiency
	Economic structure
	Gains and revenues
	Investments
	Productivity
	Savings
Environment	Efficiency
	Emissions
	Output material process
	Production and consumption
	Savings
	Use
	Other
Governance + Education	Awareness-raising
	Capacity building
	Collaboration
	Education
	Financing



	Innovation, pilots and experiments
	Monitoring and evaluation
	Public Procurement
	Regulation
	Stakeholder engagement
	Strategy and initiatives
	Other
Infrastructure and technology	Area
	Equipment
	Facilities
	Products and services
	Other
Society	Jobs and human resources



In addition to domains and sub categories, different sectors are distinguished. The OECD inventory distinguishes 11 sectors of indicators (**Figure 4**), where the majority of them do not belong to a specific one but to CE in general. These indicators are assigned to the category of *no specific sector*.

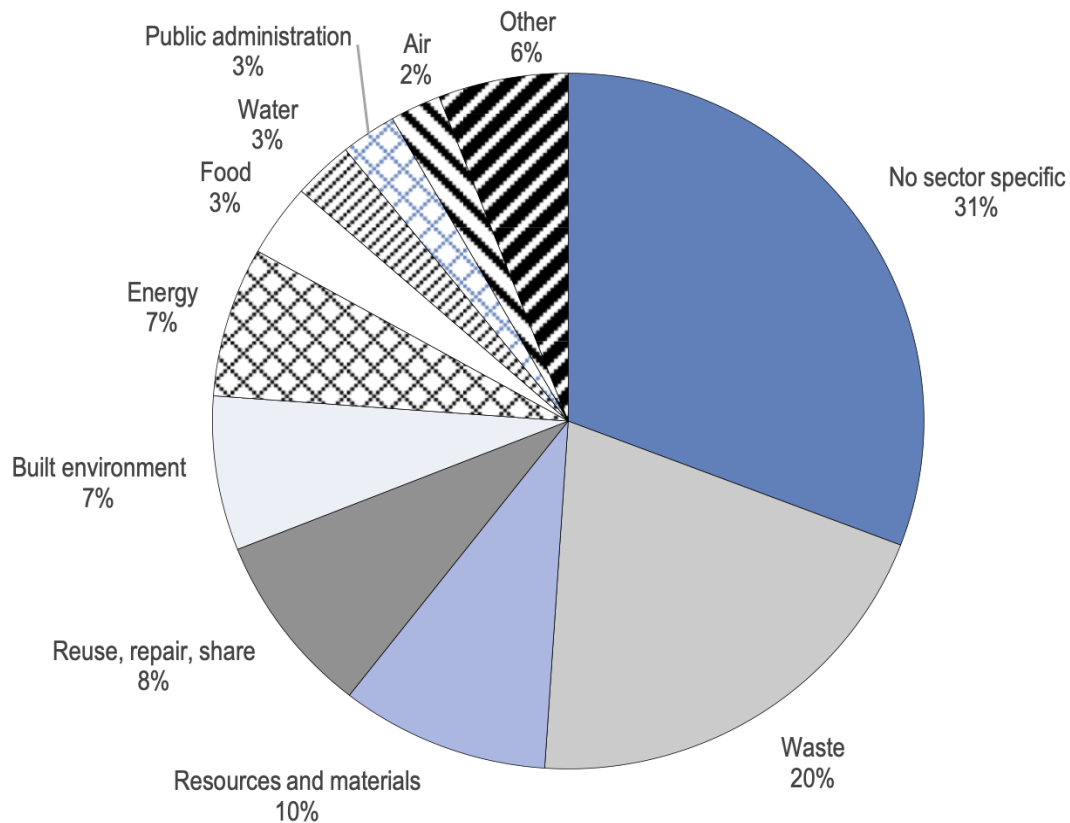


Figure 3. The 11 sectors of CE indicators distinguished by the OECD [7].

These classifications will be used to define each CSS in terms of targets to reach and actions performed to reach such targets. The provided classification easily adapts to specific case studies, as for Łódzkie, due to its variety of domains, sub categories and sectors; but it also guarantees replicability for other regions.

3.1 Lodzkie Regional Monitoring Framework (macro level)

The analysis of indicators' scales, categories, and sectors performed in the previous section represent the basis to build an extensive list provided in this section (see **Table 3**). A list of indicators that refer to the macro regional level has been selected, which serves the purpose of monitoring the CE transition.

Table 3. Macro indicators for regional monitoring frameworks [2,5,7].

Level	Category	Subcategory	Sector	Indicator	Unit	Year	Framework
Macro/ Regional	Governance + Education	Awareness-raising	Not specific	Project promoting waste recycling	Kg/year	2025	Screen
				Awareness campaigns	Number	2025	OECD
		Capacity building		Patents related to waste management and recycling	Number	2025	EMF
				Training courses on the circular economy	Number	2025	OECD
				Level of implementation of Training plan on the circular economy	Low, Medium, High	2025	OECD
		Collaboration		Implementation of an innovation platform for the circular economy	YES/NO	2025	OECD
				Number of synergies identified / implemented by economic actors	Number	2025	OECD
				Institutions willing to collaborate on a circular economy initiative	Number	2025	OECD
		Education		Publication on the circular economy	Number	2025	OECD
				Number of users actively involved in a platform of good practices and relevant stakeholders	Number	2025	OECD
				People trained in the circular economy fields of activity	Number	2025	OECD
		Financing		Financial institutions willing to collaborate on a circular economy initiative	Number	2025	OECD
				Financial assistance granted to companies related to the circular economy	Number	2025	OECD
		Innovation, pilots and experiments		Number of investments in circular-economy related R&I projects	Number	2025	OECD
				Number of pilot projects initiated for the development of territories	Number	2025	OECD



				synergies between economic actors			
		Monitoring and evaluation		Ecolabel Holders	Number	2025	OECD
		Public Procurement		Green public procurement	%	2025	EMF
				Products/services covered by circularity criteria in the public procurement	Number	2025	OECD
				Public procurement contracts with a circular economy dimension	%	2025	OECD
				Circular Public Procurement over the total of Innovative Public Procurement	%	2025	OECD
				Legal and regulatory barriers to the circular economy removal	Number	2025	OECD
		Regulation		New laws and regulations that discourage linear practices (e.g. resource tax, public circular procurement, resource passport)	Number	2025	OECD
				Stakeholder engagement	Number of economic actors mobilised for the development of territorial synergies between economic actors	Number	2025
		Number of economic actors mobilised in an innovation platform for the circular economy			Number	2025	OECD
		Number of citizens mobilised in circular economy activities			Number	2025	Frontsh1p
		Strategy and initiatives		Circular projects in total number of innovation projects	%	2025	OECD
				Level of implementation of Environmental Action Plan	Low, Medium, High	2025	OECD
Macro/ Regional	Economic And business	Added value	Not specific	Net added value of the circular economy	EUR/ Number of employment	2025	OECD
		Business		Economic operators supported in circular economies	Number	2025	OECD



				Circular business	% of total	2025	OECD
		Economic efficiency		EU self-sufficiency for raw materials	%	2025	EMF
				Trade in recyclable raw materials (Intra EU)	mTonnes	2025	EMF
				Material Import dependency	%	2025	EMF
				Economic growth of the circular economy	% GDP	2025	OECD
		Economic structure		Weight of the circular economy in GDP	% GDP	2025	OECD
		Gains and revenues		Industry turnover in more circular products		2025	OECD
		Investments		Private investments	EUR	2025	EMF
				Amount invested in circular economy projects	EUR	2025	OECD
		Savings		Waste reduction economic savings		2025	OECD
Macro/ Regional	Environment	Efficiency	Not specific	Net energy balance respect to the previous system or ‘amount of energy recovered’	Number that can be lower or higher than 1	2025	Screen
				Electricity from renewable sources (gross production)	GWh	2025	OECD
				Energy efficiency	%	2025	OECD
		Emissions		Reduction of emissions	Number that can be lower or higher than 1	2025	Screen
				GHG Emissions	tCO2/year	2025	OECD
				Greenhouse gas reduction	%	2025	OECD
				Material footprint per GDP		2025	OECD
		Output material process		Mass of waste resource recovered and re-introduced in a production cycle as a secondary raw material	Kg/year	2025	Screen
				Total waste generation per capita	kg per capita	2025	EMF
				Recycling rate of all waste excluding major mineral waste	%	2025	EMF



				End-of-live recycling input rates (EOL-RIR)	%	2025	EMF	
				Materials recovered through reuse and recycling	tonnes	2025	OECD	
				Total amount of waste produced by commerce and industry	tonnes	2025	OECD	
				Total amount of waste produced by households	tonnes	2025	OECD	
				Total waste treatment: Incineration	t/inhabitant	2025	OECD	
				Total waste treatment: Landfill	t/inhabitant	2025	OECD	
				Total waste treatment: Recycling	t/inhabitant	2025	OECD	
		Production and consumption		Circular design	Kg/year	2025	Screen	
				New production process with second raw material	Kg/year	2025	Screen	
				Re-use, re-manufacturing refurbishment, repair	Kg/year	2025	Screen	
				Waste reduction	Kg/year	2025	Screen	
				Energy from renewable sources in gross final energy consumption	%	2025	OECD	
				Consumption of raw materials	tonnes	2025	OECD	
				Water consumption	million m3	2025	OECD	
		Savings		Material savings	ktons	2025	OECD	
				Energy savings	KWh/year	2025	OECD	
				Water savings	m3/year	2025	OECD	
		Use		Circular material use rate	%	2025	EMF	
Macro/ Regional	Infrastructure and technology	Area	Not specific	New districts incorporating the principles of the circular economy	Number	2025	OECD	
		Design		Eco-designed products and services included in the regional catalogue	Number	2025	OECD	
		Facilities		Facilities with circular economy criteria	Number	2025	OECD	
		Products and services		New circular products	Number	2025	OECD	
Macro/ Regional	Society	Jobs and human resource	Not specific	Net balance of jobs	Number	2025	Screen	
				Employment in the Circular Economy	Number	2025	EMF	



*Source: The OECD Inventory of Circular Economy indicators www.OECD.org

H2020 SCREEN project: [www.http://www.screen-lab.eu/index2.html](http://www.screen-lab.eu/index2.html)

Circular Economy Monitoring Framework <https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework>

The main criteria used for the selection and creation of this list is to provide indicators that can be used in any regional context.

3.2 Industrial Symbiosis between CSSs Monitoring Framework (meso level)

Before diving into details for each CSS, In this section the links between the 4 CSSs are identified as industrial symbiosis (IS), defined as follows: “a subfield of industrial ecology engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products” (Chertow, 2000, p. 313, as cited in Fraccascia/Giannoccaro, 2020).^[8] The chosen indicators listed in **Table 4** help IS initiatives to monitor their environmental performance, to identify areas for improvement, and to demonstrate their contributions to sustainability and resource conservation. An additional dimension is included to monitor the technical exchange efficiency.

Table 4. Industrial Symbiosis between CSSs [8,9].

