



CIRCSYST

Circular Systemic Solutions



Water



Bio-Waste



Plastic,
Packaging

2024-2027

DELIVERABLE 6.1 – DEMOS

ASSESSMENT GUIDE

WORK PACKAGE 6: SYSTEM ANALYSIS, KNOWLEDGE TRANSFER AND



Funded by
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Circular
Cities & Regions
Initiative
CCRI Project



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D 6.1 Deliverable D6.1 – CircSyst Guide for CSS Demos Assessment

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EXECUTIVE SUMMARY

This document, **Deliverable D6.1 – CCRI Guide of CSS Demos**, serves as the foundational deliverable for Work Package 6 (WP6) within the CircSyst project. It outlines the methodology and strategic approach for assessing Circular Systemic Solutions (CSS) developed under the project. The deliverable provides a comprehensive guide for implementing, evaluating, and refining CSS across various demonstrators, ensuring alignment with the broader goals of circularity and sustainability in Europe.

The CircSyst Methodology is adapted from the Circular Cities and Region Initiative (CCRI) methodology, tailored specifically to meet the needs of the CircSyst project. This adaptation focuses on assessing the suitability of each CSS to address their respective circularity challenges, the context in which they operate, and their potential for transferability and replication across different regions and sectors. The methodology emphasizes the importance of stakeholder engagement, the alignment with policy frameworks, and the integration of social, environmental, and economic impacts into the assessment process.

This deliverable includes the following critical components:

1. **General Procedure Description and Rationale:** A detailed explanation of the methodology used to assess and adapt the CCRI framework for the CircSyst project.
2. **CircSyst Circular Systemic Solution Demos Summary:** A summary of each CSS Demo, highlighting the shared synergies amongst CSSs.
3. **Anexes:**
 - **Annex I:** The full CircSyst Methodology for assessing Circular Systemic Solutions, providing a step-by-step guide for evaluating each CSS.
 - **Annex II:** The Short Profile Template, which standardizes the initial assessment and documentation of each CSS.
 - **Annex III:** Detailed profiles of all nine CSS Demos, developed by each Demo leader, capturing the initial conditions, expected impacts, and potential synergies.

The insights gained from this deliverable are intended to guide the continuous improvement of each CSS, ensuring that they are robust, scalable, and capable of fostering systemic change towards a circular economy. By establishing a common framework and fostering cross-sectoral collaboration, this document aims to create a strong foundation for the successful implementation and replication of Circular Systemic Solutions across Europe.

The reference task is T6.1.



LIST OF ACRONYMS AND ABBREVIATIONS

Acronyms and abbreviations	Meaning
AI	Artificial Intelligence
CCRI	Circular Cities and Region Initiative
CSS	Circular Systemic Solution
SEP	Stakeholders Engagement Plan
WP	Work Packages



LIST OF TABLES

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1. INTRODUCTION

The CircSyst Methodology, designed and implemented in Task 6.1, is based on the [CCRI methodology](#) for the implementation of a circular economy at the local and regional scale . This CCRI guide aims to support cities and regions that intend or are transitioning towards a circular economy by implementing Circular Systemic Solutions (CSSs). The CCRI methodology is based on an open mapping of 1.1) the policy framework, 1.2) the metabolism of the territory, and 1.3) the potential stakeholders. Based on this understanding, the methodology suggests a design phase that builds on 2.1) engaging stakeholders, 2.2) identifying intervention areas & build a CSS case, 2.3) assess and evaluate the CSS, 2.4) define targets and monitor indicators.

In the context of CircSyst the solutions are already predefined and not starting from scratch. Thereby, the methodology should be focused more in assessing the suitability of each CSS to their relevant Circularity Challenges, their context, and the potential of each CSS to be transferred and replicated creating thus a collaborating network of Circular Economy actors along Europe provided with a portfolio of effective CSS ready to answer the needs of a multiplicity of scenarios and locations.

In addition, even if the regional/local governments are involved in the projects either as partners or stakeholders, the CSS leaders are not governments, but mostly research centers, clusters, and competitiveness Agencies, and thereby they do not have the decision-making capacity needed to apply the CCRI Methodology. Instead, they have more flexibility and the need to transfer the knowledge created making it useful for regional/local government to apply it, as well as to perform training and awareness-raising action highlighting the benefits of applying CSS.

For this reason, the CCRI Methodology has been reviewed, adapted, and complemented with new sections to make it fit the needs of the CircSyst CSS.



1. General Procedure Description and rationale

Task 6.1 begins with a workshop designed to familiarize project partners with the CCRI methodology. During the workshop, partners discussed the suitability of the CCRI methodology and worked on developing adaptations to address the assessment and knowledge-gathering needs of CircSyst Demos. At the conclusion of the workshop, all partners mapped the key aspects of their respective Circular Systemic Solutions (CSS).

Based on the workshop's outcomes, the Deliverable leader prepared both a new **CircSyst Methodology for assessing CSS** and a **CSS short profile**.

The CircSyst Methodology will be used by partners throughout the project to collect and transfer the knowledge generated. Each CSS will maintain its own template as a living document, updated with new information and knowledge as it is collected.

On the other hand, the short profile provides an initial assessment, capturing the knowledge that Demo leaders currently have about each CSS at this stage of the project. These profiles will be valuable for the first workshops and activities in Tasks T6.2 and T6.3, and will also serve as input for Tasks T5.1, T5.2, T5.4, and T7.1.

Additionally, the CircSyst methodology has been further enriched with inputs from CCRI-CSO experts as well as the following CCRI releases:

- [Key indicators for monitoring the circular economy](#)
- [The Circularity Gap Reports by the Circularity Gap Reporting Initiative](#)
- [The OECD Inventory of Circular Economy indicators](#)
- [A System Change Compass. Implementing the European Green Deal in a time of recovery](#)
- [Accelerating the circular economy in Europe. State and outlook 2024](#)
- [Circular Cities Declaration \(CCD\) Report 2024](#)
- [Circular economy: what we want to know and can measure](#)
- [Development of the circular bioeconomy: drivers and indicators](#)
- And the **K-CCRI Project**: [Knowledge hub to leverage existing initiatives and projects to foster the adoption of Circular economy in Cities and Regions In Europe](#).



2. CircSyst Circular Systemic Solution Demos

The following chart summarizes the main aspects of each CSS Demo, including the shared synergies.

Table 1: Circular Systemic Solution Demos Summary.

Demo	Leader	Field	Synergies	Description
1	AIDIMME	Water	Demos 2, 3, and 4	Reuse of Industrial Wastewater by on-demand treatment and distribution powered by AI.
2	KIS	Water	Demos 1, 3, and 4	Urban wastewater treatment for agricultural irrigation solving safety issues.
3	VITO	Water	None detected at this point	Addressing the seasonal water demand variability involving nature-based solutions.
4	RISE	Water	Demos 1, 2, 3 and 5	Water Flows modelling as a decision-support tool in water symbiosis.
5	LAB	Bio-waste	Demos 4, 6, 7 and 9	Flexible and intelligent biorefinery for bio-waste circularity.
6	UPV	Bio-waste	Demos 5 and 7	Beer bagasse waste as a source of high value-added substances and as a filler in plastic matrices
7	AIJU	Plastics	Demos 6, 7, 8, and 9	Transforming multi-layer PET into a raw material for plastics industry.
8	CERTH	Plastics	Demos 7 and 8	Enhancing Packaging recycling processes by involving consumers.
9	MGFU	Plastics	Demos 5, 6, 7 and 8	Implementing sustainable packaging solutions by eco-design.

3. CONCLUSION

The development of the CircSyst Methodology and the creation of short profiles for each Circular Systemic Solution (CSS) represent significant strides toward achieving the project's overarching goals of circularity and sustainability across Europe. By systematically evaluating the potential of each CSS, identifying key synergies, and ensuring alignment with both regional and local strategies, this deliverable lays a strong foundation for the successful implementation and replication of circular solutions.

The collaborative effort that led to the creation of this guide highlights the importance of stakeholder engagement and the need for adaptable, context-sensitive approaches to circular economy challenges. The integration of insights from the CCRI Methodology, alongside the tailored adaptations made to meet the specific needs of the CircSyst project, ensures that this guide is both comprehensive and practical for all project partners and stakeholders.

As this document forms the basis for the CircSyst project, the inclusion of Annexes that detail the full CircSyst Methodology, Short Profile Template, and the individual CSS Demos' short profiles provides invaluable resources for ongoing assessment, knowledge transfer, and replication efforts. The identification of initial synergies among the demonstrators underscores the potential for cross-sectoral collaboration, further enhancing the project's impact.

Moving forward, the regular monitoring, evaluation, and continuous improvement processes outlined in this deliverable will be crucial to the success of each CSS. By maintaining a dynamic approach that incorporates feedback and adapts to new challenges, the CircSyst project is well-positioned to contribute meaningfully to the transition towards a circular economy in Europe.

In conclusion, this deliverable serves not only as a roadmap for the implementation of CSS but also as a living document that will evolve alongside the project, ensuring that the CircSyst initiative remains at the forefront of circular economy innovation and practice.

4. ANNEXES

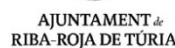
ANNEX I: CicSyst Methodology for Assessing Circular Systemic Solutions.

ANNEX II: CSS Baseline Profile Template

ANNEX III: CircSyst Circular Systemic Solutions Demos – Short Profiles



Project partners:



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Circular Cities & Regions Initiative
 CCRI Project



An initiative of the

European Commission



CIRCSYST

Circular Systemic Solutions



Water



Bio-Waste



Plastic,
Packaging

ANNEX I – CIRCSYST METHODOLOGY

WORK PACKAGE 6: SYSTEM ANALYSIS, KNOWLEDGE TRANSFER AND REPLICATION,
D6.1



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ANNEX I – CircSyst Methodology to assess Circular Systemic Solutions

Deliverable 6.1

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EXECUTIVE SUMMARY

This document outlines the CircSyst Methodology designed for the assessment of Circular Systemic Solutions (CSS) within the CircSyst project, an initiative aimed at fostering the transition towards a circular economy across various sectors and regions in Europe. The methodology serves as a comprehensive guide for evaluating CSS with a holistic and systemic approach, ensuring that each solution is thoroughly analyzed in terms of its social, environmental, technical, and economic impacts.

The CircSyst Methodology begins by providing a structured framework for understanding the problem or need that each CSS addresses. It guides the user through the process of defining the scope of the solution, including its geographical and sectoral impacts, and comparing the proposed CSS with existing solutions. This section emphasizes the importance of understanding the value proposition and how the CSS improves upon current practices.

A significant portion of the methodology is dedicated to the analysis of the social-environmental context, particularly through the examination of territorial metabolism, policy frameworks, and stakeholder mapping. This approach ensures that the CSS is not only technically and economically viable but also socially accepted and aligned with regional and local policies. The methodology provides detailed steps for conducting energy and material flow analyses, understanding biogeochemical cycles, and assessing the base level of circularity using specific tools and indicators.

The document also includes a thorough examination of the technical and environmental aspects of each CSS, focusing on the technology involved, its readiness level, and the potential for improvements or scalability. It addresses the economic dimension by guiding users through cost-benefit analyses, return on investment calculations, and the exploration of business models that could support the exploitation and sustainability of the CSS.

Finally, the methodology emphasizes the importance of continuous monitoring and evaluation, proposing key performance indicators (KPIs) and feedback loops that facilitate the ongoing improvement of each CSS. The methodology is designed to be iterative, allowing for regular updates based on new information, stakeholder feedback, and evolving circumstances.

This document is a crucial tool for stakeholders involved in the CircSyst project, providing them with a clear roadmap to assess and refine Circular Systemic Solutions effectively. It ensures that these solutions are robust, scalable, and capable of contributing to the broader goals of sustainability and circularity in Europe.



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CircSyst Methodology for Assessing Circular Systemic Solutions



Introduction to the CircSyst Methodology for Assessing Circular Systemic Solutions

The CircSyst Methodology is a comprehensive framework designed to assess and guide the implementation of Circular Systemic Solutions (CSS) within the CircSyst project. This methodology has been specifically developed to address the unique challenges and opportunities associated with transitioning towards a circular economy across different sectors and regions in Europe. Building on the foundations of the Circular Cities and Regions Initiative (CCRI) methodology, the CircSyst Methodology has been adapted to meet the specific needs of the project, ensuring that each CSS is evaluated with a holistic, multi-dimensional approach.

The primary objective of the CircSyst Methodology is to provide a structured, systematic process that enables the assessment of CSS in terms of their social, environmental, technical, and economic impacts. This methodology ensures that each CSS is not only technically viable but also socially accepted and aligned with existing policy frameworks and territorial contexts. By doing so, it supports the seamless integration of circular solutions into existing systems, enhancing their scalability and transferability across different regions.

Key components of the CircSyst Methodology include:

- 1) **Problem Definition and Solution Scope:** This section guides users in identifying the specific problems or needs that each CSS aims to address, as well as defining the geographical and sectoral scope of the solution. It also provides tools for comparing the proposed CSS with existing solutions to demonstrate its added value.
- 2) **Social-Environmental Context Analysis:** The methodology emphasizes the importance of understanding the territorial metabolism, including material and energy flows, biogeochemical cycles, and the existing policy landscape. This analysis ensures that the CSS is well-suited to the local context and can be effectively implemented within it.
- 3) **Technical and Environmental Assessment:** Detailed guidelines are provided for evaluating the technical aspects of each CSS, including the technologies involved, their readiness levels, and potential for further development. Environmental impacts are also assessed, focusing on resource efficiency, waste reduction, and overall sustainability.
- 4) **Economic Evaluation:** The methodology includes a robust economic assessment framework, guiding users through cost-benefit analyses, return on investment calculations, and the exploration of business models that can support the long-term viability of the CSS.
- 5) **Stakeholder Engagement and Policy Alignment:** Recognizing the importance of stakeholder involvement, the methodology offers tools for stakeholder mapping, engagement planning, and alignment with relevant policy frameworks. This ensures



that the CSS is supported by key stakeholders and is in harmony with regional and local strategies.