Level	Category	Subcategory	Sector	Indicator	Unit	Base Year	Year
Meso/ Territorial cluster	Economic and business	Gross economic benefits 1	Industrial symbiosis	Waste disposal costs	EUR	2023	2025
				Input purchasing costs	EUR	2023	2025
		Economic value created by Industrial symbiosis		Waste transportation costs	EUR	2023	2025
				Waste treatment costs	EUR	2023	2025
				Transaction costs of Industrial symbiosis cooperation	EUR	2023	2025
Meso/ Territorial cluster	Environment	Upstream perspective	Industrial symbiosis	Reduction of raw materials as inputs by industrial processes	% (in relation to a base year)	2023	2025
				Reduction of energy consumption as inputs by industrial processes	% (in relation to a base year)	2023	2025
				Reduction of water used as inputs by industrial processes	% (in relation to	2023	2025



					a base year)		
		Downstream perspective		<i>Reduction in the amounts of solid waste discharged in landfill or disposed conventionally</i>	% (in relation to a base year)	2023	2025
				<i>Wastewater discharged</i>	% (in relation to a base year)	2023	2025
				<i>Waste energy not exploited</i>	K	2023	2025
				<i>Greenhouse gas emissions</i>	tCO2/year	2023	2025
Meso/ Territorial cluster	Society		Industrial symbiosis	<i>Job creation related to new industrial exchanges</i>	Number	2023	2025
				<i>Job retention rate related to new industrial exchanges</i>	%	2023	2025
Meso/ Territorial cluster	Aggregated Economic and Environmental	Technical exchange efficiency 2	Industrial symbiosis	<i>Up-stream efficiency</i> (waste supply /waste demand as input)	Low/High	2023	2025
				<i>Down-stream efficiency</i> (waste supply /waste demand as input)	Low/High	2023	2025
*Source 1: What, where, and how measuring industrial symbiosis: A reasoned taxonomy of relevant indicators- https://doi.org/10.1016/j.resconrec.2020.104799							
*Source 2: Technical efficiency measures of industrial symbiosis networks using enterprise input-output analysis- https://doi.org/10.1016/j.ijpe.2016.11.003							

The indicators provided above concern the exchanges between CSSs in a specific territorial context (Territorial cluster). A territorial cluster is a socio-economic, geographical and environmental system composed of all relevant actors and including at least one public authority. This cluster is ready to implement, demonstrate and facilitate the replication of at least one Circular Systemic Solution in a specific territory ^[10].

3.3 CSS 1 CE Monitoring Framework (micro level)

Introduction

During 2020, about 1350 m³ of large timber was obtained in total in Łódzkie, which corresponds to 3.5% of the national production. Łódzkie is in 12th place among all the 16 regions in terms of harvested wood. This corresponded to a harvest rate of 346.9 m³/100 ha of forest area, which indicates the volume of large timber harvested per 100 ha of forest areas (GUS, 2021a, p. 37; Frontsh1p D3.1 p. 7).^{[11][12]} From the perspective of the sustainable use of raw wood through a circular economy approach, it is essential to manage wood waste



generated at each stage of the value chain. The classification of wood waste varies depending on the adopted subdivision criterion. There are three main groups of wood waste. The first one is waste from forest management, such as residues from maintenance works. The second group is wood waste from industry (generated in the production process of the final goods). Industrial wood waste is generated in the production of goods from wood raw material and can be in the form of particles, shavings, sawdust, wood dust, wood chips or bark. The amount of industrial waste can be estimated on data based on the material efficiency of individual production technologies. The third group of waste is post-consumer waste (from the consumption of the final goods). This is the most diverse group. A distinction can be made between usable waste, considered as secondary raw material, and non-usable waste. There is a distinction between solid wood waste (round or processed) and waste from other wood-based materials e.g. plywoods, chipboards, hardboards, blackboards (Kurowska 2016, p. 187-196; Frontsh1p D3.1 p. 8).^{[13][12]}

Based on the above description and information retrieved from previous deliverables, **Table 5** highlights the different stakeholders involved in CSS1.

PUBLIC	PRIVATE	RESEARCH AND KNOWLEDGE	OTHERS
Regional government	Wood related industries (cutting, processing, selling companies)	University of Lodz	Bioenergy Cluster for the Region (public-private cooperative initiative to support development of bioenergy along EU actions)
Local governments	Energy sector	Lodz University of Technology	CO2 and Black Carbon emitters
Policy makers		Technology transfer centre (CE research centre)	Frontsh1p scientific and technical partners
		Bionanopark (Research centre and incubators for businesses)	

Table 5. Stakeholders ecosystem of CSS1 (Source: own compilation).

CE KPIs for CSS1 - micro level

Specific KPIs for the monitoring framework of CSS1 are developed and listed in **Table 6**. It is important to specify that such KPIs can be used and/or adapted for the same level (micro), categories, and sectors in other regions as well.



Table 6. CE KPIs for CSS1 - micro level [2,5,7].

Level	Category	Subcategory	Sector	Indicator	Unit	Year	Framework
Micro	Governance + Education	Awareness-raising	Wood packaging	Project promoting (Wood) waste recycling	Number	2025	Screen
		Capacity building		Awareness campaigns to valorise wood waste	Number	2025	Frontsh1p
				Training courses on circular practices for wood sector workers	Number	2025	Frontsh1p
				People trained on circular practices in the wood sector	Number	2025	Frontsh1p
				Level of implementation of training plan on the circular economy in the wood sector	Low, Medium, High	2025	Frontsh1p
		Education		Students trained in circular economy practices related to the valorisation of wood	Number	2025	Frontsh1p
		Innovation, Pilots and experiments		Patents related to waste management and recycling	Number	2025	EMF
				Patent requests in relation to new sustainable processes presented by economic actors	Number	2025	Frontsh1p
		Monitoring and evaluation		Life cycle and cost-benefit studies in wood packaging waste management	Number	2025	Frontsh1p
		Collaboration		Number of synergies identified / implemented by economic actors	Number	2025	OECD
				Number of workshops held to link up supply and demand and boost the circular economy	Number	2025	Frontsh1p
		Public Procurement		Green public procurement	%	2025	EMF
				Circular procurement	%	2025	OECD
				Identified legal barriers for the Circular Public Procurement related to wood packaging sector	Number	2025	Frontsh1p



				CO2 savings as a result of Circular Public procurement activities related to wood packaging sector	ktons	2025	Frontsh1p
				Reduced emissions through Circular Public procurement related to wood packaging sector	relation to a base	2025	Frontsh1p
				Reduced waste through Circular Public procurement related to wood packaging sector	%	2025	Frontsh1p
		Regulation		Legislative and normative incentives created (wood sector)	Number	2025	Frontsh1p
				Legal and regulatory barriers to the circular economy removed (wood sector)	Number	2025	Frontsh1p
		Stakeholder engagement		Number of economic actors participating in an Inclusive Recycling Program	Number	2025	Frontsh1p
				Number of economic actors mobilised for the development of territorial synergies between economic actors	Number	2025	Frontsh1p
				Number of citizens mobilised in circular economy activities	Number	2025	Frontsh1p
		Strategy and initiatives		Wood packaging management initiatives	Number	2025	Frontsh1p
				Level of implementation of Environmental Action Plan related to wood packaging waste	Low, Medium; High	2025	Frontsh1p
				Number of environmental initiatives to valorise wood waste	Number	2025	Frontsh1p
Micro	Economic and business	Added Value	Wood packaging	Economic value generated by new circular economy processes	EUR	2025	Frontsh1p
				Value-added Products (Renewable Energy from biomass)	EUR	2025	Frontsh1p
		Business		Number of companies or products with tax benefits to incentivise the circular economy (wood sector)	Number	2025	Frontsh1p
				Economic operators supported in new circular economy practices (wood sector)	Number	2025	Frontsh1p



				<i>Percentage of companies innovating for circular reasons (wood sector)</i>	%	2025	Frontsh1p
		Economic Efficiency		EU self-sufficiency for raw materials	%	2025	EMF
				Share in recyclable raw materials (Intra EU)	mtonnes	2025	EMF
				Material Import dependency	%	2025	EMF
				<i>Material intensity</i>	kg/EUR	2025	Frontsh1p
		Gains and revenues		<i>Revenue generated from the adoption of more circular solutions within the wood sector.</i>	Million EUR	2025	Frontsh1p
		Investments		Private investments	EUR	2025	EMF
				<i>Private investments related to circular economy practices in the wood sector</i>	Thousand EUR	2025	Frontsh1p
				<i>Public investments related to circular economy practices in the wood sector</i>	Thousand EUR	2025	Frontsh1p
		Productivity		<i>Biomaterials Productivity</i>	EUR/kg	2025	Frontsh1p
		Savings		<i>Money saved as a consequence of recovery and reuse of wood materials</i>	EUR	2025	Frontsh1p
				<i>Energy cost savings</i>	EUR	2025	Fronths1p
Micro	Environment	Efficiency	Wood packaging	Net energy balance respect to the previous system or ‘amount of energy recovered’		2025	Screen
				Recycling rates for specific waste streams	kg/year	2025	EMF
				End-of-life recycling input rates (EOL-RIR)	%	2025	EMF
				<i>Energy efficiency of new proposed processes</i>	%	2025	Frontsh1p
				<i>Bioenergy plants installed capacity</i>	MW	2025	Frontsh1p
				<i>Renewable energy share</i>	% of energy use	2025	Frontsh1p
				<i>Renewable heat available</i>	GWh	2025	Frontsh1p
		Emissions		Reduction of emissions		2025	Screen
				<i>CO2 emissions reduction</i>	ktonnes	2025	OECD
				<i>GHG Emissions</i>	tCO2/year	2025	OECD



				Reduction of carbon emissions associated to recycling, treatment processes	% (in relation to a base year)	2025	Frontsh1p
				Contribution of greenhouse gases associated to recycling, treatment processes	CO2eq (kt)	2025	Frontsh1p
				Greenhouse gas reduction associated to proposed solutions	%	2025	Frontsh1p
		Output material process		Mass of (biomaterials) resource recovered and re-introduced in a production cycle as a secondary raw material	kg/year	2025	Screen
				Total waste generation per capita	kg per capita	2025	EMF
				Percentage increase in materials recovery (t) and organic recovery (t)	%	2025	OECD
				Percentage reduction of incoming / outgoing flows	%	2025	OECD
				Amount of recovered wood waste through recycling	tonnes	2025	Frontsh1p
				Amount of recovered wood waste for production of energy	tonnes	2025	Frontsh1p
				Use of packaging waste articulated to extended producer responsibility	NA	2025	OECD
				Percentage increase of reusable packaging wood waste	%	2025	Frontsh1p
				Recycling rate of wooden packaging	%	2025	Frontsh1p
				Char Yield	%	2025	Frontsh1p
				Syngas Yield	%	2025	Frontsh1p
				Percentage of carbon black substituted with char	%	2025	Frontsh1p
				CO2 capture efficiency	%	2025	Frontsh1p
				Production and consumption	Re-use, re-manufacturing, refurbishment, repair	kg/year	2025
		Circular design			kg/year	2025	Screen
		Waste reduction			kg/year	2025	Screen
		New production process with second raw materials			Number	2025	Screen



				<i>Share of Renewable Energies in the gross final consumption of energy</i>	%	2025	Frontsh1p
				<i>Consumption of virgin materials</i>	tonnes	2025	Frontsh1p
				<i>Use of recycled raw materials in production processes</i>	Cyclical material use rate	2025	OECD
		Savings		<i>Virgin material savings due to proposed solutions</i>	ktonnes	2025	Frontsh1p
		Use		<i>Energy savings due to proposed solutions</i>	kWh	2025	Frontsh1p
				<i>Circular material use rate</i>	%	2025	OECD
Micro	Infrastructure and Technology	Area	Wood packaging	<i>Number of collection points for reuse of materials</i>	Number	2025	OECD
				<i>Number of waste disposal sites with a reuse area</i>	Number	2025	OECD
				<i>Preparation for reuse</i>	%	2025	OECD
		Certificates		<i>Number of products and services with any kind of eco-label</i>	Number	2025	OECD
		Products		<i>New circular products (Syngas , char as pigment/filler, CO2 for industrial processes)</i>	Number	2025	Frontsh1p
		Facilities		<i>Number of power plants implementing proposed solutions</i>	Number	2025	Frontsh1p
		Equipment		<i>Number of integrated systems installed (gas boiler-PCC)</i>	Number	2025	Frontsh1p
Micro	Society	Jobs and human resources	Wood packaging	Net balance of jobs		2025	Screen
				<i>Number of new jobs created and secured by the implementation of circular economy practices in the sector</i>	Number	2025	Frontsh1p
*Source: The OECD Inventory of Circular Economy indicators www.OECD.org							
H2020 SCREEN project: www.http://www.screen-lab.eu/index2.html							
Circular Economy Monitoring Framework https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework							



3.4 CSS 2 - CE Monitoring Framework (micro level)

Introduction

The food industry is among the most important and the most rapidly developing industries in Łódzkie. Apart from industrial plants, there are also small and medium enterprises, such as 20 catering companies and 11 frozen food manufacturers. There are also 20 companies manufacturing food, and 14 companies that produce ready-to-cook food (Regional Waste Management Plan 2021; Marshall Office Łódź, 2021; Frontsh1p D4.1, p.22).^{[14][15][16]} In 2020, residents of Łódzkie collected just 41 kg of bio-waste per inhabitant in separate collections, falling below the national average (Statistics Poland, 2021; Frontsh1p D4.1, p.12 Fig. 7).^{[17][16]} This includes vegetable and fruit peelings, eggshells, coffee grounds, and wilted flowers. Biodegradable waste from various sources, constituting 14%, is geared for composting or fermentation (GUS – Local Data Bank, 2022.; Fronths1p D4.1, p.13, Fig 8).^{[18][16]} Bio-waste processing facilities in Łódzkie have an annual capacity of 72,445 tons. Projections for 2023-2025 suggest a decline in non-municipal biodegradable waste in Łódzkie, possibly due to reduced population and increased awareness. A system of bio-waste management should be mostly based on the reduction of the amount of waste produced. Production of such waste can be limited by implementing clean (waste-less) technologies in the industry and production; and by conducting activities with the aim to reduce the production of kitchen waste in households (Regional Environmental Protection Agency, draft Waste Management Plan for the Łódź Region for 2019-2025; Frontsh1p D4.1, p.17).^{[19][16]}

Limiting bio-waste production requires educational efforts to boost social awareness and alter daily food consumption habits. Rural areas can contribute by managing green and bio-waste in compost bins or agricultural biogas plants. Household compost bins in single-family dwellings also play a role. Based on the above description and information retrieved from previous deliverables, **Table 7** highlights the different stakeholders involved in the CSS2.

Table 7. Stakeholders ecosystem of CSS2 (Source: own compilation).



PUBLIC	PRIVATE	RESEARCH AND KNOWLEDGE	OTHERS
Regional government	Households (Citizens)	University of Lodz	Frontsh1p scientific and technical partners
Local governments	Owners of marginal lands	Lodz University of Technology	
Policy makers	Farmers		
Municipal waste management	Food industry		
	Waste processing companies		

CE KPIs for CSS2 - micro level

Specific KPIs for the monitoring framework of CSS2 are developed and listed in **Table 8**. It is important to specify that such KPIs can be used and/or adapted for the same level (micro), categories, and sectors in other regions as well.

Table 8. CE KPIs for CSS2 - micro level [2,5,7].

Level	Category	Subcategory	Sector	Indicator	Unit	Year	Framework
Micro	Governance + Education	Awareness-raising	Food' and Feed	Project promoting Bio-waste recycling	Number	2025	Screen
				<i>Awareness campaigns to valorize food waste</i>	Number	2025	Frontsh1p
		Capacity building		<i>Training courses on circular practices for young farmers</i>	Number	2025	Frontsh1p
				<i>People trained on circular practices in the agri-food sector</i>	Number	2025	Frontsh1p
				<i>Level of implementation of training plan on the circular economy in the agri-food sector</i>	Low, Medium, High	2025	Frontsh1p



		Education		<i>Students trained in circular economy practices related to the valorization of agri-food waste</i>	Number	2025	Frontsh1p
		Innovation, pilots and experiments		tents related to waste management and recycling	Number	2025	EMF
				<i>Patent requests in relation to new sustainable processes presented by economic actors</i>	Number	2025	Frotnsh1p
		Monitoring and evaluation		<i>Life cycle and cost-benefit studies in agro-industrial waste management</i>	Number	2025	Frontsh1p
		Collaboration		<i>Number of synergies identified / implemented by economic actors</i>	Number	2025	OECD
				<i>Number of workshops held to to link up supply and demand and boost the circular economy</i>	Number	2025	Frontsh1p
		Public Procurement		Green public procurement	%	2025	EMF
				Circular procurement	%	2025	OECD
				<i>Identified legal barriers for the Circular Public Procurement related to the agri-food sector</i>	Number	2025	Frontsh1p
				<i>CO2 savings as a result of procurement activities related to agri-food sector</i>	ktonnes	2025	Frontsh1p
				<i>Reduced emissions through green public procurement related to agri-food sector</i>	% (in relation to a base year)	2025	Frontsh1p
				<i>Reduced waste through Circular Public procurement related to the agri-food sector</i>	%	2025	Frontsh1p
		Regulation		<i>Legislative and normative incentives created (agri-food sector)</i>	Number	2025	Frontsh1p
				<i>Legal and regulatory barriers to the circular economy removed (agri-food sector)</i>	Number	2025	Forntsh1p
				<i>Directives adopted to improve wood packaging recyclabili</i>	Number	2025	Frontsh1p



		Stakeholder engagement		<i>Number of economic actors participating in an Inclusive Recycling Program</i>	Number	2025	Frontsh1p
				<i>Number of economic actors mobilised for the development of territorial synergies between economic actors</i>	Number	2025	Frontsh1p
				<i>Number of citizens mobilised in circular economy activities</i>	Number	2025	Frontsh1p
		Strategy and initiatives		<i>Agro-ecological initiatives</i>	Number	2025	OECD
				<i>Level of implementation of Environmental Action Plan related to agri-food sector</i>	Low, Medium, High	2025	Frontsh1p
				<i>Level of implementation of Biowaste management strategies</i>	Low, Medium, High	2025	Frontsh1p
Micro	Economic and business	Added Value	Food and Feed	<i>Economic value generated by new circular economy processes</i>	EUR	2025	Frontsh1p
				<i>Value-added products (Biolubricants, compostable bags)</i>	EUR	2025	Frontsh1p
		Business		<i>Number of companies or products with tax benefits to incentivise the circular economy (agri-food sector)</i>	Number	2025	Frontsh1p
				<i>Economic operators supported in new circular economy practices (agri-food sector)</i>	Number	2025	Frontsh1p
				<i>Percentage of companies innovating for circular reasons (agri-food sector)</i>	%	2025	Frontsh1p
		Economic Efficiency		EU self-sufficiency for raw materials	%	2025	EMF
				Trade in recyclable raw materials (Intra EU)	mtonnes	2025	EMF
				Material Import dependency	%	2025	EMF
				<i>Material intensity</i>	kg/EUR	2025	Frontsh1p
		Gains and revenues		<i>Revenue generated from the adoption of more circular solutions within the agri-food sector.</i>	Million EUR	2025	Frontsh1p
		Investments		Private investments	EUR	2025	EMF



				<i>Private investments related to circular economy practices in the agri-food sector</i>	Thousand EUR	2025	Frontsh1p
				<i>Public investments related to circular economy practices in the agri-food sector</i>	Thousand EUR	2025	Frontsh1p
		Productivity		<i>Biomaterial Productivity</i>	EUR/kg	2025	Frontsh1p
		Savings		<i>Money saved as a consequence of recovery and reuse of agri-food materials</i>	EUR	2025	Frontsh1p
				<i>Energy cost savings</i>	EUR	2025	Frontsh1p
Micro	Environment	Efficiency	Food and Feed	Net energy balance respect to the previous system or ‘amount of energy recovered’		2025	Screen
				Recycling rates for specific waste streams	kg/year	2025	EMF
				End-of-live recycling input rates (EOL-RIR)	%	2025	EMF
				<i>Energy efficiency of new proposed processes</i>	%	2025	Frontsh1p
				<i>Installed MW of biomass generation</i>	MW	2025	Frontsh1p
				<i>Renewable energy share</i>	% of energy use	2025	Frontsh1p
				<i>Renewable heat available</i>	GWh	2025	Frontsh1p
		Emissions		Reduction of emissions		2025	Screen
				<i>CO2 emissions reduction</i>	ktonnes	2025	OECD
				<i>GHG Emissions</i>	tCO2/year	2025	OECD
				<i>Reduction of carbon emissions associated with pre-treatment processes</i>	% (in relation to a base year)	2025	Frontsh1p
				<i>Contribution of greenhouse gases associated to proposed solutions</i>	CO2eq (kt)	2025	Frontsh1p
				<i>Greenhouse gas reduction associated to proposed solutions</i>	CO2eq (kt)	2025	Frontsh1p
		Output material process		Mass of (biomass) resource recovered and re-introduced in a production cycle as a secondary raw material	kg/year	2025	Screen



			Total waste generation per capita	kg per capita	2025	EMF
			Percentage increase in materials recovery (t) and organic recovery (t)	%	2025	OECD
			Percentage reduction of incoming / outgoing flows	%	2025	OECD
			Amount of recovered biowaste through an inclusive recycling programme	tonnes	2025	Frontsh1p
			Amount of recovered biowaste for producing FFAs	tonnes	2025	Frontsh1p
			Amount of recovered biowaste for producing compostable bags	tonnes	2025	Frontsh1p
			Amount of recovered biowaste for producing biolubricants	tonnes	2025	Frontsh1p
			Increase of volume of food waste (biomass) generated	tonnes	2025	Frontsh1p
			Percentage of recovered waste over generated (Agricultural and Industrial waste)	%	2025	Frontsh1p
			Biomass Yield	%	2025	Frontsh1p
			Free Fatty Acids (FFAs) Yield	%	2025	Frontsh1p
			Compostable bags Yield	%	2025	Frontsh1p
			Biolubricants Yield	%	2025	Frontsh1p
		Production and consumption	Re-use, re-manufacturing, refurbishment, repair	kg/year	2025	Screen
			Circular design	kg/year	2025	Screen
			Waste reduction	kg/year	2025	Screen
			New production process with second raw materials	Number	2025	Screen
			Share of Renewable Energies in the gross final consumption of energy	%	2025	OECD
			Food waste avoided through a circular consumption	tonnes	2025	OECD
			Use of recycled raw materials in production processes	al material use	2025	OECD