- 6) **Monitoring and Continuous Improvement:** The methodology also emphasizes the importance of ongoing monitoring and evaluation, proposing key performance indicators (KPIs) and feedback loops to facilitate continuous improvement of each CSS throughout its implementation.

This introduction to the CircSyst Methodology sets the stage for a detailed exploration of each component in the following sections, providing a clear and practical roadmap for assessing and implementing Circular Systemic Solutions within the CircSyst project.



1. General Description of the CSS Proposed

1.1. Problem Addressed or Need Detected

What problem or need is covered by your CSS?

1.2. Solution Proposed

Briefly describe what is your solution and how does it solve the Problem/need addressed.

1.3. Scope: Geographic Scope and Sectorial Scope

What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope?. If possible, add a map. Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

1.4. Value Proposal

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

1.5. Value Chain Overview and Stakeholders' Identification

1st Draw a scheme of your value chain:



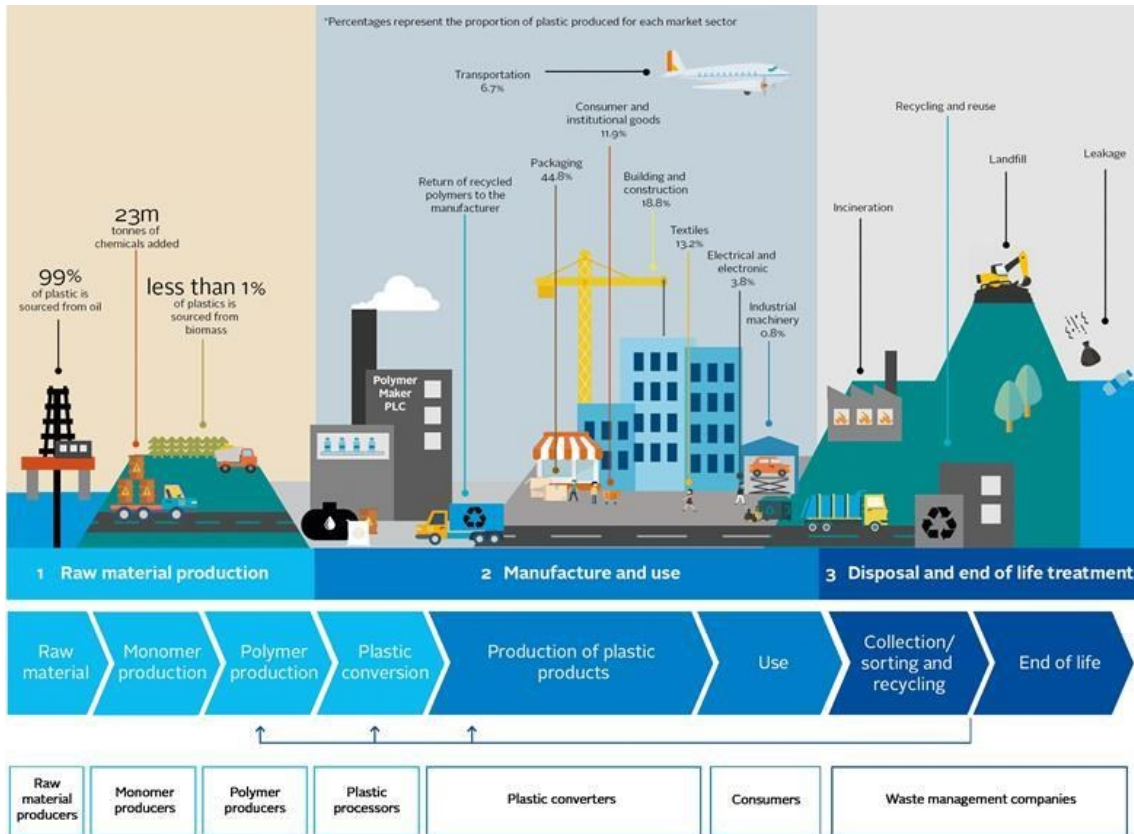


Figure 1: Example of a simplified Value Chain Diagram of the Plastics with stakeholders categories.

Source: <https://www.unpri.org/circular-economy/risks-and-opportunities-along-the-plastics-value-chain/4774.article>

2nd Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

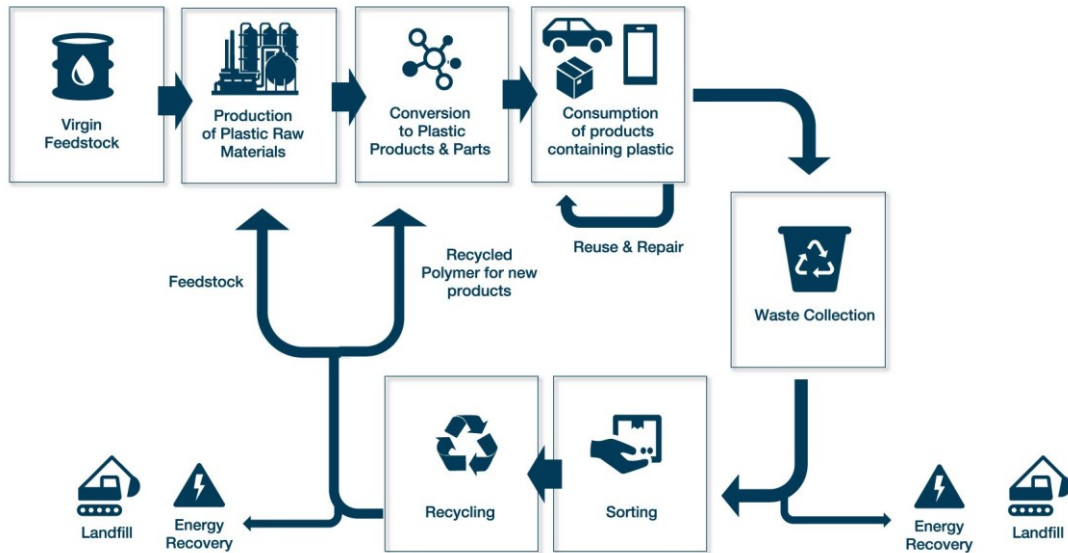


Figure 2: Example of a very simplified Circular value chain scheme for plastics.

Source: <https://www.gpca.org.ae/2020/11/15/how-a-circular-economy-for-plastics-can-help-the-gcc-realize-its-sustainability-potential/>

3rd Identify the stakeholders involved that will be affected by the CSS shift in each stage of both chains.

1.6. Regulatory Framework Overview: Which Regulations Affect Your Solution?

Provide a first approach of the regulations that are relevant to your CSS in a local, regional, national, or European level.

1.7. Aims and Goals

Define the purposes and future steps you want to carry on for your CSS.

2. Social-Environmental Context Analysis

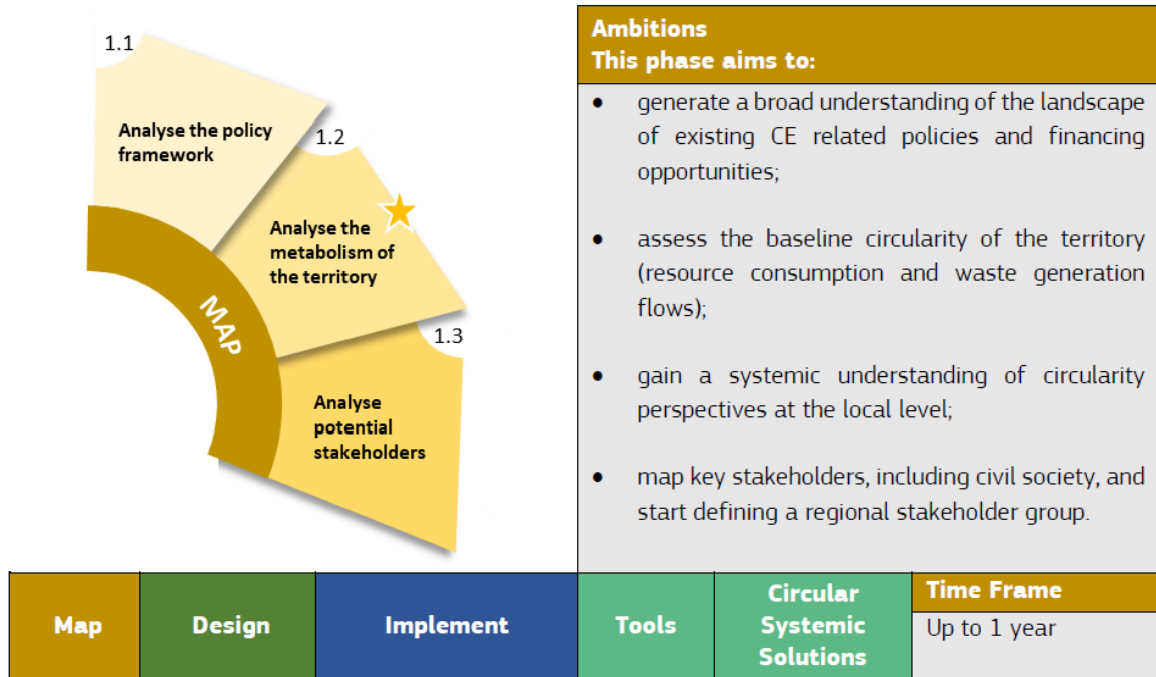


Figure 3: Mapping, the First Phase of the CCRI Methodology.

Source: CCRI Methodology Guidelines.

A thorough comprehension of the local territory is essential for developing effective circular solutions. Since the circular economy is centered around the movement and accumulation of materials, dedicating time and resources to fully understand the local metabolism will aid in both the detailed design of a Circular Systemic Solution (CSS) and its successful deployment. Beyond analyzing material flows and stocks, it is also crucial to carefully examine local development policies to ensure that the CSS aligns with broader regional strategies.

2.1. Territorial Metabolism Analysis

(Energy and Material Flows Analysis)

Analyze the relevant part (for your CSS) of the metabolism of your territory and explain how your CSS fits and how will improve the sustainability of the metabolism.

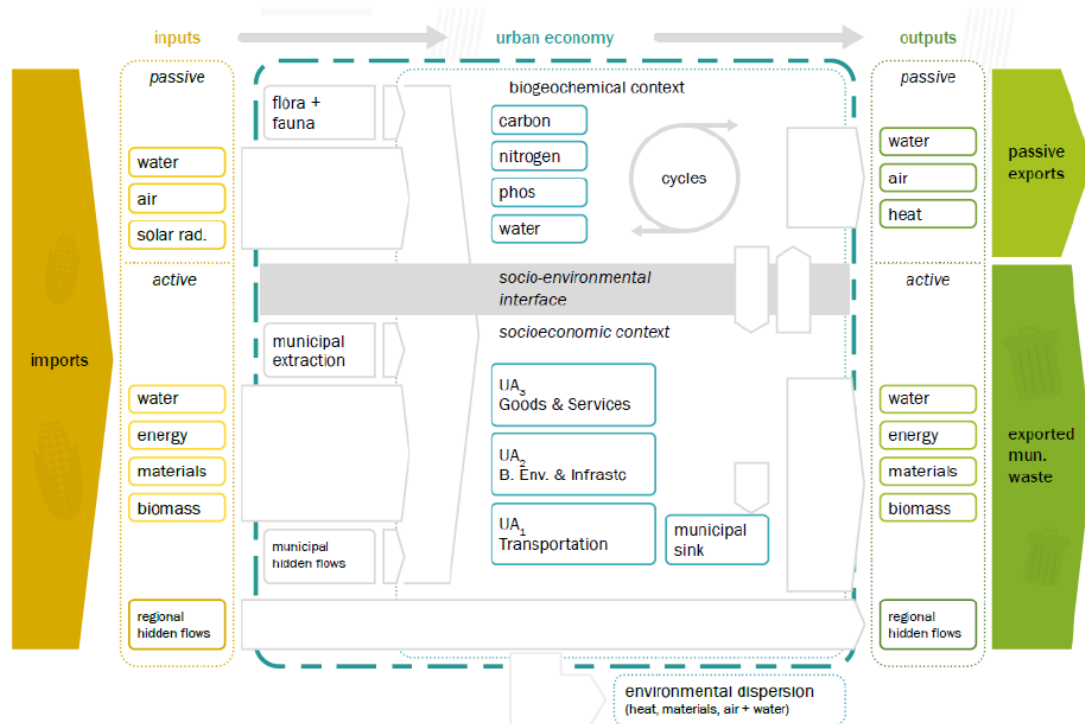


Figure 4: Example of a Territory Metabolism Scheme used in the CCRI Guide.

Source: Roadmap for a Circular Resource Efficiency in cities – Circular Economy Partnership (2020).

The Urban Metabolism framework helps to provide an overview of all the streams and helps studying the interactions between systems, and therefore works well for a city, so, a city can gain more insight into the characteristics of resources and resource flows, such as which resource flows are going through the city, are stored there, are changed because of different metabolic processes (for instance waste treatment), flow rates, involved stakeholders, economic value and are leaving the city.