				Land Use, direct	% cultured land	2025	OECD
				Percentage (%) of Marginal land converted to valuable land	ginal land conv	2025	Frontsh1p
				Percentage reduction of soy bean meal imported from outside EU	%	2025	Frontsh1p
		Savings		Virgin material savings due to proposed solutions	ktonnes	2025	Frontsh1p
		Use		Energy savings due to proposed solutions	kWh	2025	Frontsh1p
				Circular material use rate	%	2025	OECD
Micro	Infrastructure and Technology	Area	Food and Feed	Number of collection points for reuse of materials	Number	2025	OECD
				Number of waste disposal sites with a reuse area	Number	2025	OECD
				Preparation for reuse	%	2025	OECD
				Area of marginal land recovered for new sustainable models	ha	2025	Frontsh1p
		Certificates		Number of products and services with any kind of eco-label	Number	2025	Frontsh1p
		Products		New circular products (Bio-products from FFAs)	Number	2025	Frontsh1p
				New circular products (Biolubricants , bio-oil for insulating materials & animal feed)	Number	2025	Frontsh1p
				New circular products (Compostable bags for OFMSW)	Number	2025	Frontsh1p
				Total amount of waste collected through compostable bags	tonnes	2025	Frontsh1p
				Total amount of soybean protein meal substituted with circular bio-oil meal	kg	2025	Frontsh1p
				Total amount of agro-industrial waste pre-treated with biotechnological treatments	tonnes	2025	Frontsh1p



Micro	Society	Jobs and human resources	Food and Feed	Net balance of jobs	Number	2025	Screen
				<i>Number of new jobs created and secured by the implementation of circular economy practices in the sector</i>	Number	2025	Frontsh1p
*Source: The OECD Inventory of Circular Economy indicators www.OECD.org							
H2020 SCREEN project: www.http://www.screen-lab.eu/index2.html							
Circular Economy Monitoring Framework https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework							



3.5 CSS 3 - CE Monitoring Framework (micro level)

Introduction

This CSS explores how to use sewage sludges (mud-like residue resulting from wastewater systems) generated by wastewater treatments to produce biogas. The largest wastewater treatment plant in the Łódzkie Region is the Wastewater Treatment Plant of Łódź, located in the Łódź city, which ensures the treatment of about $\frac{1}{3}$ of waters coming from Łódzkie inhabited areas (GOŚ ŁAM, 2017; GUS – Local Data Bank, 2022; Frontsh1p D5.1, p. 21).^{[20][18][21]} In 2021, more than 90% of wastewater was treated in municipal wastewater treatment plants. The rates of fees for wastewater discharge to sewage systems are approved by the State Water Holding Polish Waters. These fees cover the costs of collecting, treating and discharging wastewater into waters and ground. Residuals generating post wastewater treatment end up in sewage sludges (GUS – Local Data Bank, 2022; Frontsh1p D5.1, p.25).^{[18][21]} Comparing the amount of sewage sludges generated in the Łódzkie Region with the amount of sludge subjected to recovery processes, it results that about 60% of municipal sludge and about 90% of industrial sludge was not subjected to any recovery process in 2021 (GUS – Local Data Bank, 2022; Frontsh1p D5.1, p.26 Table 9).^{[18][21]} This indicates a high demand for new installations enabling the recovery of sewage sludge in the Łódzkie Region. These sludges could be used, for example, to biogas production in the anaerobic digestion process. In 2021, there were 18 biogas plants in the Łódzkie Region enabling the use of biogas to produce electricity (URE, 2022b; Frontsh1p D5.1, p.29 Table 10).^{[22][21]} The production of electricity from biogas was unprofitable until 2020, since then the situation has improved and a significant increase in investments has been observed. The trend observed between 2020 and 2021 should continue and even accelerate. However, a factor inhibiting the development of the industry may be social protests related to the construction of biogas plants, especially using municipal or slaughter waste. One can see positive and promising forecasts regarding the development of the biogas economy in Poland (Rada Ministrów, 2021; Frontsh1p D5.1, p.29).^{[23][21]}

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Based on the above description and information retrieved from previous deliverables,

Table 9 highlights the different stakeholders involved in the CSS3.



PUBLIC	PRIVATE	RESEARCH AND KNOWLEDGE	OTHERS
Regional government	Wastewater treatment plant of Lodz	University of Lodz	Frontsh1p scientific and technical partners
Local government		Lodz University of Technology	
Municipal wastewater			
State Water Holding Polish Waters			

Table 9. Stakeholders ecosystem of CSS3(Source: own compilation).

CE KPIs for CSS3 - micro level

Specific KPIs for the monitoring framework of CSS3 are developed and listed in **Table 10**. It is important to specify that such KPIs can be used and/or adapted for the same level (micro), categories, and sectors in other regions as well.

Table 10. CE KPIs for CSS3 - micro level [2,5,7].

Level	Category	Subcategory	Sector	Indicator	Unit	Year	Framework
Micro	Governance + Education	Awareness-raising	Water and Nutrients	Project promoting Wastewater recycling.	Number	2025	Screen
				Awareness campaigns to valorize wastewaters.	Number	2025	Frontsh1p
		Capacity building		Training courses on circular practices for wastewater management	Number	2025	Frontsh1p
				People trained on circular practices in the water and wastewater sector	Number	2025	Frontsh1p
				Level of implementation of training plan on the circular economy in the water and wastewater sector	Low, Medium, High	2025	Frontsh1p
		Education		Students trained in circular economy practices related to the valorization of wastewater	Number	2025	Frontsh1p
				Students related to waste management and recycling	Number	2025	EMF



		Innovation, pilots and experiments		<i>Patent requests in relation to new sustainable processes presented by economic actors</i>	Number	2025	Frotnsh1p
		Monitoring and evaluation		<i>Life cycle and cost-benefit studies in water and wastewater management</i>	Number	2025	Frontsh1p
		Collaboration		<i>Number of synergies identified / implemented by economic actors</i>	Number	2025	OECD
				<i>Number of workshops held to to link up supply and demand and boost the circular economy</i>	Number	2025	Frontsh1p
		Public Procurement		Green public procurement	%	2025	EMF
				Circular procurement	%	2025	OECD
				<i>Identified legal barriers for the Circular Public Procurement related to the water and wastewater sector</i>	Number	2025	Frontsh1p
				<i>CO2 savings as a result of procurement activities related to water and wastewater sector</i>	ktonnes	2025	Frontsh1p
				<i>Reduced emissions through Circular Public procurement related to water and wastewater sector</i>	% (in relation to a base year)	2025	Frontsh1p
				<i>Reduced waste through Circular Public procurement related to water and wastewater sector</i>	%	2025	Frontsh1p
				Regulation	<i>Legislative and normative incentives created (water and wastewater sector)</i>	Number	2025
		<i>Legal and regulatory barriers to the circular economy removed (water and wastewater sector)</i>			Number	2025	Frontsh1p
		<i>Directives adopted to improve water efficiency and water reuse</i>			Number	2025	Frontsh1p
		Stakeholder engagement		<i>Number of economic actors participating in water valorisation initiatives</i>	Number	2025	Frontsh1p



				Number of economic actors mobilised for the development of territorial synergies between economic actors	Number	2025	Frontsh1p
				Number of citizens mobilised in circular economy activities	Number	2025	Frontsh1p
				Wastewater management initiatives	Number	2025	Frontsh1p
		Strategy and initiatives		Level of implementation of Environmental Action Plan related to wastewater treatment	Low, Medium, High	2025	Frontsh1p
Micro	Economic and business	Added Value	Water and Nutrients	Economic value generated by new circular economy processes	EUR	2025	Frontsh1p
				Value-added Products (fuels, biostimulants, biofertilizers)	EUR	2025	Frontsh1p
		Business		Number of companies or products with tax benefits to incentivise the circular economy (water and wastewater sector)	Number	2025	Frontsh1p
				Economic operators supported in new circular economy practices (water and wastewater sector)	Number	2025	Frontsh1p
				Percentage of companies innovating for circular reasons (water and wastewater sector)	%	2025	Frontsh1p
				Economic Efficiency	Self-sufficiency for raw materials	%	2025
		Trade in recyclable raw materials (Intra EU)			mtonnes	2025	EMF
		Material Import dependency			%	2025	EMF
		Material intensity			Kg/EUR	2025	Frontsh1p
		Gains and revenues		Revenue generated from the adoption of more circular solutions within the water and wastewater sector.	Million EUR	2025	Frontsh1p
		Investments		Private investments	EUR	2025	EMF
				Private investments related to circular economy practices in the water and wastewater sector	thousand EUR	2025	Frontsh1p



				<i>Public investments related to circular economy practices in the water and wastewater sector</i>	Thousand EUR	2025	Frontsh1p
		Productivity		<i>Biomass Productivity</i>	EUR/kg	2025	Frontsh1p
		Savings		<i>Money saved as a consequence of the reuse of regenerated water from wastewater</i>	EUR	2025	Frontsh1p
				<i>Energy cost savings</i>	EUR	2025	Frontsh1p
Micro	Environment	Efficiency	Water and Nutrients	Net energy balance respect to the previous system or ‘amount of energy recovered’		2025	Screen
				Recycling rates for specific waste streams	kg/year	2025	EMF
				End-of-live recycling input rates (EOL-RIR)	%	2025	EMF
				<i>Energy efficiency of new proposed processes</i>	%	2025	Frontsh1p
				<i>CO2 sequestration Efficiency related to energy consumption</i>	kg CO2/kWh	2025	Frontsh1p
		Emissions		Reduction of emissions		2025	Screen
				<i>CO2 emissions reduction</i>	ktonnes	2025	Frontsh1p
				<i>Reduction of carbon emissions associated with wastewater treatment process</i>	% (in relation to a base year)	2025	Frontsh1p
				<i>Contribution of greenhouse gases associated with wastewater treatment process</i>	CO2eq (kt)	2025	Frontsh1p
				<i>Greenhouse gas reduction</i>	%	2025	Frontsh1p
				<i>Environmental Impact of proposed solutions</i>	NA	2025	
		Output material process		Mass of (biomass) resource recovered and re-introduced in a production cycle as a secondary raw material	kg/year	2025	Screen
				Total waste generation per capita	kg per capita	2025	EMF
				<i>Percentage increase in materials recovery (t) and organic recovery (t)</i>	%	2025	OECD