2.1.1 Flows of Materials and Energy within the territorial scope of your CSS

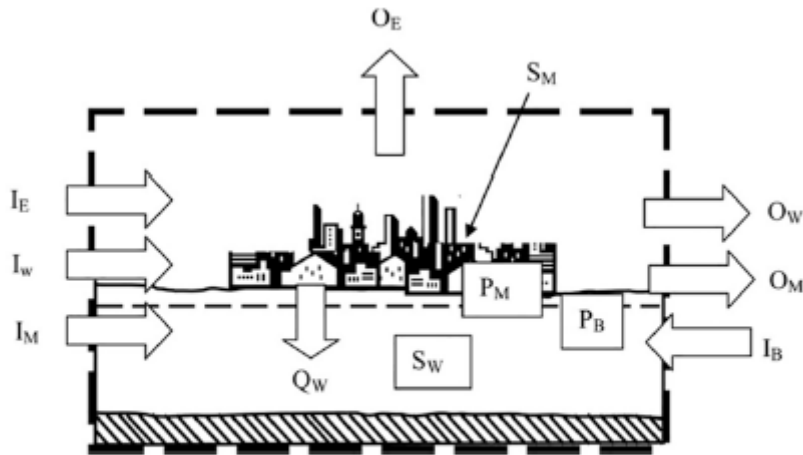


Fig. 1. Urban Metabolism framework: The boundary of an urban system showing inflows (I), outflows (O), internal flows (Q), storage (S), and production (P) of biomass (B), minerals (M), water (W), and energy (E) [17].

Figure 5: Simplified Metabolism Accounting Framework.

Source: Ling Min Tan, Hadi Arbabi, Paul E. Brockway, Danielle Densley Tingley, Martin Mayfield, *An ecological-thermodynamic approach to urban metabolism: Measuring resource utilization with open system network effectiveness analysis* (<https://doi.org/10.1016/j.apenergy.2019.113618>)

Try to create a simplified scheme of the flows of matter and energy in your context and explain the potential effects of your CSS on the system.

2.1.2 Biogeochemical Cycles

One part of the Territory metabolism analysis studies the Biogeochemical Cycles. Try to draw the biogeochemical cycles affected by your CSS, understand the role of your innovation withing global and local contexts, and explain the effects that are expected:

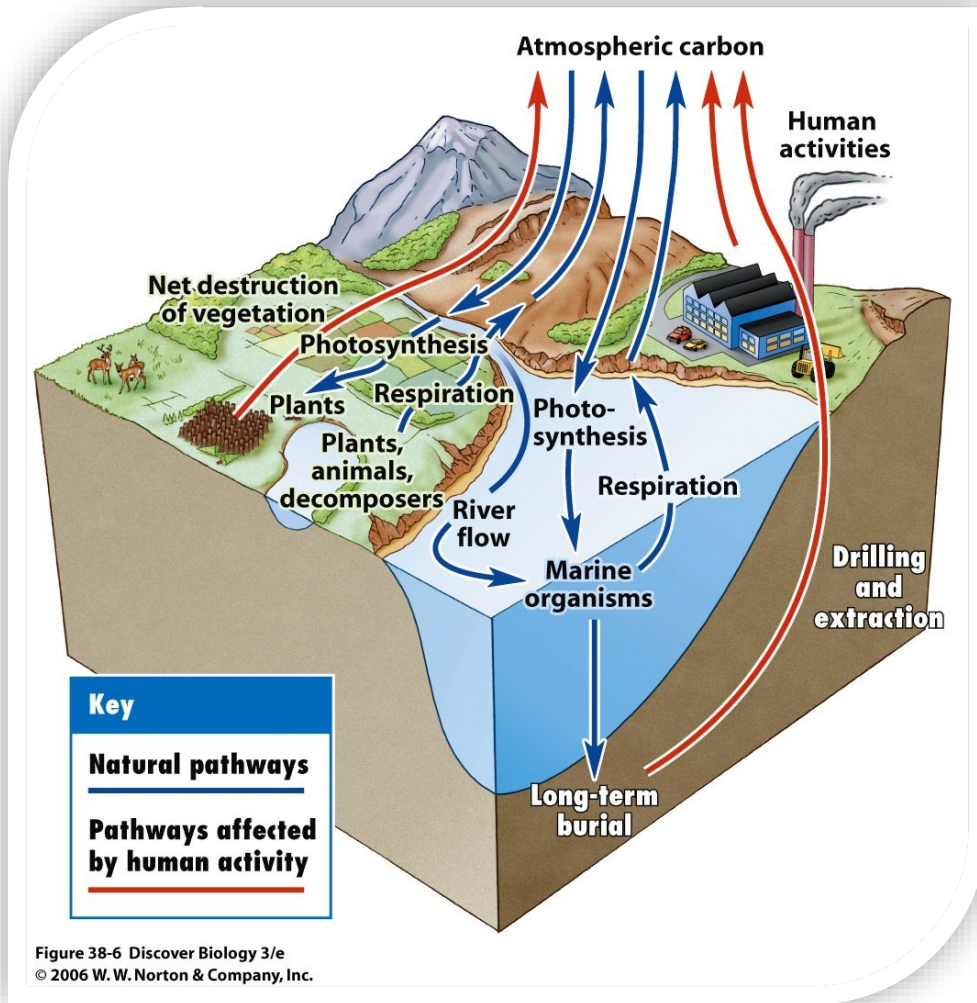


Figure 6: Example of the Biogeochemical Cycle of the Carbon showing anthropic effects.

Source: <https://animalia-life.club/qa/pictures/biogeochemical-cycle-biology>

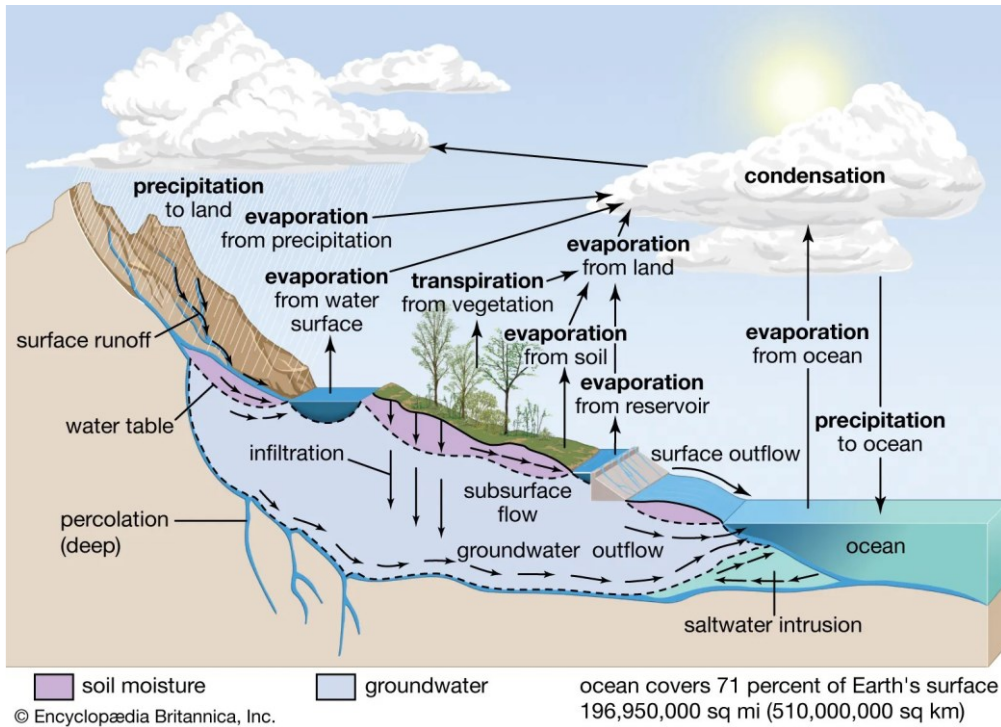


Figure 7: Example of the Biogeochemical Cycle of Water.

Source: <https://www.britannica.com/science/biogeochemical-cycle>

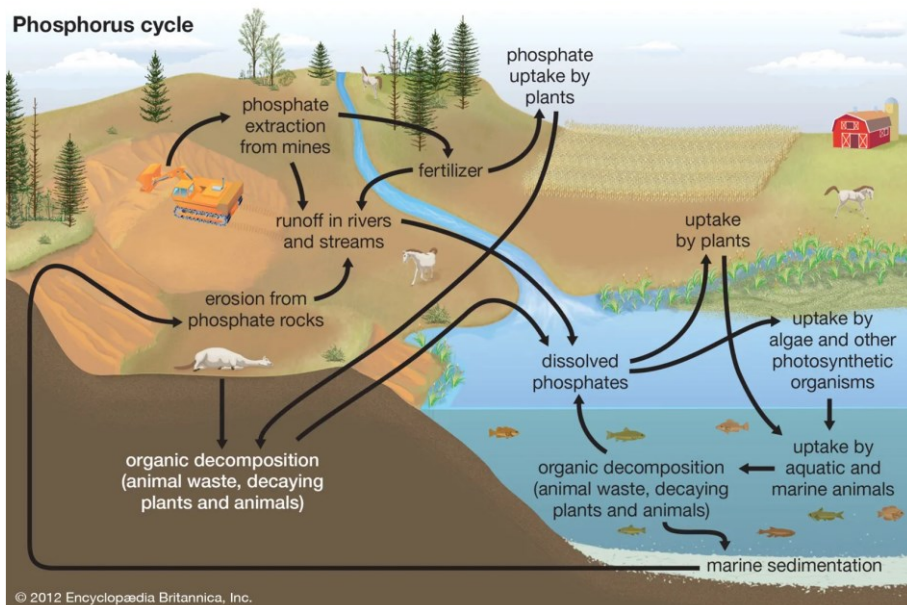


Figure 8: Example of the Biogeochemical Cycle of Phosphorus.

Source: <https://www.britannica.com/science/biogeochemical-cycle#/media/1/65875/139360>



2.2. Figuring Out the Circularity Base Level (CCRI Self-Assessment Tool)

Once studied the input and output of your System, you can establish the Key Performance indicators to measure the Level of Circularity of your sector and calculate how is it improved by your CSS.

You can follow Section 1.2 of the CCRI Methodology to find ideas and examples of indicators to be used for your CSS.

2.2.1 Tools and approaches to be used in the description and monitoring of the metabolism of your context.



Tool name: UMan	
<p>Description: The Urban Metabolism Analyst (UMAn) tool offers a methodology for the computation of material flow accounts at urban scale. The UMAn approach is derived from the Economy-Wide Material Flow Analysis (EW-MFA) methodology, though the UMAn model adapts this methodology to be used for a smaller spatial unit, such as the urban scale. The model considers different aspects appearing in material flows at an urban level: matter movement through boundaries; extraction and production of materials and goods; and their consumption in addition to stock and emissions to nature.</p> <p>The UMAn also allows to exploit a set of 'plug-ins' LCIA databases for more detailed analysis of urban flows, including the material composition of flows and the respective environmental impacts.</p> <p>The use of UMAn requires expertise in urban metabolism, quantitative modelling and LCA.</p>	<p>CCRI Methodology step</p> <p>Design</p>
	<p>Thematic area</p> <p>Urban metabolism</p>
	<p>Complexity</p> <p>★★★</p>
	<p>Time</p> <p>★★★</p>
	<p>Financial effort</p> <p>★★★</p>
<p>Reference</p> <p>URBANWINS. (2017)). Deliverables, UrbanWINS D2.1 Model architecture. https://www.urbanwins.eu/wp-content/uploads/2019/02/D2.1-report.pdf</p> <p>URBANWINS. (2019). Deliverables, UrbanWINS D2.2 Urban metabolism guide. https://www.urbanwins.eu/wp-content/uploads/2019/05/UrbanWINS_D2.2-UMAn-guide-1.pdf</p>	
<p>Visual identity</p> <p>The diagram illustrates the UMan Model process. On the left, a vertical stack of boxes labeled 'Statistically Reported Data' includes: Transport Statistics, Industrial Statistics, Agricultural Statistics, ITS, Statistics on Waste & Air Emissions, and Employees & Population. An arrow points from this stack to a central rounded rectangle labeled 'UMAn Model'. This central box is divided into three horizontal sections: 'Plugin Databases' (top) containing Product Life Cycle Phase, Material Composition of Products, and Product Lifespan; 'Calculator' (middle) containing AR, Production, Material Consumption, Material Throughput, Distribution by Economic Activity, and Spatial Distribution; and 'Outputs' (bottom) containing Main Indicators, Advanced Indicators, and Indicators upon User Request. Arrows indicate a downward flow from the Plugin Databases to the Calculator, and from the Calculator to the Outputs.</p>	

Figure 9: Tool "Urban Metabolism Analyst".

Source: CCRI Methodology.

Urban Circularity Assessment (UCA)		
<p>Description: The UCA is an urban, EW-MFA and stock accounting method, which paired with indicators, enables the assessment of material circularity of a municipality or city. Its aim is to monitor progress towards a CE from an economy-wide perspective at city level, rather than just at the level of individual products sectors. The method is directed at policy makers and practitioners who are interested in measuring the material circularity of their city or municipality.</p> <p>The UCA consists of three main parts:</p> <ol style="list-style-type: none"> 1. Material flow and stock accounting 2. Analysis of Flows and Stocks: Measuring Indicators 3. Analysis of Indicators: Assessing Circularity. <p>The use of the UCA requires expertise in urban metabolism and EW-MFA accounting. It can also be very time intensive in data collection or data generation (when data is not directly available). The tool can also provide a geo-localised view of stock and flows. The UCA can be used during the mapping phase to visualise stock and flows and throughout the design phase to analyse circularity and assess scenarios.</p>	<p>CCRI Methodology step</p> <p>Design</p> <p>Thematic area</p> <p>Urban metabolism</p> <p>Complexity</p> <p>★★★</p> <p>Time</p> <p>★★★</p> <p>Financial effort</p> <p>★★★</p>	
	<p>Reference</p> <p>CITYLOOPS – Metabolism of cities. (2022). https://cityloops.eu/resource?t=Urban%20Circularity%20Assessment</p>	
	<p>Visual identity</p>	
	<p>Source: CITYLOOPS – Metabolism of cities. (2022). https://cityloops.eu/resource?t=Urban%20Circularity%20Assessment</p>	

Figure 10: Tool "Urban Circularity Assessment".

Source: CCRI Methodology.

Geodesign Decision Support Environment (GDSE)

Description:

The GDSE is an online and open-access software designed for workshop sessions where small groups of participants cooperatively develop strategies for a more circular economy with a special focus on waste and resource management. The GDSE relies on the activity-based spatial material flow analysis (ASMFA), and it allows visualising the flows using classic Sankey diagrams as well as map representations.

The GDSE is structured in five steps:

1. Study Area: the users define their study area and the key flows on which the workshops (or the research activity) will focus on. This includes defining key stakeholders working groups (WGs).
2. Status Quo: this step takes a detailed look at the status quo situation of the material and waste flows between the different activities in the study area.
3. Targets: WGs rank the overall objectives for the later strategy developments and transform them into mostly quantitative targets.
4. Strategy: WGs puts together a strategy (combination of solutions from a predefined catalogue) aiming to reach the objectives and targets set in the step before and implements them within the study area.
5. Conclusions: WGs meet in a plenary session to draw conclusions from the results.

The GDSE constituted the main digital support tool for both the research and the interactive workshop sessions for all six case studies in the REPAIR project. The use of the tool requires expertise in urban metabolism (and eventually programming skills if the code needs to be adapted). It can be time intensive in desk research for data accounting/modelling and requires active engagement of interested parties. The GDSE can also be used since the mapping phase throughout the design phase.

CCRI Methodology phase

Design

Thematic area

Urban metabolism

Complexity

★★★

Time

★★★

Financial effort

★★★

Reference

REPAIR. (2020). *GDSE description*. <http://h2020repair.eu/gdse-software-package/>

The GDSE and its source code can be found in the following GitHub repository: <https://github.com/MaxBo/Repair-Web>

Visual identity



Source: REPAIR. (2020).

Figure 11: Geodesign Support Environment

Source: CCRI Methodology



2.3. Policy Framework in Affected Areas

It is essential to review the existing regional and/or local policy and institutional context to identify the goals and actions of public administrations that could support circular economy initiatives. Conversely, analyzing the policy framework can also uncover policy objectives that may inhibit or restrict circular economy activities, which must be taken into account. Additionally, evaluating regional and/or local policy objectives and the activities of public administrations concerning the circular economy is crucial to ensure that Circular Systemic Solutions (CSS) are aligned with regional or local strategies. In this context, CSS should be integrated into a broader territorial action plan while effectively applying circular economy principles.

The CCRI methodology (section 1.1) proposes an analysis based on six Priority Areas:

Policy intervention types	Examples
Education, information and awareness	Integration of circular economy/system/life cycle thinking into university and schools curricula
	Public communication and awareness campaigns
Collaboration platforms	PPPs with business at regional and city level
	Promotion of voluntary industry collaboration platforms, encouraging value-chain and cross-sectoral initiatives and information sharing
	R&D programmes
Business support schemes	Financial support to business (e.g., subsidies, provision of capital, financial guarantee)
	Technical support, advisory, capacity building and demonstration of best practices to business
Public Procurement and Infrastructure	Green Public Procurement
	Sustainable Finance
Regulatory Framework	Regional strategies and associated targets on resource productivity, decarbonisation and circular economy
	Product regulations, including design and extended warrants
	Waste regulation, including collection and treatment standards, and targets and take-back systems
Fiscal Framework	VAT or excise duty reduction for circular products and services

Figure 12: Policy Interventions

Source: CCRI Methodology.

Gaining an understanding of the policy and institutional context can be achieved by identifying the various sectoral policies and engaging with the relevant departments. While administrative responsibilities may differ between countries, particularly at the subnational level, local public authorities typically play a crucial role in managing land use and planning, the built environment and construction, water and waste management, as well as transport and mobility. These areas provide opportunities for direct public interventions that support

circular initiatives. Therefore, it is essential to be aware of the institutional context, including where previous initiatives have been implemented, the primary objectives, and which administrative departments may be most inclined to participate in the development of a CSS.

Policy areas proposed by the CCRI Methodology:

- Land use and spatial planning
- Built environment and construction
- Water management
- Waste management
- Transportation and mobility

2.3.1 Political and Legal Analysis

Summarize the results of the analysis. Explain which Policy areas are affected by the CSS and if they consist in a Barrier or a Driver.

You can do a chart similar to the following one:

Table 1: Policy Framework Summary.

Level	Area	Type	Policy	Barrier/Driver	Improvements	Stakeholders
...
...
...
...

Where:

- **Level:** Geographical Scope of the Policy (Europe, National, Regional, Local).
- **Area:** Sectors covered by the policy
- **Type:** Types of intervention in Table 1
- **Policy:** The specific Policy you are analyzing
- **Barrier/Driver:** Explain why and how the Policy constitutes a barrier or a driver for the implementation of your CSS.
- **Improvements:** How do you propose to improve the policy so it can become more supportive to your CSS.

The information collected in Section 2.3 will directly feed Section 5 “Strategic Decision-Making process”.

2.3.2 Policymaking stakeholders

Once you have identified the Policy areas and specific policies and strategies related to your CSS, identify the stakeholders responsible of those policies and those who have a relevant role in the creation or implementation of the policies.

This information will feed Sections 2.5 and 2.6.

2.4. Legal Analysis Detecting Hiders and Bottlenecks

Start from the list of regulations identified in section 1.6.

Fill the following chart:

Table 2: Regulatory Framework summary.

Level	Regulation	Requirements	Barrier	Driver	Modifications
EU	Directive xxx	...	...	...	...
EU	Regulation xxx	...	...	...	...
National	Law xxx	...	...	...	...
Regional	Normative ...	...	...	...	...
Local	Order xxx	...	...	...	...
Sectorial	Standard xx	...	...	...	...

Start from the list of regulations identified in section 1.6.

Where:

- **Level:** Geographical Scope of the regulation. Either European union, National, Regional, Local/Municipal and sectorial (standards for the sector involved such as ISO or other).
- **Regulation:** The identified Regulation affected by your CSS
- **Requirements:** Specific requirements that your CSS must accomplish to fulfill the regulation.
- **Barrier:** State if the regulation requirements constitute a Barrier for your CSS.
- **Driver:** explain if and how your CSS supports the fulfilment of current or future requirements and is, thereby, a solution that will be demanded by the end-users.
- **Modifications:** Explain if the current regulation needs to be modified to better reflect the reality of the Circular Economy so your CSS can be accepted and supported. This will become a KPI for the development of your CSS and shall be included in Sections 5 and 6.

The information collected in Section 2.4 will directly feed Section 5 “Strategic Decision-Making process”.

2.5. Stakeholders Mapping and Analysis (T5.1 and T6.2)

Within the CCRI framework, stakeholders are defined as individuals and organizations with a direct or indirect interest in CSSs, who are involved in the activities that make these solutions possible. Given the systemic nature of circular solutions, it is essential for decision-makers involved in the design and implementation of CSS to broaden the decision-making process to include a wide range of actors. This approach enriches public policies with diverse perspectives, laying the foundation for public accountability and fostering interdisciplinary dialogue across various fields and sectors.

Before engaging directly with stakeholders—which in the CCRI Methodology is the initial step in the Design phase—it is crucial to identify key stakeholders by addressing strategic questions such as ‘who’, ‘what’, ‘how’, and ‘when’. These questions help clarify the importance of each stakeholder to the project and the potential benefits they could gain from participating. This process ensures that stakeholders’ interests are understood and that their active and ongoing involvement is secured.

In practice, key stakeholders can be identified by considering the following questions:

- Who will be most impacted by the implementation of a CSS? Who has the greatest influence over the implementation of a CSS?
- What shared vision can we create with the stakeholders? What are our objectives with their involvement? What motivates the proposal of this CSS?
- How and when should stakeholders participate in the decision-making process? What types of engagement mechanisms or incentives could be utilized?

The primary objective of the stakeholder analysis is to initiate the development of a Stakeholder Engagement Plan (SEP). This plan is a dynamic document that is regularly updated throughout the project and outlines the governance of the stakeholder engagement process, including the planning, management, and monitoring of activities and commitments. Figure 14 demonstrates the three key activities that aid in identifying and selecting the primary stakeholders to be involved, which form the foundation for creating an SEP.

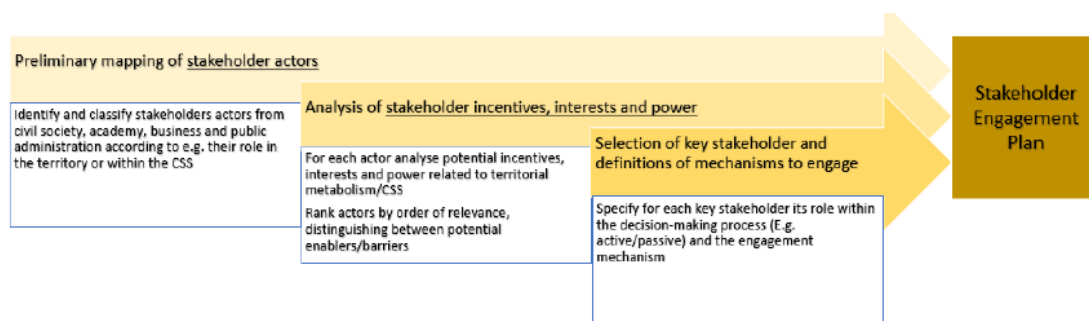


Figure 13: Stakeholders mapping and selection.

Source: CCRI Methodology.

There are several methods available for identifying stakeholders, each with its own specific goals, advantages, and disadvantages. These pros and cons can relate to the quality or quantity of the outcomes produced by the method, or the costs associated with its implementation. Additionally, certain methods may be more appropriate for different stages within the stakeholder identification process, as many approaches, such as snowball mapping, require a preliminary list of stakeholders as input. However, this task is often complex, and using a combination of methods can be beneficial. Table 8 presents four different methods along with their respective strengths and weaknesses.

Alongside stakeholder identification, it is also important to begin distinguishing between different types of stakeholders. This involves developing an understanding of how various stakeholders and groups are impacted by, or can influence, the decision or policy at hand, as well as their interests and perspectives. Various approaches exist to achieve this level of understanding, some of which are more systematic than others. The most structured methods categorize stakeholders based on criteria that are typically relevant for achieving specific objectives in a given context. For instance, Table 8 outlines two approaches—'Stakeholder mapping by territorial metabolism components' and 'Stakeholder mapping by CSS life cycle perspective'—which systematically categorize stakeholders according to their role in the territory's metabolism and their role in a CSS from a life cycle assessment (LCA) perspective. These are examples of a highly organized approach to stakeholder differentiation. Less systematic methods include those that rely on qualitative insights gained through close interaction with stakeholders, such as brainstorming sessions. Given the diverse strengths and limitations of these methods, different objectives may require different approaches, and often, a combination of methods will be particularly effective.



Method	Overview	Strengths	Weaknesses
Territorial metabolism components	It: 1) decomposes the metabolism of a territory in various components – (material) inputs and (waste) outputs, as well as territorial (non-material) endowments; and 2) identifies relevant stakeholders for each of them.	Systematic; Cost-effective; No pre-identified stakeholders needed; Explicit consideration of territory stakes.	Requires the analysis of the metabolism of the territory.
CSS life cycle thinking	It: 1) applies a life cycle logic to the target CSS; and 2) identifies stakeholders per life cycle stage.	Very systematic; Highly cost-effective; No pre-identified stakeholders needed; Explicit consideration of sustainability dimensions.	Requires the pre-identification of the CSS.
Brainstorming sessions	These can be summarised as organised discussions of a pre-determined topic in a focus-group like setting. This method aims at collecting large amounts of qualitative information on stakeholders, their interests and their knowledge.	Offers deep understanding of complex processes; Convenient for creation of comprehensive stakeholder categories and classification criteria.	Requires a high level of preparation. Requires a number of stakeholders pre-identified; Requires a skilled facilitator.
Snowball mapping	It aims at ultimately achieving the identification of all relevant stakeholders, starting by interacting with the most accessible ones, first (base stakeholders). The expectation is to be able to extract from them information on further stakeholders, as well as contact information of stakeholders already in their social networks.	Fast and straightforward (undemanding of resources, time and expertise); Easy access to base stakeholder social network (snowballing); Most suitable for completing a list of stakeholders.	Potentially biased outcome due to the use of the snowballing technique; Not very strong on its own (combination with other methods is desirable).

Figure 14: Stakeholders identification methods proposed by the CCRI Methodology.
Source: CCRI Methodology.

2.5.1 Sociogram or Similar Classification of Stakeholders

Identifying relationships between stakeholders or stakeholder groups typically involves examining the existence, quality (type), or quantity (strength) of these connections. Consequently, many methods for identifying inter-stakeholder relationships rely on various scales to assess the presence, nature, or absence of a relationship. A practical and cost-effective approach is to create a table (or matrix) where all relevant stakeholders are listed in the first column. The corresponding rows are then filled with information about the relationship between stakeholders, such as the strength of the connection, which could be classified as weak (W), medium (M), or strong (S). If there is insufficient information about a particular relationship, the corresponding boxes can be left blank.