			<i>Percentage reduction of incoming / outgoing flows</i>	%	2025	OECD
			<i>Volume of recovered or reclamation of water from wastewater for non-potable usage</i>	m3/year	2025	Frontsh1p
			<i>Percentage reduction of eutrophication in water bodies</i>	%	2025	Frontsh1p
			<i>Change in the volume of wastewater treated</i>	dam3	2025	Frontsh1p
			<i>Change in the volume of sludge masses recovered</i>	Mg	2025	Frontsh1p
			<i>Amount of Nutrients (N, P, K) recovered from wastewater treatment</i>	Kg/m3	2025	Frontsh1p
			<i>Microalgae Biomass Yield</i>	Kg/m3	2025	Frontsh1p
			<i>Co2 fixation rate related to proposed solutions</i>	kg/m3/day	2025	Frontsh1p
		Production and consumption	Re-use, re-manufacturing, refurbishment, repair	kg/year	2025	Screen
			Circular design	kg/year	2025	Screen
			Waste reduction	kg/year	2025	Screen
			New production process with second raw materials	Number	2025	Screen
			<i>Regenerated wastewater (consumption)</i>		2025	Frontsh1p
			<i>Wastewater discharge avoided through a circular consumption</i>	tonnes	2025	Frontsh1p
			<i>Use of recycled raw materials in production processes</i>	cyclical material use rate	2025	Frontsh1p
			<i>Regenerated water used as a source of water supply</i>	%	2025	Frontsh1p
		Savings	<i>Material savings due to proposed solutions</i>	ktonnes	2025	Frontsh1p
			<i>Energy savings due to proposed solutions</i>	kWh	2025	Frontsh1p
		Use	<i>Circular material use rate</i>	%	2025	OECD



Micro	Infrastructure and Technology	Area	Water and Nutrients	<i>Surface area used for the microalgae cultivation from wastewater</i>	ha	2025	Frontsh1p
				<i>Preparation for reuse</i>	%	2025	OECD
				<i>Area of marginal land recovered for new sustainable models</i>	ha	2025	Frontsh1p
		Certificates		<i>Number of products and services with any kind of eco-label</i>	Number	2025	Frontsh1p
		Products		<i>New circular products (Biofuels , biofertilizers and biostimulants)</i>	Number	2025	Frontsh1p
		Facilities		<i>Number of wastewater treatment plants implementing microalgae-based solutions</i>	Number	2025	Frontsh1p
Micro	Society	Jobs and human resources	Water and Nutrients	Net balance of jobs	Number	2025	Screen
				<i>Number of new jobs created and secured by the implementation of circular economy practices in the sector</i>	Number	2025	Frontsh1p
*Source: The OECD Inventory of Circular Economy indicators www.OECD.org							
H2020 SCREEN project: www.http://www.screen-lab.eu/index2.html							
Circular Economy Monitoring Framework https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework							



3.6 CSS 4 - CE Monitoring Framework (micro level)

Introduction

In the Łódzkie Region plastic is widely used both in households and in industrial activities. In 2019, the municipal waste produced in the Region constituted 9.0% of the total amount of produced waste. In the same year, the amount of landfilled mixed waste was 38.8% (the national average – 40.5%), ranking the Łódzkie Region sixth in the country and following a positive trend of reduction of municipal waste ending up in landfills. However, low effectiveness of separate collection systems remains a problem. In the Łódzkie 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 was 25.0%), these amounts were still low both for a regional and national standards (BPPWŁ, 2021; Frontsh1p D6.1 p. 15).^{[24][25]} A Solution to such problems, such as effective processing of polymeric compound products and waste, should be found as soon as possible. Incinerating plants and pyrolysis processes are activities aimed at energy recovery more favourable than landfilling. 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 3 incinerators, a number that ideally should increase to favour such an expansion (Provincial Waste Management Plan Dz.U. 2015, item 1016; Frontsh1p D6.1, p. 32).^{[26][25]}

Based on the above description and information retrieved from previous deliverables, **Table 11** highlights the different stakeholders involved in the CSS4.

PUBLIC	PRIVATE	RESEARCH AND KNOWLEDGE	OTHERS
Regional government	Citizens	University of Lodz	Frontsh1p scientific and technical partners
Local government	Recycling companies	Lodz University of Technology	
Municipal waste management	Packaging supply companies		
	Incinerator plants		

Table 11. Stakeholders' ecosystem of CSS4 (Source: own compilation).



CE KPIs for CSS4 - micro level

Specific KPIs for the monitoring framework of CSS4 are developed and listed in **Table 12**. It is important to specify that such KPIs can be used and/or adapted for the same level (micro), categories, and sectors in other regions as well.

Table 12. CE KPIs for CSS4 - micro level [2,5,7].

Level	Category	Subcategory	Sector	Indicator	Unit	Year	Framework
Micro	Governance + Education	Awareness-raising	Rubber And plastics	Project promoting Rubber and plastics recycling	Number	2025	Screen
				<i>Awareness campaigns to valorize plastics waste.</i>	Number	2025	Frontsh1p
		Capacity building		<i>Training courses on circular practices for plastics</i>	Number	2025	Frontsh1p
				<i>People trained on circular practices in the plastics sector</i>	Number	2025	Frontsh1p
				<i>Level of implementation of training plan on the circular economy in the water and plastics sector</i>	Low, Medium, High	2025	Frontsh1p
		Education		<i>Students trained in circular economy practices related to the valorization of plastics</i>	Number	2025	Frontsh1p
		Innovation, pilots and experiments		Patents related to waste management and recycling	Number	2025	EMF
				<i>Patent requests in relation to new sustainable processes presented by economic actors</i>	Number	2025	Frotnsh1p
		Monitoring and evaluation		<i>Life cycle and cost-benefit studies in Rubber and Plastics waste</i>	Number	2025	Frontsh1p
		Collaboration		<i>Number of synergies identified / implemented by economic actors</i>	Number	2025	OECD
				<i>Number of workshops held to link up supply and demand and boost the circular economy</i>	Number	2025	Frontsh1p
		Public Procurement		Green public procurement	%	2025	EMF
				Circular procurement	%	2025	OECD
				<i>Identified legal barriers for the Green Public Procurement related to the rubber and plastics sector</i>	Number	2025	Frontsh1p



				CO2 savings as a result of procurement activities related to the rubber and plastics sector	ktonnes	2025	Frontsh1p
				Reduced emissions through green public procurement related to the rubber and plastics sector	% (in relation to a base year)	2025	Frontsh1p
				Reduced waste through green public procurement related to the rubber and plastics sector	%	2025	Frontsh1p
		Regulation		Legislative and normative incentives created (rubber and plastics sector)	Number	2025	Frontsh1p
				Legal and regulatory barriers to the circular economy removed (rubber and plastics sector)	Number	2025	Frontsh1p
		Stakeholder engagement		Number of economic actors participating in an Inclusive Recycling Program	Number	2025	Frontsh1p
				Number of economic actors mobilised for the development of territorial synergies between economic actors	Number	2025	Frontsh1p
				Number of citizens mobilised in circular economy activities	Number	2025	Frontsh1p
		Strategy and initiatives		Rubber and plastics management initiatives	Number	2025	Frontsh1p
				Number of environmental initiatives to valorise plastic waste	Number	2025	Frontsh1p
				Level of implementation of Environmental Action Plan related to plastic waste	Low, Medium; High	2025	Frontsh1p
Micro	Economic and business	Added Value	Rubber and plastics	Economic value generated by new circular economy processes	EUR	2025	Frontsh1p
				Value-added Products (Insulating bio-materials, Green foams, filaments for 3D printers)	EUR	2025	Frontsh1p
				Value-added Products (bio-char, bio-gas, bio-oil)	EUR	2025	Frontsh1p



		Business		Number of companies or products with tax benefits to incentivise the circular economy (rubber and plastics sector)	Number	2025	Frontsh1p	
				Economic operators supported in new circular economy practices (rubber and plastics sector)	Number	2025	Frontsh1p	
				Percentage of companies innovating for circular reasons (rubber and plastics sector)	%	2025	Frontsh1p	
		Economic Efficiency		EU self-sufficiency for raw materials	%	2025	EMF	
				Trade in recyclable raw materials (Intra EU)	mtonnes	2025	EMF	
				Material Import dependency	%	2025	EMF	
		Gains and revenues		Material intensity	kg/EUR	2025	Frontsh1p	
				Investments	Revenue generated from the adoption of proposed circular solutions within the rubber and plastics sector (biomaterials for insulation).	Million EUR	2025	Frontsh1p
					Private investments	EUR	2025	EMF
		Savings			Private investments related to circular economy practices in the rubber and plastics sector.	Thousand EUR	2025	Frontsh1p
				Public investments related to circular economy practices in the rubber and plastics sector.	Thousand EUR	2025	Frontsh1p	
				Productivity	Biomaterials Productivity	EUR/kg	2025	Frontsh1p
				Money saved as a consequence of adopting low-cost biomaterials for insulation.	EUR	2025	Frontsh1p	
				Energy cost savings	EUR	2025	Frontsh1p	
Micro	Environment	Efficiency	Rubber and plastics	Net energy balance respect to the previous system or ‘amount of energy recovered’		2025	Screen	
				Recycling rates for specific waste streams		2025	EMF	
				End-of-live recycling input rates (EOL-RIR)	%	2025	EMF	
				Energy efficiency of new proposed processes	%	2025	Frontsh1p	



		Emissions	CO2 sequestration Efficiency related to energy consumption	Kg CO2/kWh	2025	Frontsh1p
			Reduction of emissions		2025	Screen
			CO2 emissions reduction	ktonnes	2025	OECD
			Reduction of carbon emissions associated to recycling, pre-treatment and pyrolysis process	% in relation (a base year)	2025	Frontsh1p
			GHG Emissions	CO2/year	2025	OECD
			Contribution of greenhouse gases associated to recycling, pre-treatment and pyrolysis process	CO2eq (kt)	2025	Frontsh1p
			Greenhouse gas reduction associated to proposed solutions	%	2025	OECD
		Output material process	Mass of (biomaterials) source recovered and re-introduced in a production cycle as a secondary raw material	kg/year	2025	Screen
			Total waste generation per capita	g per capita	2025	EMF
			Percentage increase in materials recovery (t) and organic recovery (t)	%	2025	OECD
			Percentage reduction of incoming / outgoing flows	%	2025	OECD
			Amount of recovered plastic waste for insulating biomaterials	kg/year	2025	Frontsh1p
			Amount of recovered plastic waste for bio-based foam materials	kg/year	2025	Frontsh1p
			Amount of recovered plastic waste for producing Filament polymer as feedstock for 3D printer	kg/year	2025	Frontsh1p
			Change in the volume of plastic waste treated	m3/year	2025	Frontsh1p
			Change in the volume of biomaterial recovered	m3/year	2025	Frontsh1p
			Bio-Oil Yield	m3/year	2025	Frontsh1p
			Bio-char Yield	m3/year	2025	Frontsh1p
			Bio-gas Yield	m3/year	2025	Frontsh1p



				<i>Co2 fixation rate related to proposed solutions</i>	kg/m3/day	2025	Frontsh1p
		Production and consumption		Re-use, re-manufacturing, refurbishment, repair	kg/year	2025	Screen
				Circular design	kg/year	2025	Screen
				Waste reduction	kg/year	2025	Screen
				New production process with second raw materials	Number	2025	Screen
				<i>Reduction of the use of chemical blowing agents such as azodicarbonamide</i>	kg/year	2025	Frontsh1p
				<i>crease of the use of supercritical CO2 as foaming agent (as replacement of iso-butane)</i>	%	2025	Frontsh1p
				<i>Use of recycled raw materials in production processes</i>	cyclical material use rate	2025	OECD
		Savings		<i>Virgin material savings due to proposed solutions</i>	ktonnes	2025	Frontsh1p
				<i>Energy savings due to proposed solutions</i>	kWh	2025	
	Use	<i>Circular material use rate</i>	%	2025	OECD		
Micro	Infrastructure And Technology	Area	Rubber And plastics	<i>Area of public space used as collection and sorting facilities</i>	ha	2025	Frontsh1p
				<i>Preparation for reuse</i>	%	2025	OECD
		Certificates		<i>Number of products and services with any kind of eco-label</i>	Number	2025	OECD
		Products		<i>New circular products including biomaterials, Green foams and 3D printer filaments)</i>	Number	2025	Frontsh1p
				<i>New circular by-products (Bio-oil, bio-gas, bio-char)</i>	Number	2025	Frotnsh1p
		Facilities		<i>Number of sorting plants for selective collection of plastic waste</i>	Number	2025	Frontsh1p



		Equipment		<i>Number of plastic collection devices installed</i>	Number	2025	Frontsh1p
				Net balance of jobs	Number	2025	Screen
				<i>Direct jobs associated with the 3D printing social enterprise</i>	Number	2025	Frontsh1p
				<i>Number of new jobs created and secured by the implementation of circular economy practices in the sector</i>	Number	2025	Frontsh1p
*Source: The OECD Inventory of Circular Economy indicators www.OECD.org							
H2020 SCREEN project: www.http://www.screen-lab.eu/index2.html							
Circular Economy Monitoring Framework https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework							



4. Public Private Partnership

Public-Private Partnerships (PPPs) within the European Union constitute collaborative ventures between governmental entities and private organisations aimed at executing public endeavours such as infrastructure, transportation, and healthcare development. These alliances harness the complementary strengths of both sectors, leveraging governmental accountability alongside the private sector's efficiency and innovation. Initiated by identifying projects necessitating additional funding or expertise, PPPs entail contractual agreements that distribute risks, funding, and responsibilities among all partners.