This table can be further enhanced with a visual representation, such as a two-axis graph. For example, stakeholders might be categorized based on their level of interest (x-axis) and



power/influence (y-axis), though other scales can be used to better align with the specific context. This approach allows for a quick identification of the dynamics within the stakeholder network and provides a structured foundation for determining the appropriate levels of future stakeholder involvement. For further guidance, the reader can refer to the Stakeholder Value Mapping Tool factsheet.

The CCRI Methodology distinguishes 4 categories of stakeholders:

- Public Administration and Local Entities
- Industry & Business
- Civil Society and NGOs
- Academia and Technological Organizations

Once you have the list of stakeholders, the categories classification, and the relation between all members, the best way to analyze the social system is to shape all the information into a sociogram.

In the next links, you can find a short introduction and resources to create and interpretate sociograms:

- <https://www.slideshare.net/slideshow/sociogram-understanding-maps1103a1/10476530>
- <https://link.springer.com/article/10.1007/s10758-019-09416-7>
- <https://www.edrawmax.com/online/en/>

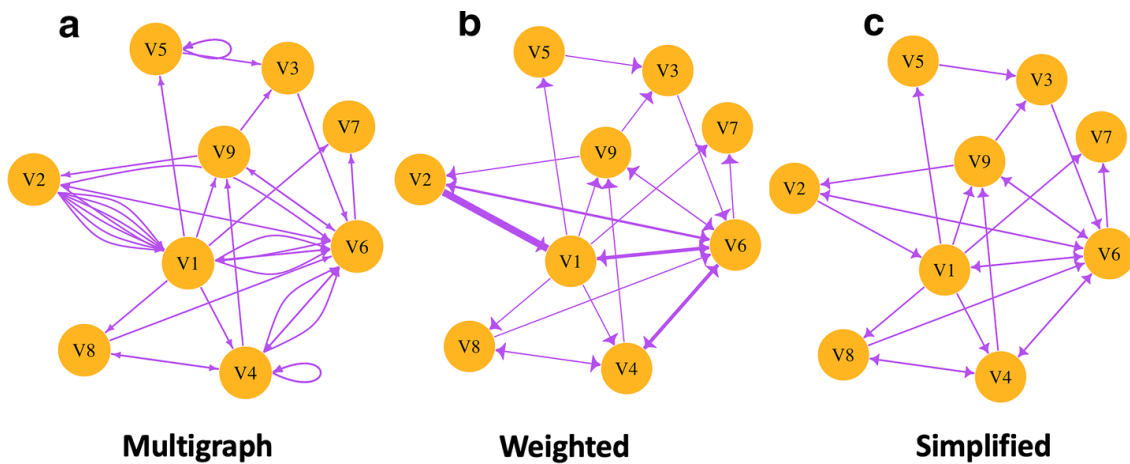


Figure 15: Example of different Sociograms.

Source: <https://link.springer.com/article/10.1007/s11412-020-09322-6/figures/1>

2.6 Stakeholders Participation (co-creation and validation workshops)

The systemic nature of transitioning to circular economies in cities and regions necessitates the involvement of multiple stakeholders who engage in discussions, collaboration, and the creation of incentives and frameworks to foster synergies. This diverse group of stakeholders brings a wealth of ideas, perspectives, and efforts that are crucial to the process. However, it is important to recognize that these stakeholders often have different, and sometimes conflicting, interests and objectives. Therefore, it is essential to identify early on which mechanisms or dynamics are most suitable for involving each group of stakeholders. Addressing any concerns from stakeholders at the beginning of the decision-making process can help prevent obstacles and save valuable time. Consequently, active and effective engagement is critical to ensuring collaborative efforts and the participatory development of new policy actions, as well as the identification of more relevant and challenging opportunities.

The purpose of stakeholder engagement activities is to create opportunities for dialogue between those implementing a circular economy initiative and its stakeholders, with the goal of providing a well-informed foundation for decisions related to the initiative’s development. While stakeholder engagement always involves some form of communication and exchange between parties, the way this process is structured can vary greatly. For circular economy initiatives, the engagement process should be organized in a way that allows stakeholders to discuss, collaborate, contribute ideas, and voice concerns related to circular solutions. There are many ways to engage stakeholders, and each Circular Systemic Solution (CSS) should explore and identify the most suitable strategies for its specific context. As a potential framework for defining the precise stakeholder engagement strategy for circular economy initiatives, Salvioni and Alici (2020) propose a classification of engagement forms based on the desired level of engagement (low, medium, high) and the nature of the relationship (short, medium, or long-term). This is summarized in Figure 16 Stakeholders’ Engagement Methods below:

	Short-term nature	Medium-term nature	Long-term nature
Low engagement level	Passive engagement (communications through the media, newsletters and project websites)	Monitor (communications and advice from certain stakeholder, for example, through targeted interviews)	Advocate (continuous advocacy efforts to certain stakeholders)
Medium engagement level	Inform (direct communication with the stakeholder, including through conferences and presentations)	Transact (medium-term engagement through specific agreements and collaborations)	Consult (regular consultations on key issues through focus groups, meetings and workshops)
High engagement level	Negotiate (punctual engagement on a specific issue to reach a consensus)	Involve (joint learning and advice through forums, advisory sessions and consensus-building initiatives)	Collaborate and empower (joint learning and decision-making, the stakeholder plays critical role in shaping the initiative)

Figure 16: Stakeholders Engagement Methods.

Source; CCRI Methodology



In the realm of circular economy initiatives, stakeholders are individuals and entities with a vested interest in CSSs, who take part in activities necessary for their realization. Building on the stakeholders identified in Part I of this methodology, along with the key stakeholder groups highlighted in the introduction, the following categories of participants should be engaged—or at least considered—during the development of any CSS. This approach aims to maximize the chances of creating a collaborative and inclusive decision-making process.

- **Local authorities:** These entities can play a pivotal role in the transition to a circular economy. They can act as proactive agents in circular economy activities, facilitate discussions, contribute valuable insights and expertise, and advocate for the CSS and project activities.
- **Industry and businesses:** Given their integral role in local and regional economies, these stakeholders are crucial to CSS. They can provide critical expertise, resources, and knowledge, which are essential to the decision-making process.
- **Consumers:** Consumers can offer vital feedback and advice, making them key participants in any CSS. Consumer organizations and NGOs can serve as intermediaries to engage, reach, and inform consumers.
- **Knowledge institutions:** Universities and research institutions can contribute with valuable knowledge, specialized research, and expertise that are critical to the success of CSS.
- **Not-for-profit organizations and other civil society entities:** These groups should be involved as they bring much-needed grassroots ideas and help raise awareness. Drawing on the stakeholder analysis, which addresses the strategic questions of ‘who’, ‘what’, ‘how’, and ‘when’ in relation to CSS activities, it is important to identify the most suitable engagement methods for each stakeholder group, as outlined in Table 9. Additionally, assessing each stakeholder's level of influence and interest is crucial. This allows stakeholders to be categorized into four broad groups, with tailored communication channels and engagement strategies that match the required level of engagement and the nature of the relationship.
- **Key Players (high interest – high influence):** These stakeholders have the power to block or drive solutions. They require special attention during the engagement process as they significantly influence the success of the circular economy initiative and are highly invested in it. The most effective engagement methods for this group fall at the intersection of high and medium engagement and are typically long to medium-term in nature.
- **Context setters (low interest – high influence):** Although they have a strong influence on the project's outcome, their interest may be minimal, possibly due to perceiving the project as peripheral to their concerns. Low-level, consistent involvement is necessary. Suitable engagement methods for this group fall at the intersection of medium and low engagement, with long to medium-term relationships.
- **Subjects (high interest – low influence):** While highly interested in the initiative, these stakeholders are unlikely to have a significant impact on its development. Their concerns should be acknowledged, but their contributions may be limited. Engagement methods appropriate for this group are those that fall within high and medium engagement and short to medium-term relationships.
- **Crowd (low interest – low influence):** This group neither significantly influences the initiative's success nor has much interest in it. Consequently, there is little need to



focus on them extensively. Engagement methods for this group should fall at the intersection of low and medium engagement with short to medium-term interactions.

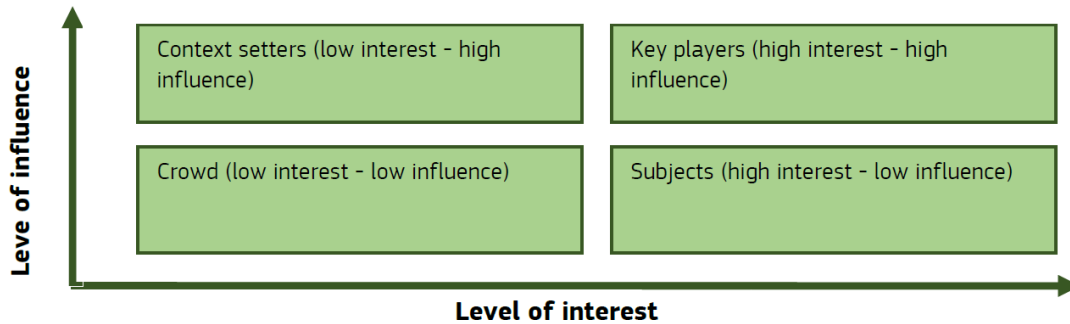


Figure 17: Categorization of the different types of stakeholders.

Source: CCRI Methodology.

2.6.1 Stakeholders Engagement Plan

Given the systemic nature and complexity of circular solutions, the decision-making process for creating and implementing a CSS will not only involve a broad range of stakeholders but will also span several years. Therefore, it is advisable to plan and systematically monitor stakeholder engagement activities through the creation of a Stakeholder Engagement Plan (SEP).

A SEP facilitates communication with stakeholders to secure their support for the CSS project. The plan should specify the communication methods, points of contact, and the frequency of interactions. The CSS project coordinator, along with key participants, should begin developing this document at the earliest stages—ideally during the stakeholder analysis phase—and update it regularly as stakeholder needs evolve. A well-constructed SEP promotes transparency and garners support from all involved parties. A comprehensive and effective SEP contributes to:

- Building trust among the various actors, stakeholders, and promoters of the CSS;
- Creating opportunities for exchange and innovation;
- Enhancing local expertise and capacity, which further aids the success of the circular economy initiative.

In practical terms, the SEP should ensure that all relevant and necessary stakeholders are included at each stage of the decision-making process, from the initial planning phases through to the implementation of the CSS. The stakeholder analysis outlined in the previous section will be instrumental in identifying and selecting the appropriate stakeholders and in initiating the development of the SEP. This plan should be a dynamic document, continuously updated throughout the project, outlining and overseeing the governance of stakeholder engagement in terms of planning, managing, and monitoring the activities and commitments of the involved parties.

The SEP should clearly define the following elements:

- **Stakeholder list:** Including the contact person and preferred communication channel for each stakeholder.
- **Project phase:** Identification of stakeholders relevant to each phase of the CSS project.
- **Interest level:** The stakes identified for each stakeholder, illustrating how their interests align with the CSS project, their goals, and their reasons for involvement.
- **Influence level:** The capacity of each stakeholder to halt, modify, or accelerate the CSS.
- **Engagement approach:** Strategies for engaging each stakeholder, including the frequency and forms of communication—such as daily, weekly, or monthly emails, phone calls, or face-to-face meetings. The content of these communications—such as design details and project updates—should also be specified.

The SEP should also anticipate the topics and issues to be addressed with each stakeholder and through each engagement method, even though these may evolve during the project's progression. Examples of themes and topics that could be covered in stakeholder engagement sessions include best practices in circular economy initiatives and targeted consultations on stakeholder concerns and contributions.

STAKEHOLDER IMPLICATIONS AND EXPECTED MAIN ROLES

The support of citizens can make the difference between a lasting CSS and a CSS that fails after a few years. People can actively take part in public policies in different ways and on different levels. To achieve stronger civic engagement, actions and good practices should be developed based on five principles.



- **Transparency:** the intention of the initiative must be clear. People must know the real potential outcomes and what commitments are expected from them.
- **Benevolence:** to develop a benevolent and respectful atmosphere for everybody, it is necessary to ensure a safe space that can help to channel divergent opinions.
- **Shared expertise:** encourage and enable greater accessibility for participation by finding relevant ways to meet and question citizens. Appropriate tools must be used for facilitating a constructive discussion.
- **Accessibility:** it is important to make sure that there are different options and services to include all kind of citizens (e.g., people who work, have children, have physical disabilities, cannot afford transportation, have difficult access to language or computers, etc.).
- **Experimentation:** ask for ideas, talk with participants and listen.

People have a strong need for belonging, and communities are great tools for connecting different issues and different stakeholders who can share similar goals. Civil society must feel part of an initiative that aligns their values and has a strong identity. Further information on how to involve citizens in circular economy can be found in CECEI, an Interreg project aiming at transferring knowledge among regions to bring more relevant and efficient policies to promote citizen involvement in circular economy.

Figure 18: Stakeholders roles.

Source: CCRI Methodology

2.7 CircSyst Workshops with Stakeholders

CircSyst proposes a series of workshops for working together with stakeholders. While the involvement methods are described in the sections above, the instructions to carry on those workshops will be detailed in the Annexed deadlines, which will be issued by the partners with the deepest responsibilities in WP6.

Nevertheless, there are some dates and types of workshops that will need to be implemented in each region hosting a demonstrator and that will be responsibility of each Demo leaders.

The tentative schedule for the Workshops is as follows

Specific regional workshops might be also considered for involving policymakers in the implementation of the CSS.

Demo leaders and other partners are free to organize national, regional, and local Workshops as many times as needed to achieve the objectives of the project and to gather the information for this document.

2.9 Social Impact Assessment

(Social Benefits)

Once you have implemented the workshops with stakeholders, provide an idea of the social benefits that your CSS will provide.

"Social impact" refers to the effects on individuals and communities resulting from the adoption of circular economy practices. This includes changes in social structures, behaviors, and well-being due to improved resource efficiency, reduced waste, and sustainable practices.

"Social benefits" are the positive outcomes derived from these impacts, such as job creation, enhanced community engagement, economic resilience, improved environmental health, social inclusion, and increased quality of life. These benefits contribute to the overall sustainability and well-being of society.

The information gathered here will directly feed Sections 4.4, 4.5, 4.6, and 4.7 of this document.



3. Technical-Environmental Assessment

3.1 Environmental Analysis

3.1.1 Materials and Energy Balance in the Current Situation

A material and energy balance is a fundamental concept in engineering and environmental science used to analyze and quantify the flow of materials and energy in a system.

A method to account for all the inputs, outputs, and changes in material within a system, following the equation:

$$\text{Input} = \text{Output} + \text{Accumulation}$$

Drawing material and energy balance scheme will help you understand the current level of sustainability where you want to apply the situation and will help creating a baseline to measure the effectiveness of your CSS.

It will also be helpful to find synergies between your CSS and other CircSyst CSS.

If you need more information on how a M&E Balance works, you can check the following links:

- <https://books.rsc.org/books/monograph/1757/chapter-abstract/1235467/Material-and-Energy-Balances?redirectedFrom=fulltext>
- <https://learncheme.com/screencasts/mass-energy-balances/>
- <https://learncheme.com/quiz-yourself/interactive-self-study-modules/material-balances/material-balances-screencast/>
-

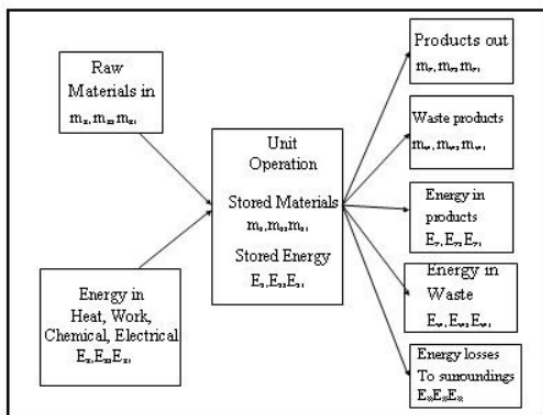


Figure 19: Material and Energy Balance Diagram example.

Source:

https://www.opexworks.com/KBase/Energy_Management/Energy_and_Environment/Material_and_Energy_Balance.htm

3.1.2. Future Materials and Energy Balance Once the CSS is Applied.

Once your solution is applied, a part of the output of the materials shall become a new input either to the same system or to other systems.

Draw a scheme of the new balance after applying the CSS. Identify if new systems are involved (if your output becomes input in other systems), or some of your former output becomes input in the same system.

The amount of output becoming input can help **defining a KPI** for monitoring your CSS and for assessing its scalability potential.

Other parameters such as energy consumption can be considered for your **KPIs**.

Review the CircSyst assessment of the other CSS ¿are there any synergies in terms of inputs and outputs that can be exchanged?

The definition of synergies can increase your level of circularity and can become a part of another **KPI**.

Now you might want to get back to Section 2.1, and review how the shift in your balance can affect the broader context in which your CSS will be applied.

Can you identify new impacts of your CSS? Can you find local/regional Synergies?

3.1.3 Improvements Analysis and Environmental Impact Assessment

Using the data from the two previous sections, you can have an idea of the environmental impact derived from the application of your CSS.

Try to analyze the environmental impact of the CSS either positive or negative, considering the following aspects:

- Waste reduction and generation.
- Pollution control
- Resources consumption
- Energy and greenhouse gas emissions
- Use of land
- Biodiversity



3.2 Technical Description

3.2.1. Description of the Technology Involved

Provide a description of the technology that needs to be deployed in your CSS. Keep in mind that you have to avoid mentioning anything that can be protected under Intellectual Property Rights or similar figures. Provide a diagram of the functioning of the CSS. Explain why the technology involved is the best option for your CSS.

3.2.3 TRL of Each Technology Involved and TRL of the General Integration

Provide an idea on the maturity of the technology and on the maturity of the full CSS.

- *TRL 1 – basic principles observed*
- *TRL 2 – technology concept formulated*
- *TRL 3 – experimental proof of concept*
- *TRL 4 – technology validated in lab*
- *TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)*
- *TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)*
- *TRL 7 – system prototype demonstration in operational environment*
- *TRL 8 – system complete and qualified*
- *TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)*

3.2.4 Improvements or Developments Needed to Make Your Solution Operative

Explain what the next steps in the technical/technological field would be to keep developing and implementing your solution.

Explain what kind of technical/technological improvement you need to scale-up your CSS or to apply it to different scenarios (transfer).

The further developments needed can constitute a KPI for monitoring your CSS progress.

Information from this section will also feed 4.1 and sections 5 and 6.



4. Economic Assessment

4.1. Implementation Costs

Calculate as accurately as possible the costs for the implementation of your CSS on full operative capacity, including Further Technology Development/Research if needed. Compare the costs with those incurred by current solutions.

4.2. Operation Costs

Calculate as accurately as possible the operation costs that your CSS will need to be used. Compare the costs with those incurred by current solutions as well as with the costs of the current situation.

4.3. Potential for Growth and Job Creation

Provide an approximate idea on the potential for generating wealth. Can it be exploited as a business generating revenues? Will it need an increase in taxes? Do you foresee that it will require new jobs to be operated?

After writing this, you might want to review section 2.8 on social impact.

4.4. Costs/Benefits Analysis

In this section you will first need to gather information from previous Economic Assessment sections (costs) and from Sections 2.8, 3.1 and 4.3 (Benefits)

Now you should analyze the balance between costs and benefits, considering the Economic, Environmental, and Social aspects.

It is advised to perform an analysis estimating monetary values for costs and benefits that do not have a market price, using Shadow Prices¹, Contingent Valuation², or other similar methods.

The cost/benefit analysis is a powerful tool for decision making in the implementation of large projects with multiple public and private stakeholders.

¹ Examples of Shadow Prices Method in Environmental Assessment:

- <https://uvadoc.uva.es/bitstream/handle/10324/56785/Monetary-valuation-unsorted-waste.pdf?sequence=1>
- https://www.oecd-ilibrary.org/environment-and-sustainable-development/estimating-shadow-prices-of-pollution-in-selected-oecd-countries_5jxvd5rnjnx-en
- Handbook: <https://cedelft.eu/publications/shadow-prices-handbook-valuation-and-weighting-of-emissions-and-environmental-impacts/>

²Contingent Valuation explained: <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/contingent-valuation>

Example of use: https://ecosystemvaluation.org/contingent_valuation.htm



The result of this analysis shall be considered as a **KPI** for monitoring your CSS. The more the benefits surpass the costs, the more successful will be your CSS.

Also keep in mind that a negative costs/benefits analysis can constitute an economic barrier while a positive one can become a driver. This information will feed Section 5 on decision making.

4.5. Determination of the Return on Investment (RoI)

The use of monetary values will provide the opportunity to calculate the Return on Investment.

This parameter can also become a **KPI** for your CSS, as it estimates when (timewise) the investment will be justified and surpassed by the benefits.

4.6. Business Models and Strategies to Exploit the CSS



5. Conclusions and Strategic Decision-Making Process

5.1. Barriers and Drivers Analysis



Figure 20: Examples of typical barriers and their categories according to the CCRI Methodology.



Figure 21: Example of Barriers and Drivers Analysis scheme.

Source: Own elaboration.



The barriers and drivers analysis can also be represented as a problem-objectives analysis diagram. A short guide on how to do it: <https://www.slideserve.com/dianne/developing-problem-tree-solution-tree>

5.2. PESTEL Analysis

PESTEL analysis		
<p>Description: PESTEL stands for Political, Economic, Social, Technological, Environmental and Legal and it is a framework generally used to gain a better understanding of the external environment related to a business position and to provide direction for future operations. The PESTEL framework has been applied to the concept of a circular economy to assess the factors having an impact (positive or negative) on the development of such economy.</p> <p>PESTEL analysis has two basic functions for a CSS. The first is that it allows identification of the environment within which a CSS operates. The second basic function is that it provides data and information that will enable cities and regions to predict situations and circumstances that it might encounter in the future.</p> <p>The PESTEL framework is generally implemented during the initial phases of CE/CSS strategy design to identify main barriers and drivers of the local territory. A first PESTEL analysis can be performed on desk-based research. This would later provide the starting point for discussion in the stakeholder seminar. Alternatively, PESTEL can also be implemented directly in a workshop by asking stakeholders to express their views on the different PESTEL factors. The framework is very intuitive and does not require experts to use it, but its simplicity also limits a more systemic understanding of territorial dynamics.</p>	CCRI Methodology phase Design Thematic area Understanding CSS barriers and drivers Complexity ★ Time ★ Financial effort ★	
	<p>Reference Obsterg et al., (2019). Urban Regions Shifting to Circular Economy: Understanding Challenges for New Ways of Governance. <i>Urban planning</i>, Volume 4, 19-31. https://doi.org/10.17645/up.v4i3.2158</p>	
	<p>Visual identity</p>	

Figure 22: Example of PESTEL analysis.

Source: CCRI Methodology.

Some other examples of a PESTEL analysis can be found in the following link:

<http://webapi.bu.edu/pestle-analysis-housing-industry.php>

5.3. SWOT Analysis


SWOT analysis for the regions of Switzerland and Liechtenstein <i>ESPON CIRCTER SPINOFF project – Switzerland and Liechtenstein (2021).</i> 	
<p>Strengths</p> <ul style="list-style-type: none"> • Highly efficient collection and recycling systems • Well-established industry in advanced manufacturing • Industry and key areas supported strongly by education and research institutes • Platforms and networks help sharing experiences and disseminate innovations across the country and internationally • Cutting-edge take-back system • Favourable financial and business environment • Transport logistic node with important corridors running through Europe • Public awareness and institutional commitment on environmental/sustainability issues 	<p>Weaknesses</p> <ul style="list-style-type: none"> • High municipal waste generation per capita • Lack of natural resources and consequent dependence on foreign countries • Shrinking employment in some regions (e.g., Ticino or Lake Geneva region) • Different/'mismatched' geography for waste management initiatives at the local level • Lack of industrial parks for industrial symbiosis
<p>Opportunities</p> <ul style="list-style-type: none"> • Capability to adopt smart technological sustainable solutions • Building closer collaboration of business innovation and research for circular-designed products • Smart public solutions and competitive advantage for business through innovative public procurements • Sustainable industry including production, new materials, digitalisation and circular business models • Active participation in European collaborations/initiatives 	<p>Threats</p> <ul style="list-style-type: none"> • Increasing generation of municipal waste • Increasing dependence from foreign countries • Incineration lock-in effect • Increasing urban-rural disparities and intra-regional centralisation • Non-comprehensive planning for attractive rural areas

Figure 23: Example of a SWOT analysis.

Source: CCRI methodology.

Here a couple of links on how to perform SWOT analysis:

- <https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/swot-analysis/main>
- <https://extension.psu.edu/conducting-a-swot-analysis>

5.4. Final Decisions and Roadmap for Implementation

Using the information extracted from all previous sections, state here the decisions regarding the CSS implementation, and prepare a roadmap with the next steps to be taken.



6. Monitoring and Continuous Evaluation

6.1. Definition of KPIs and Targets

In the context of the CircSyst project, the definition of Key Performance Indicators (KPIs) and targets is essential for monitoring the progress and success of Circular Systemic Solutions (CSS). KPIs serve as measurable values that reflect the effectiveness, efficiency, and impact of the CSS throughout its development and implementation. Establishing clear and relevant KPIs ensures that all stakeholders can track progress, make informed decisions, and adjust strategies as needed to achieve the desired outcomes.

Key Steps in Defining KPIs and Targets:

1. Identify Relevant KPIs:

- **Environmental KPIs:** These might include metrics such as waste reduction percentages, energy savings, reduction in greenhouse gas emissions, material reuse rates, and improvements in resource efficiency. For example, a target might be set to reduce waste by 20% within the first year of implementation.
- **Social KPIs:** Measure the social impact of the CSS, such as job creation, community engagement levels, social inclusion indices, and improvements in quality of life. For instance, one target could be to create 50 new jobs in the local community within two years.
- **Economic KPIs:** These include cost savings, return on investment (RoI), revenue generated from circular activities, and economic growth within the targeted sectors. An economic KPI might be achieving a RoI of 15% within five years.

2. Set Specific Targets:

- For each KPI, establish clear and achievable targets that are time-bound and relevant to the overall goals of the CSS. These targets should be realistic yet ambitious enough to drive meaningful progress.
- For example, if the goal is to improve energy efficiency, a target could be set to reduce energy consumption by 30% over the next three years.

3. Align KPIs with Project Objectives:

- Ensure that the KPIs and targets are aligned with the broader objectives of the CircSyst project, such as promoting sustainability, enhancing circularity, and fostering systemic change. This alignment guarantees that the KPIs support the overall mission and vision of the project.

4. Use Existing Frameworks:

- Leverage existing frameworks and tools, such as the Circular Cities and Regions Initiative (CCRI) methodology, to inform the selection and definition



of KPIs. These frameworks provide valuable guidance on indicators that are widely recognized and relevant to circular economy initiatives.