A PPP is considered a public, competitive contract and is thus subject to the regulations outlined in the Public Procurement Directive 2014/24/EU^[27] and adheres to the principles of the Treaty of the Functioning of the European Union, encompassing free movement rules as well as transparency, equal treatment, proportionality, and mutual recognition. Addressing challenges posed by global warming requires various measures such as for example infrastructure enhancements. However, tackling global warming incurs a financial shortfall concerning both capital investment and operational expenses. Recent EU initiatives such as the Circular Economy Action plan therefore take use of PPP contracts. This is mentioned within the non-legislative Regulation (EU) 2021/2085 establishing the joint undertakings under Horizon Europe^[28] addressing PPPs. The regulation aims to establish 9 joint undertakings as public-private partnerships within the Horizon Europe program, outlining their objectives, tasks, membership, and operational guidelines. These collaborations collectively aim to strengthen key points such as scientific capabilities, global collaboration, competitiveness, resilience, and sustainability, aligning with EU strategic priorities and initiatives like the European Green Deal and recovery plans. They target specific sectors such as bio-based solutions, clean aviation, hydrogen, rail, global health, innovative health, digital technologies, air traffic management, and smart networks. The main recommendations resulting from EU regulations to set up a PPP are summarised as follows:

- Motivation for the private sector to participate in the establishment of a PPP;
- The participants should agree to a legal basis when creating a PPP;
- Public institutions should lead the PPP or the national action plan for PPP;
- PPPs should invest on internal private-private and public-public collaboration;
- Investing on open communication and a pragmatic approach towards building a PPP;
- Public representatives participating in meetings with non-disclosure agreement;
- Small and Medium Enterprises (SMEs) should also participate in PPPs.



4.1 Inputs for Circular Łódzkie

Within the region of Łódzkie, PPP could be translated in a regional hub, where public administrative figures (such as the region of Łódzkie, Bzura, Parcezw and SŁOM-the Union of Metropolitan areas of Łódzkie) and private organisation join in a unique body to gain a clearer overview of the circularity transition and speed up CE projects through investments within the region with many advantages as shown in **Figure 5**.

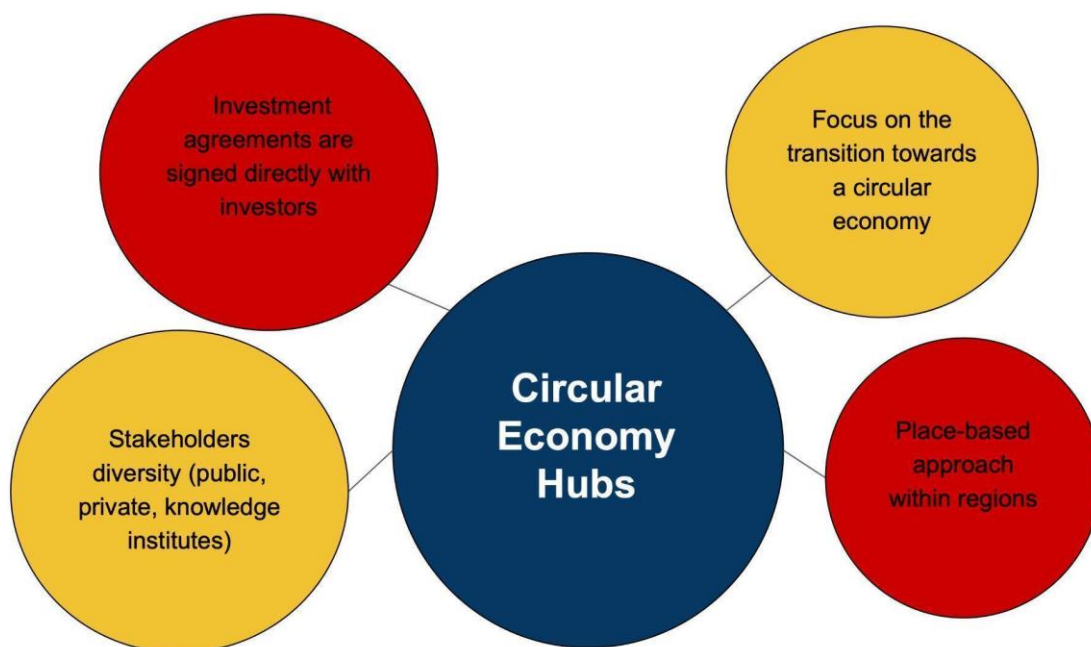


Figure 5. Regional Circular Economy hubs key features (Source: own compilation).

There are good practices of CE regional hubs that have demonstrated a positive impact for boosting circularity projects within regions. Hereafter are listed info about how the conditions within hubs from Belgium, the Netherlands and Spain were created:

- **Circular Flanders.** Circular Flanders was instigated by the Flemish Government in 2017 and reaffirmed by the present administration (2019-2024). Through the initiative Flanders aims for preeminence in circular practices, striving to disconnect material consumption's impact from economic growth, targeting a 30% reduction by 2030. The start of Circular Flanders dates back to 2006 when OVAM, the Public Waste Agency of Flanders, convened a panel of experts to address the necessity for sustainable materials management in the region.



This consortium evolved into a think-tank, subsequently forming the Flanders' Materials Programme (VMP). In 2017, Circular Flanders united prior initiatives, launching its vision for 2050^[29]. The initiative fosters collaboration among government bodies, businesses, civil society, and academic institutions, recognizing the need for customised solutions across various issues, delineating between simple, complicated, and highly complex challenges. Throughout its existence, Circular Flanders has emphasised systemic innovation over mere efficiency enhancements within unsustainable systems. Geared toward empowering practitioners, Circular Flanders equips them with actionable insights and tools to drive effective progress toward a circular future. Representatives from around 20 diverse organisations collectively craft the partnership's strategy and actions, aligning their endeavours with the shared ambition^[30].

- **Circular Friesland.** The inception of Circular Friesland traces back to 2015 as seven companies and two government bodies united to explore how the Friesland region could embrace greater circularity and sustainability. Collaborating with the Province of Friesland and the Municipality of Leeuwarden, these entities commissioned an in-depth analysis of material flows within Friesland. This examination aimed to identify the inflow and outflow of raw materials, pinpoint where energy contributes to our province, and uncover areas where energy is dissipated. Partnering Metabolic and Urgenda conducted a comprehensive Regional Analysis for Friesland. Their work involved mapping the regional context, understanding commodity flows, and assessing the needs of local stakeholders. Additionally, they also made extensive interviews with over 50 local entrepreneurs. This analysis, coupled with a participatory stakeholder process, culminated in a comprehensive document pinpointing circular opportunities poised to be developed into landmark projects. The report, presented with an in-depth material flow analysis, proved inspiring to hundreds of entrepreneurs, knowledge institutions, various organisations, and governmental bodies. It offered a plethora of circular possibilities, highlighted Frisian opportunities, and showcased promising cycles. Today, the association boasts over 100 active members^[31].

- **Circular Navarre.** Since 2007, the Government of Navarre region in Spain has pursued the development of a circular economy through a series of projects and agendas. Their 2030 Agenda emerged in 2016 as a pivotal framework for circular economy advancement within Navarre. In 2021, the transition to a new Smart Specialisation Strategy (S4) was developed to enhance the existing one by integrating thematic priorities aligned with the economic, scientific, and technological potential of the region. Smart policies tailored to these priorities aim to optimise regional development, encompassing a participatory methodology and a continuous tracking system^[32].

Subsequent milestones included collaborative efforts across European regions through the SCREEN project in 2018, the ORHI Project focusing on the agri-food industry, participation in the LCA4Regions



Project in 2019, and addressing construction waste in the RCDiGreen project in 2020^[33]. They actively seek new partnering opportunities within prominent EU programs like Horizon Europe, LIFE, and INTERREG. The launch of the 'Circular Navarre Catalog' in 2020, later updated in 2021 and 2022, further highlighted the region's commitment to circular economy principles. Through Circular Navarre, 50 organisations are involved and adhere to circular economy principles, emphasising the identification of value creation across the value chain. They focus on fostering positive social, environmental, and economic impacts, along with an interest in international collaboration ^[34].

The description and reference to these 3 CE regional hubs might serve as good practice for Łódzkie and other regions that aspire to set up a PPP that brings advantages to the development and management of CE projects,

4.2 Roadmap for Circular Łódzkie

In territorial systems that have reduced capacity for self-adaptation to the circular economy, it is necessary to adopt a "step-by-step" approach governed by Regional Public authorities. However, this approach must still leave ample room for the initiative of Private stakeholders, to ensure a real and effective adaptation of the system. Therefore, it is necessary for the regional administration to implement an innovative operational model that supports the transition while increasing the perception and awareness of its local stakeholders. The shift from a linear to a circular economy model, requires a multi-layered approach, with a long-term vision that involves systemic changes supported by a multi-stakeholder network. To achieve the desired transformation at different levels: economic, social, and environmental, a collaborative multi-stakeholder engagement is therefore crucial.

The implementation of the model "Circular Łódzkie", a platform that functions as a "Circular economy Hub", based on a Public-Private Partnership between the Regional and local stakeholders, in accordance with the definition provided by the European Circular Economy Stakeholder Platform; should bridge the gaps created by different types of governance and represent an important step towards the circular economy transition of the region. The foreseen circular economy hub should therefore bring together existing and emerging centres, platforms and networks that contribute efficiently to the implementation of circular economy principles and minimise the preconditions that hinder the transformation at regional level. The successful implementation of a CE Hub in Łódzkie, depends on the application of new approaches to conventional public governance. A network governance is therefore a crucial addition to support the transition. A strong network that aligns stakeholders and ensures that all involved actors work together in a symbiotic way, will guarantee the correct activation of circular initiatives.