5. **Continuous Monitoring and Evaluation:**

- Implement a robust system for monitoring and evaluating the KPIs over time. This system should include regular data collection, analysis, and reporting to assess progress towards the targets. Feedback loops should be established to allow for adjustments in strategies and actions based on the findings.

6. **Engage Stakeholders in the Process:**

- Involve key stakeholders in the definition of KPIs and targets to ensure that they are relevant, comprehensive, and supported by those who are critical to the CSS's success. Stakeholder engagement also helps in identifying potential challenges and opportunities related to the achievement of the targets.

By clearly defining KPIs and setting specific, measurable targets, the CircSyst project can ensure that its CSS initiatives are effectively guided towards achieving significant and lasting impacts. These KPIs will serve as vital tools for decision-making, helping to steer the project towards its goals of sustainability and circularity across Europe.

6.2. Regular Monitoring and Evaluation Processes

Regular monitoring and evaluation are critical components of the CircSyst project, ensuring that the Circular Systemic Solutions (CSS) remain on track to achieve their defined KPIs and targets. These processes are designed to provide ongoing insights into the performance of each CSS, enabling timely adjustments and improvements to maximize impact and ensure alignment with project goals.

Objectives of Monitoring and Evaluation:

The primary objectives of the monitoring and evaluation processes are to:

- **Track Progress:** Continuously assess the progress of the CSS against the established KPIs and targets. This involves the regular collection and analysis of data to determine whether the project is advancing as planned.
- **Identify Challenges:** Detect any barriers, challenges, or deviations from the expected outcomes early in the process. This allows for proactive problem-solving and the implementation of corrective measures.
- **Ensure Accountability:** Provide a transparent and accountable framework where all stakeholders can see how resources are being used, how decisions are being made, and how the project is progressing towards its objectives.
- **Facilitate Continuous Improvement:** Use the insights gained from monitoring and evaluation to refine and improve the CSS, enhancing its effectiveness and efficiency over time.

Key Components of the Monitoring and Evaluation Processes:

1. Data Collection:

- **Frequency:** Establish a regular schedule for data collection that aligns with the timelines set for the KPIs and targets. For example, data might be collected on a monthly, quarterly, or annual basis, depending on the specific indicator.
- **Methods:** Utilize a combination of qualitative and quantitative methods to gather comprehensive data. This could include surveys, interviews, observational studies, sensor data, and reports from stakeholders.
- **Tools and Technologies:** Implement appropriate tools and technologies to streamline data collection and ensure accuracy. Digital platforms, monitoring software, and data analytics tools can play a significant role in enhancing the efficiency of this process.

2. Data Analysis:

- **Regular Review:** Establish a process for the regular review and analysis of the collected data. This analysis should be aimed at identifying trends, patterns, and areas where performance is either exceeding or falling short of expectations.
- **Benchmarking:** Compare the performance data against the set KPIs, targets, and industry benchmarks to evaluate the effectiveness of the CSS.
- **Reporting:** Develop a standardized reporting format to communicate findings to stakeholders. Reports should be clear, concise, and focused on actionable insights.

3. Feedback Mechanisms:

- **Stakeholder Feedback:** Regularly engage with stakeholders to gather their perspectives on the CSS's performance. This feedback is invaluable for understanding the on-the-ground realities and potential impacts of the CSS.
- **Adaptive Management:** Implement a feedback loop that allows for the adaptive management of the CSS. When the data reveals a need for change, the project team should be prepared to make necessary adjustments to strategies, processes, or resource allocations.

4. Risk Management:

- **Early Warning System:** Develop an early warning system that identifies potential risks or issues that could impact the success of the CSS. This system should trigger alerts when certain thresholds are crossed, enabling timely intervention.
- **Mitigation Strategies:** Ensure that the monitoring process includes the identification and implementation of risk mitigation strategies. Regular evaluations should assess the effectiveness of these strategies and recommend improvements where needed.

5. Documentation and Record Keeping:

- **Comprehensive Records:** Maintain detailed records of all monitoring and



evaluation activities, including data collected, analyses performed, decisions made, and actions taken. This documentation is crucial for transparency and accountability.

- **Learning and Knowledge Sharing:** Use the records and reports to share lessons learned with other stakeholders and project teams. This knowledge-sharing fosters a culture of continuous improvement and innovation across the CircSyst project.

By implementing a robust and systematic monitoring and evaluation process, the CircSyst project can ensure that its CSS initiatives are consistently meeting their goals and adapting effectively to any challenges or changes in the environment. This ongoing process is key to achieving long-term success and sustainability in the transition towards a circular economy.

6.3. Feedback Loops for Continuous Improvement

The implementation of feedback loops is a crucial element in the continuous improvement of Circular Systemic Solutions (CSS) within the CircSyst project. Feedback loops ensure that the project remains dynamic and responsive to new information, changing conditions, and stakeholder input, thereby enhancing the overall effectiveness and sustainability of the solutions.

Purpose of Feedback Loops:

The primary purpose of feedback loops is to facilitate ongoing learning and adaptation throughout the lifecycle of the CSS. By systematically collecting and analyzing feedback, the project team can identify areas for improvement, adjust strategies, and implement changes that contribute to the long-term success of the initiative.

Key Components of Effective Feedback Loops:

1. Data Collection and Analysis:

- Continuously gather data from various sources, including monitoring and evaluation processes, stakeholder feedback, and external developments that may impact the CSS.
- Analyze this data to identify trends, challenges, and opportunities for improvement. This analysis should be integrated with the KPIs and targets established in section 6.1 to assess the performance of the CSS against its goals.

2. Stakeholder Engagement:



- Engage stakeholders regularly to solicit their feedback on the CSS. This can be achieved through surveys, interviews, workshops, and other participatory methods that encourage open dialogue.
- Ensure that stakeholders are informed about how their feedback is being used to make improvements, fostering a sense of ownership and collaboration in the project.

3. Adaptive Management:

- Use the insights gained from feedback to make informed adjustments to the CSS. This may involve refining processes, modifying targets, reallocating resources, or altering the overall strategy to better align with the project's objectives.
- Establish a formal process for reviewing and implementing changes based on feedback, ensuring that decisions are made transparently and inclusively.

4. Communication of Changes:

- Clearly communicate any changes or adjustments made to the CSS as a result of feedback to all relevant stakeholders. This communication should include the rationale behind the changes, expected outcomes, and how these changes will impact the project moving forward.
- Utilize multiple communication channels to ensure that all stakeholders are aware of updates and have the opportunity to ask questions or provide further input.

5. Documentation and Learning:

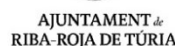
- Document all feedback received, the analyses conducted, and the changes implemented. This documentation should be maintained as part of the project's records and used as a reference for future decision-making.
- Encourage a culture of learning within the project team and among stakeholders, where feedback is viewed as an opportunity for growth and continuous improvement rather than criticism.

6. Regular Review and Iteration:

- Schedule regular reviews of the feedback loops themselves to assess their effectiveness. Are the loops capturing the right information? Are they facilitating meaningful improvements?
- Be prepared to iterate on the feedback loop process, making adjustments as necessary to enhance its efficiency and impact.

By integrating feedback loops into the CircSyst project, each CSS Demo can ensure that the CSS remains flexible, responsive, and aligned with both the project's goals and the needs of its stakeholders. This ongoing process of evaluation and adaptation is essential for driving the continuous improvement that is critical to the success of circular economy initiatives.

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European Commission



CIRCSYST

Circular Systemic Solutions



Water



Bio-Waste



Plastic,
Packaging

ANNEX II – BASELINE PROFILE TEMPLATE

WORK PACKAGE 6: SYSTEM ANALYSIS, KNOWLEDGE TRANSFER AND
REPLICATION, D6.1



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ANNEX II: CSS Baseline Profile Template

Deliverable 6.1

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EXECUTIVE SUMMARY

ANNEX II outlines the template provided to Demo Leaders to create the baseline profile for each one of their CSS after the discussions in the First WP6 workshop.



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Baseline Profile of CircSyst Demonstrators and First Assessment of Synergies

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Demo x...

1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

2 Scope and Territory

2.1 The territorial context

Geographical Scope: What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope? If possible, add a map.

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices



Table 1: Regulatory Framework

Level	Normative	Requirements for your CSS
EU	Directive xxx	
EU	Regulation	
National	Law xxx	
Regional	Decree xxx	
Local	Order xxx	

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

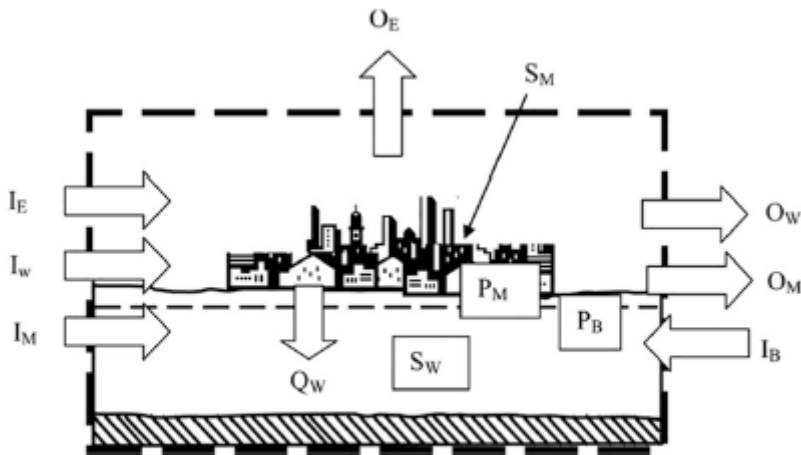


Fig. 1. Urban Metabolism framework: The boundary of an urban system showing inflows (I), outflows (O), internal flows (Q), storage (S), and production (P) of biomass (B), minerals (M), water (W), and energy (E) [17].

Figure 1: Simplified Metabolism Accounting Framework.

Source: Ling Min Tan, Hadi Arbabi, Paul E. Brockway, Danielle Densley Tingley, Martin Mayfield, An ecological-thermodynamic approach to urban metabolism: Measuring resource utilization with open system network effectiveness analysis (<https://doi.org/10.1016/j.apenergy.2019.113618>)

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

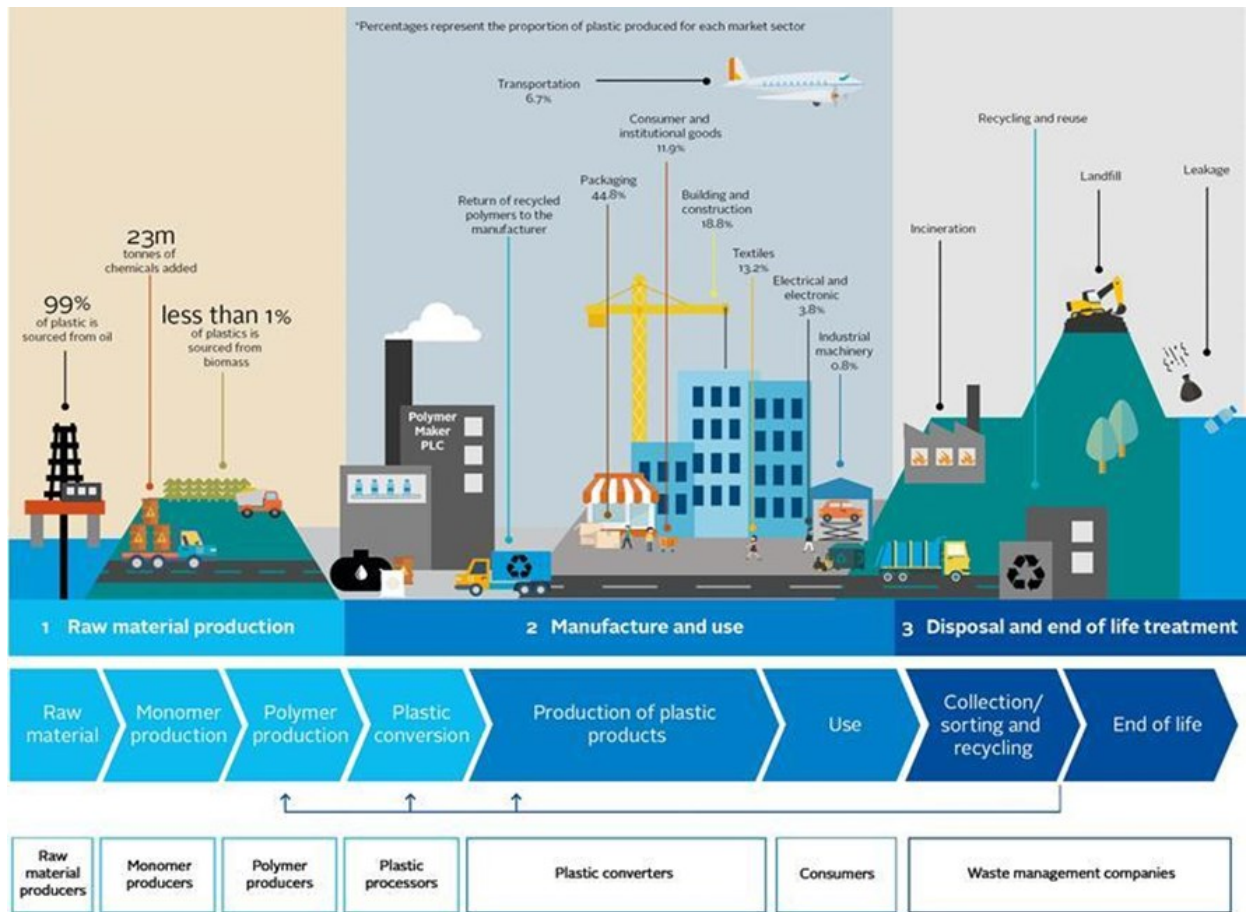


Figure 2: Vale chain example to be deleted.