Figure 6 shows the connection between Public Governance (Regional Government), which supplies policy tools and charts the course towards a set goal, and Network Governance, essential for engaging stakeholders and overseeing their efforts, including the content of proposed initiatives, establishing the foundation for a thriving and effective Circular Economy Hub^[35].

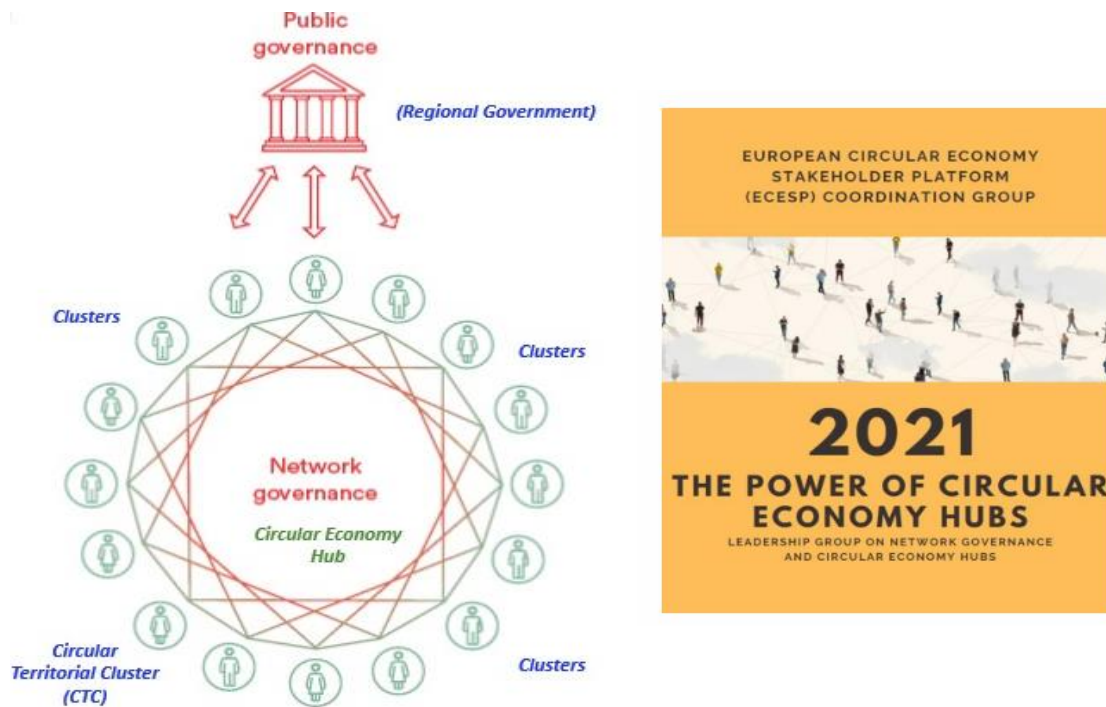


Figure 6. Relation between Public Governance and Network Governance [35].

Circular Territorial Clusters (CTCs) are important elements to build the roadmap towards Circular Łódzkie. As explained in deliverable 2.1 of FRONTSH1P, the focus on territoriality emphasises the significance of the territory's features and the key stakeholder groups in boosting the competitiveness of CTC. Territorial clusters are tied to local economic, social, and environmental conditions and centred around key stakeholders of spatial proximity. As such, stakeholder collaboration within a CTC aims to uncover untapped opportunities within non-conventional goods, a facet often overlooked in analysing industrial cluster networks. Creating this cluster demands an entrepreneurial social ecosystem, blending innovation and ecological principles by involving locals as producers. In the case of FRONTSH1P, the 19 municipalities forming the Bzura Intermunicipal Union form such a cluster. This area, in the northern Łódzkie Region, involves various stakeholders such as regional institutions, scientific bodies, civil society representatives, agricultural entrepreneurs, and industry groups.

As it is also mentioned in deliverable 2.2, the community's active engagement is vital for the CTC, not only in terms of its awareness but also in terms of active participation, transforming norms, and



influencing its market dynamics. Within this setup, networking, communication, and management operate horizontally, prioritising flat structures over traditional hierarchies.

Also, a relevant planning approach for the establishment of Circular Łódzkie is CircuPuncture. CircuPuncture is a systematic plan designed to transform the economy of a territory into a circular model. It involves collaborating across public, social, and private sectors to address market failures and issues in cooperation with government bodies. The main area of use is adapted for territories facing challenges adapting to CE principles, particularly where regulatory hurdles exist. The plan is specifically adapted for locals struggling to embrace circular practices and thus needing a different approach to Circular Governance, and emphasises incremental progress and adaptability to achieve objectives ^[36].

As also described in Deliverable 2.2, solutions within CircuPuncture are to be tested, refined, and continually implemented through sandbox projects, allowing for ongoing adjustments to facilitate the advancement of missions and resolve challenges. It's a holistic approach using communication and technical tools to make gradual investments when a full-scale development plan isn't feasible. This method engages a variety of stakeholders that coordinate among various cross-sectoral activities, fostering a balanced coexistence of social, economic, and natural spheres while focusing on local action, essentially creating CTCs that can then be replicated in other areas.

The roadmap for setting up and supporting the establishment of Łódzkie Circular Economy Hub is divided into five phases as shown in **Figure 7**:

- Stakeholders
- Activities and focus area.
- Business model
- Governance
- Action



Roadmap for setting up and supporting Łódzkie Circular Economy Hub

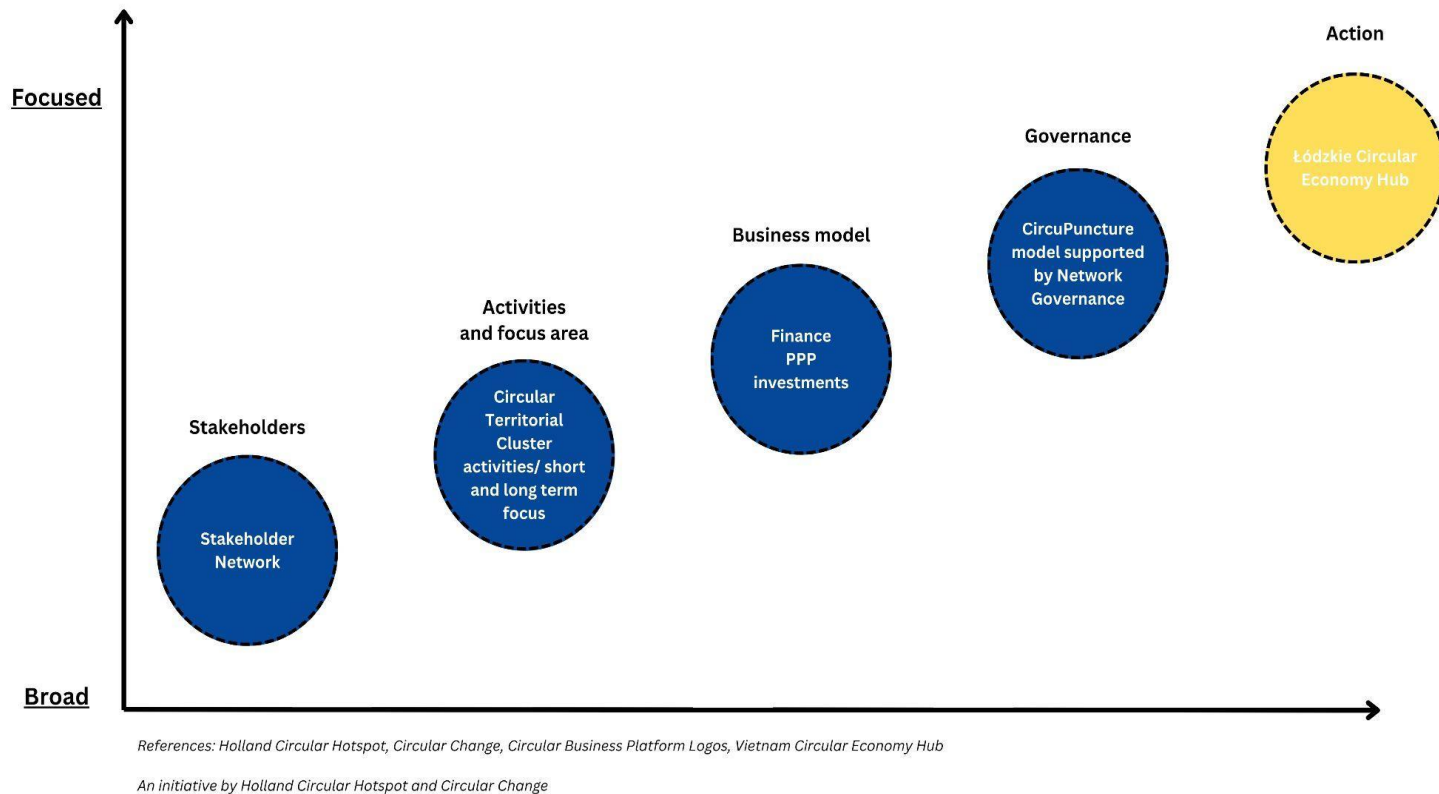


Figure 7. Roadmap for Circular Lodzkie [36]. Source: Own compilation

- **Stakeholders:** The initial phase, "Mapping of Stakeholders," encompasses a range of activities. It begins with creating a database of potential stakeholders, then progresses to categorising and fine-tuning this list based on their respective sectors and interests. Subsequently, a prioritisation of key stakeholders should be conducted, culminating in the identification of influential leaders or brokers.
- **Activities and focus area:** This stage encompasses initiatives aimed at specific focus areas, defined to bring short and long-term impacts.
- **Business model:** In this stage, the focus is on crafting and introducing innovative business models that can accelerate the transition. It also includes fostering new collaborations that encourage both public and private investments.
- **Governance:** Collaborative governance models, Public Governance models supported by a strong Network governance working towards well-defined circularity goals.



- **Action:** The final stage involves the implementation of the Circular Economy Hub, a coordinated group of entities (platform) with complementary skills and a non-profit goal to support the holistic transition towards a circular economy in a specific territory or area.

The roadmap for establishing the Circular Łódzkie Economy Hub is a comprehensive and dynamic model for transitioning to a circular economy in the Łódzkie region. This model emphasises the importance of a multi-stakeholder, multi-layered approach, integrating the roles of both public and private entities. The steps, ranging from stakeholder mapping to the final implementation of the Circular Economy Hub, highlight the necessity of a collaborative and well-coordinated effort, focusing on innovative business models, governance structures, and targeted actions. The success of this roadmap lies in its ability to adapt to local needs while aligning with broader, systemic changes required for a sustainable and circular economic transformation. This approach serves as a model replicable to other areas (one of the main objectives of the Forntsh1p project) seeking to undergo a similar transformation, showcasing the effectiveness of meticulous strategic planning, active stakeholder involvement, and a collective commitment to a sustainable future.



5. Circular Public Procurement

Circular Public Procurement (CPP) can be defined as the process by which public authorities purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across their whole life-cycle. It differs from sustainable public procurement, which takes into account environmental, economic, and social aspects. Procurement is a way to accelerate the macro-scale societal transitions in line with EU Commission's green deal and Circular Action Plan to reduce society's environmental impact while contributing to creating jobs and economic growth, a transition that involves all levels of society. Within this category, circular procurement often aims to recycle or in other ways extend the life cycle of products, resources and services^[37].

There are guidelines issued by the European Commission that indicate the policy context and several models of circular procurement. Variances in understanding CPP arise from different interpretations of fundamental criteria like 'process,' 'reduced environmental impact,' and 'similar purchase items' ^[38]. City Loops is a collaborative EU funded project that has developed a circular procurement handbook to serve as a tool for internal and external parties in successful circular procurement implementation to aid interested regions and parties. The handbook includes examples across the EU of circular procurement implementation practices, as shown in **Table 13**.

Table 13. The Circular Handbook examples to enhance CPP [39, 40, 41, 42, 43, 44].

Case Studies	Construction and Demolition Waste	Bio-Waste
Denmark	• Local government collaborating with local building authority to reuse concrete after building demolition. • Criteria to determine concrete's quality was possible through the use of a passport to classify concrete.	-



Spain	• Public water operator EMASESA partnering with construction firms to embed circular principles in public contracts. • Creation of a guide for construction waste management • Development of a digital tool to optimise citizen's waste and to monitor data	• LIPASAM, the municipal waste management in Seville, invested in the distribution of bio-waste containers in the city, activity supported by an information campaign • Collaboration between EMASESA and LIPASAM facilitated the use of sewage sludges to co-digest bio-waste to produce methane
The Netherlands	• Collaboration between Apeldoorn municipality and Saxion university by co-designing together strategies to close material loops and use construction waste for other infrastructure projects • Circularity principles were integrated into the procurement process by offering contractors a slight advantage for considering circular practices in their proposals.	• Apeldoorn municipality explored the possibility to use bio-waste as soil enhancer and to develop biochar through pyrolysis
Portugal	-	• Porto municipality promoting the use of bio-waste as compost • Circular procurement was boosted through the introduction of a Green Space Certification System and by hosting the FoodLoop Contest



Furthermore, the handbook outlines the following steps for a successful circular procurement implementation:

- Firstly a pre-tender phase, where a comprehensive procurement strategy aligning with circular principles is developed, defining clear project scopes and gathering essential material information;
- This then moves into the tender phase, where circular-focused requirements are set, along with criteria and benchmarks for quality assessment. The weights of these criteria could be balanced between for example, sustainability and price considerations, and lead to the establishment of circular contracts integrating specific circularity principles;
- Lastly the Post-tender phase, where continuous monitoring is established to ensure contract alignment with circular economy goals, supported by benchmarks and a 'Plan-Do-Check-Act' cycle for ongoing improvements through evaluations and collaborative learning.

These steps emphasise the critical role of collaborative databases for circular products in fostering holistic understanding and driving innovation and stakeholder engagement as a way for fostering support, and identifying innovative solutions. They also underscore the importance of advocating for new laws, setting clear objectives, and addressing practical challenges through research and collaborative efforts to achieve effective circular procurement.

4.1 Circular Public Procurement inputs for Łódzkie

Based on the indications provided by the previous examples and the Circular Procurement Handbook, a CPP scheme for the Łódzkie region referred to the 4 CSSs is created and shown in **Figure 7**. It relies on 3 main steps:

- Defining CSSs principles and translating them in CPP objectives
- Defining CSSs strategies and their key points to reach the objectives
- Identifying CSSs action requirements to implement the strategies



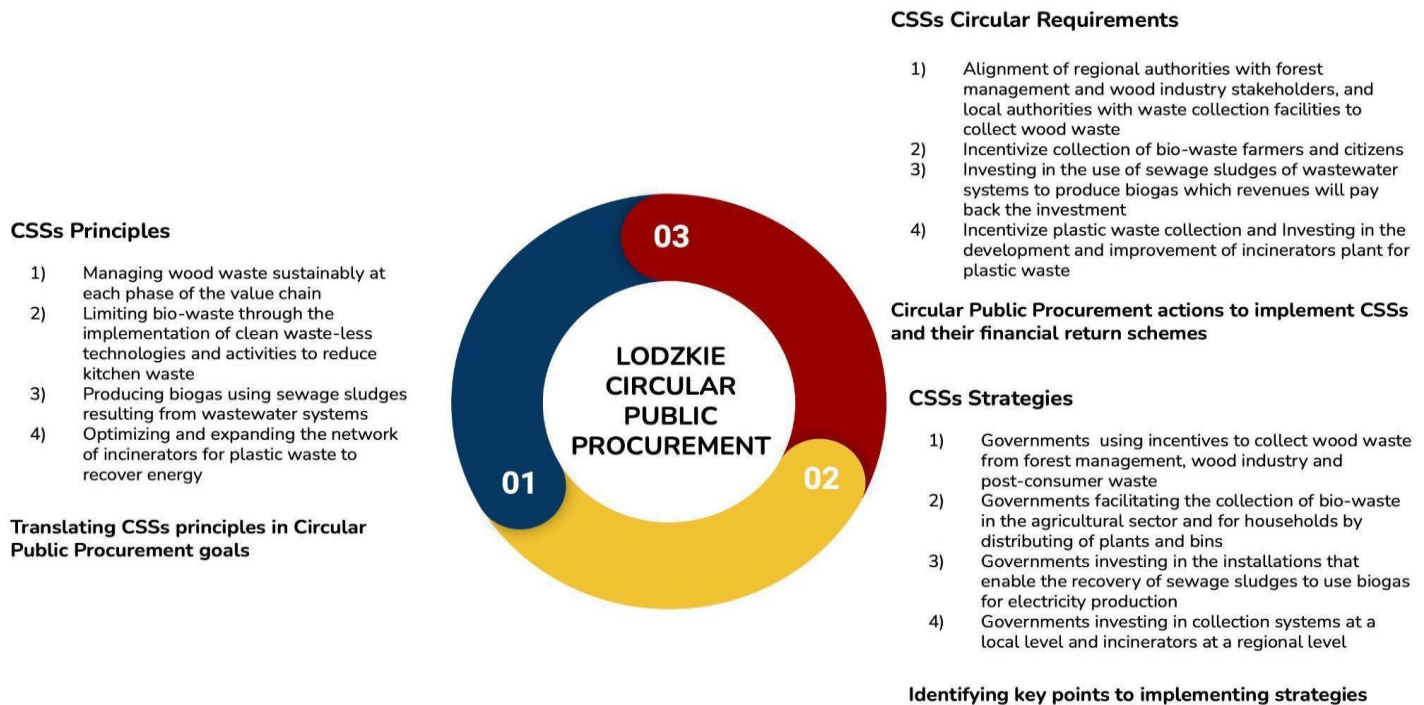


Figure 7. Łódzkie CPP scheme. (Source: own compilation).

Within the Frontsh1p project there are also 2 different tools that can be useful to monitor the CPP scheme and to identify the actions that can improve it:

- Firstly, the **Regional Booster Toolkit** (RBT)^[45], in development phase within Frontsh1p, is an online tool that assesses resource streams within the region, such as waste streams, raw materials streams, and reusing and recycling rates. This tool would facilitate the CE transition within the region and the GPP through collecting and sharing information among public and private stakeholders to create sustainable business opportunities in Łódzkie and support the development of the CSSs.
- In addition, the **Circular Benchmark Tool** ^[46] (CBT) launched in 2021 as part of the EU project REPLACE is a valuable digital tool to assess the transition towards CE for regions. An added value of CBT is that it was developed by regions and improved by them after multiple feedback sessions. One of its 6 indicators is Circular Procurement, which assesses the way how a region sources products and services from suppliers who apply circular practices. The CBT manual^[46] was recently published, and it functions as a step by step guide for regional authorities to perform the assessment.

Whilst the Regional Booster Toolkit provides more quantitative information related to waste streams and resources, the Circular Benchmark Tool gives a more qualitative assessment with identification of action points. Therefore, the 2 tools are complementary with each other and together can better support CPP.

- Additional information regarding CBT role:

This deliverable presented the model with its supporting tools. However, the CBT tool has been applied in the Łódzkie region as a practical and operational tool, not merely as a theoretical framework in a subsequent deliverable D7.5 due in October 2024. Specifically, it was tested through two inter-municipal associations — the Association of Bzura and the Łódź Metropolitan Area Association (SLOM) — which together represent the region's Circular Territorial Cluster (CTC). These two associations conducted the CBT assessment independently, allowing for both a comparative and individual analysis of their circular economy maturity levels across the six indicators. This pilot implementation provided valuable insights into the regional potential for circularity and helped identify specific strengths and gaps. Therefore, the CBT is not only introduced conceptually but has been concretely tested and used in practice to guide and support the circular transition in the Łódzkie region. (Frontsh1p, D7.5 p. 12-14).^[47]

-Additional information on updates to the Monitoring framework after initial submission:

Since its initial development, additional indicators have been introduced to the Monitoring Framework through the CircuPuncture Economy Action Plan (CpEAP). These new indicators adopt a resource- and territorial-based approach, emphasizing a bottom-up engagement with regional stakeholders to identify key circular challenges in the context of the Circular Territorial Cluster in Łódzkie region. The updated list of indicators will be presented as part of the updated Deliverable 2.6 : Circular Governance Model, operational framework, the Lodzkie Region CEAP enhancement and implementation updates (ongoing).



6. Conclusion

The Frontsh1p project plays a pivotal role in advancing the circular economy (CE) in the Łódzkie region of Poland through the development of a CE monitoring framework that comprehends Indicators, innovative Public-Private Partnerships (PPP), and Circular Public Procurement (CPP) models. This comprehensive approach, rooted in local specifics yet adaptable for broader contexts, sets guidelines for sustainable development and effective governance. The project methodologies and tools, including the proposed Monitoring Framework, provide a structured understanding of CE through tailored indicators and sectoral analyses. These tools and models focus on both macro-regional and local scales, emphasising the importance of industrial symbiosis and the integration of territorial clusters for effective CE practices. The indicators provided for the Circular Systemic Solutions (CSSs) are 'ready to use' and will be narrowed down to the specific measuring and monitoring requirements of each CSS. This makes them adaptable for other regional contexts.

Public Private Partnerships within the EU, exemplified by successful models in Flanders, Friesland, and Navarre; highlight collaborative efforts crucial for implementing CE projects and addressing global challenges like climate change. In Łódzkie, PPPs are envisioned as regional hubs to accelerate CE projects, demonstrating the effectiveness of collaborative efforts in fostering circular practices. The roadmap for establishing the Circular Łódzkie Economy Hub is a testament to the multi-stakeholder, multi-layered approach necessary for a sustainable and circular economic transformation. This roadmap, adaptable to local needs, encompasses stakeholder mapping, business model development, governance, and action phases, providing a model for other regions seeking similar transformations.

Lastly, Circular Public Procurement (CPP) emerges as a key strategy in supporting the transition towards a CE. A scheme adapted to Łódzkie is provided and can be supported by tools like the Regional Booster Toolkit (RBT) and the Circular Benchmark Tool (CBT), which offer both quantitative and qualitative assessments for monitoring CPP and contributing to a regional Circular Economy Action Plan (CEAP). These initiatives collectively drive the Łódzkie region towards a sustainable, circular economy, setting a scalable and replicable example for other regions.



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