Source: <https://www.unpri.org/circular-economy/risks-and-opportunities-along-the-plastics-value-chain/4774.article>

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

3.2 Value Chain Overview and Stakeholders' identification

Identify the stakeholders involved that will be affected by the CSS shift. Please characterise the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

3.4 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

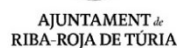
As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?**

Table 2: Identification of Synergies amongst CSSs

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	



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CIRCSYST

Circular Systemic Solutions



Water



Bio-Waste



Plastic,
Packaging

ANNEX III – CSS BASELINE PROFILES

WORK PACKAGE 6: SYSTEM ANALYSIS, KNOWLEDGE TRANSFER AND REPLICATION, D6.1



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CircSyst Circular Systemic Solutions

Baseline Profiles

Deliverable 6.1

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EXECUTIVE SUMMARY

This document provides a comprehensive overview of the baseline profiles for the CircSyst Circular Systemic Solutions (CSS) Demonstrators. Each demonstrator is designed to address specific challenges in the circular economy through innovative approaches tailored to their respective sectors and geographical contexts. The profiles outlined in this document offer detailed insights into the territorial context, policy frameworks, stakeholder engagement, and the circular solutions proposed by each demonstration project.

The CircSyst project is part of a broader effort to transition towards a more sustainable and circular economy in Europe, aligning with key objectives of the European Green Deal and the Sustainable Development Goals (SDGs). Each CSS demonstrator aims to create systemic changes in their respective domains by introducing new technologies, processes, and collaboration models that enhance resource efficiency, reduce waste, and promote the reuse of materials.

The document details the scope and impact of each CSS, highlighting how they intend to contribute to solving critical societal, economic, and environmental challenges. The profiles also identify potential barriers and risks, providing strategies to mitigate these challenges and ensure successful implementation. Additionally, the document explores potential synergies among the different CSS demonstrators, emphasizing the importance of cross-sectoral collaboration to maximize impact and foster systemic symbiosis.

This baseline profile serves as a foundational step for the CircSyst project, offering a detailed roadmap for the development, implementation, and scaling of Circular Systemic Solutions across Europe. By documenting the initial conditions and strategies of each demonstrator, this report lays the groundwork for future assessments and the continuous improvement of circular practices within the CircSyst framework.



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Baseline Profile of CircSyst Demonstrators and First Assessment of Synergies



Demo 1: Reuse of Industrial Wastewater by on- demand treatment and distribution powered by AI.



1. The idea in brief

***Problem Addressed or Need Detected:** Briefly describe the problem or need addressed by your CSS.*

Spain is currently experiencing severe droughts, a situation that has been exacerbated by climate change. In fact, the last IPCC report (AR6, 2021) pointed a medium-high risk of water scarcity in most of South Europe, but also in several regions further to the East and North of Europe by 2050. Rising temperatures and shifting weather patterns have led to prolonged periods of low rainfall, significantly reducing water levels in rivers, reservoirs, and aquifers. This has not only impacted agriculture and ecosystems but has also strained the water supply for urban and industrial use.

Water consumption in Spain is a critical factor contributing to the worsening drought conditions. The agricultural sector is the largest consumer, utilizing about 80% of the nation's water resources. However, industrial activities also play a significant role, adding further pressure to the already limited water supplies. The heavy industrial consumption of water impacts its availability, leading to stricter water usage regulations and necessitating more efficient water management practices. As industries continue to expand and demand increases, the competition for water resources intensifies, exacerbating the effects of drought.

The combined effects of climate change and high-water consumption underscore the urgency of adopting comprehensive water management strategies and technologies to mitigate the impact of droughts and ensure a sustainable water future for Spain.

***Solution Proposed:** Briefly describe what is your solution and how does it solve the Problem/need addressed.*

The proposed solution focuses on promoting and optimizing the reuse of treated industrial wastewater in industrial areas, implementing advanced wastewater treatment technologies that will allow industries to recycle and reuse water within their operations. Industries water demands will be sensorize in order to, through the implementation of IA-based systems, optimize the production of different water qualities that will match with the ones needed. This approach not only alleviates the pressure on freshwater resources but also offers a sustainable way to meet the high water demands of various industries.

***Short introduction to the demonstrator:** What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?*

The proposed solution involves implementing a system that uses sensors and artificial



intelligence (AI) to detect the specific water quality and quantity needs of various companies. This allows a wastewater treatment plant (WWTP) to apply the necessary treatments automatically, producing water that meets the precise requirements identified by the AI. This innovative approach represents a significant shift in how industrial water reuse is managed and optimized, offering substantial social, economic, and environmental benefits.

From a social perspective, ensuring a reliable and high-quality water supply for industrial use helps protect public water resources, making more freshwater available for communities and agriculture. This contributes to water security, public health, and the well-being of citizens, aligning with the United Nations Sustainable Development Goal (SDG) 6: Clean Water and Sanitation, by promoting sustainable water management and sanitation for all. On the other hand, economically, the optimized reuse of treated industrial wastewater reduces costs associated with water extraction and treatment for industries. By improving water efficiency and recycling, companies can improve their resilience against severe droughts, water restrictions on water consumption or sudden water shortages. This innovation also supports SDG 9: Industry, Innovation, and Infrastructure, by fostering resilient infrastructure, promoting inclusive and sustainable industrialization, and encouraging innovation. And, lastly, from an environmental perspective, the reduction in freshwater consumption and the enhanced management of wastewater contribute to the preservation of natural water bodies and ecosystems. This approach mitigates the impact of droughts and helps in the fight against climate change, directly supporting the European Green Deal's objectives of protecting biodiversity and reducing pollution. Additionally, it aligns with SDG 12: Responsible Consumption and Production, by ensuring sustainable consumption and production patterns.

By leveraging advanced sensor technology and AI, this system ensures that water reuse processes are precisely tailored to the needs of different industries. This not only maximizes efficiency but also minimizes waste and environmental impact. The integration of such smart technologies into water management practices significantly improve and increase its effectiveness, which is a crucial step towards achieving the goals of the European Green Deal, which aims to make Europe climate-neutral by 2050, promote resource efficiency, and restore biodiversity.

In conclusion, the proposed system represents a transformative change in industrial water management. By aligning with specific SDGs and the European Green Deal, it addresses critical social, economic, and environmental challenges, ensuring a more sustainable and resilient industries, especially in those areas more affected by droughts and climate change.



2 Scope and Territory

2.1 The territorial context

Geographical Scope: *What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope? If possible, add a map.*

The project will be developed in an Industrial Park located in the municipality of Riba-roja del Túria (Valencian Community, Spain). Even though initially it has a local scope, the proposed solution could be upscaled and replicated in different WWTP (both in the Valencian Community and Spain).

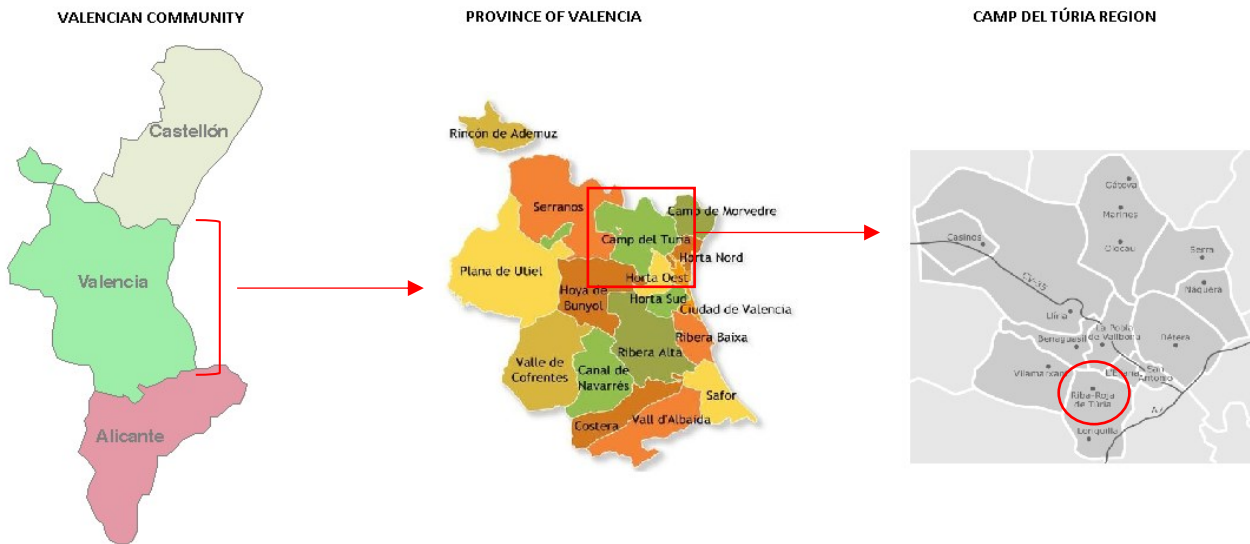


Figure 1: Geographical Location

Sectorial Scope: *Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?*

The CWSS deployment will improve wastewater treatment and reduce freshwater consumption. It has the potential to be a transversal solution, positively impacting any sector that uses water in its processes.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

In the context of projects focused on the reuse of treated water for advancing a circular economy, various policy instruments at European, national, and regional levels play a crucial role. One of the most significant is the EU Circular Economy Action Plan, administered by the European Commission, which aims to facilitate the transition towards a circular economy across Europe. This plan promotes efficient resource use, waste reduction, and the reuse of materials, providing legal and financial frameworks that support innovation and the implementation of sustainable practices, including the reuse of treated water.

At the European level, REGULATION (EU) 2020/741 establishes minimum requirements for the reuse of treated water, ensuring its safe and effective use, particularly in agricultural irrigation. This regulation supports the broader goals of the Circular Economy Action Plan by setting standards that enhance the sustainability of water resources and reduce the environmental impact.

At the national level, it is worth highlighting the Spanish Circular Economy Strategy (EEEC), which establishes (among other areas) a goal of improving efficiency in water use by 10%. This strategy points out the policies that address water management as a key to the transition towards the circular economy, and the reuse of water as a priority line of action in this regard.

Royal Decree 1620/2007, of December 7, further complements these efforts by setting the legal regime for the reuse of treated water. It provides a framework for managing treated wastewater, promoting its safe and beneficial use in various applications, and contributing to circular economy objectives.

At the regional level, the Valencian Community enacted Law 2/1992, of March 26, on the sanitation of wastewater, establishing the regulatory framework for managing wastewater treatment and reuse in the Valencian Community, supporting local circular economy initiatives.

These legislative and regulatory frameworks collectively enhance the promotion of circular economy practices, particularly in the context of water reuse. They provide essential guidelines, incentives, and support for projects that aim to integrate recycled and treated materials into sustainable economic models, aligning with the EU's broader sustainability and environmental goals.



2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices

Table 1: Main Regulations Framing Demo 1

Level	Regulation	Requirements
EU	EU Circular Economy Action Plan (European Commission).	It promotes the transition to a circular economy. Promotes the reuse and recycling of materials, which is essential for the valorization of bagasse as a secondary raw material.
EU	REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse	It establishes minimum requirements to ensure the quality and safety of water reused for agricultural irrigation.
National	Spanish Circular Economy Strategy (EEEEC)	Establishes (among other areas) a goal of improving efficiency in water use by 10%. This strategy points out the policies that address water management as a key to the transition towards the circular economy, and the reuse of water as a priority line of action in this regard.
National	Royal Decree 1620/2007, of December 7, establishing the legal regime for the reuse of treated water.	It establishes the legal framework for the reuse of treated wastewater, regulating its safe and effective use in various applications.
National	Royal Decree-Law 4/2023, of May 11, adopting urgent measures in agricultural and water matters in response to the drought and the worsening conditions of the primary sector resulting from the war in Ukraine and weather conditions, as well as promoting	It adopts urgent measures to address the drought, the impact of the conflict in Ukraine, and adverse weather conditions, promoting public transport use among young people and preventing occupational risks during episodes of high temperatures.

	the use of public land transport by young people and preventing occupational risks in episodes of high temperatures.	
Regional	Law 5/2022, of November 29, on waste and contaminated soils for the promotion of the circular economy in the Valencian Community.	It establishes measures to promote waste reduction, reuse, and recycling, as well as the remediation of contaminated soils, driving a circular economy in the region.
Regional	Law 2/1992, of March 26, of the Valencian Government, on the sanitation of wastewater in the Valencian Community.	It establishes the framework for the sanitation and treatment of wastewater in the Comunidad Valenciana.
Local	Order nº 44 - 21/11/2013 Riba-roja de Túria Town Hall Edict of the Riba-roja de Túria Town Hall on final approval of the Municipal Ordinance on the Discharge of wastewater into the Municipal Network	Municipal Ordinance on the discharge of wastewater into the municipal network, regulating standards and procedures for wastewater management.

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

Pilot 1 aims to demonstrate the circularity and symbiosis of water as a necessary resource in a given ecosystem made up of industrial companies and services related to citizens. In the demonstrator, the inputs and outputs of used and discharged water will be analysed to study its possible reuse.

The origin of the flows is based on the water discharged by the companies or services located in the industrial area and which is collected and treated by the corresponding WWTP of the industrial estate. After its appropriate treatment, the water could be reused for other uses depending on the different qualities that can be obtained.

The pilot will also have an AI-based management system that will relate water demands with the quality needs of said water, improving the efficiency and performance of the WWTP.

The destination of the different flows may be industrial companies that need to consume water of certain qualities, or services offered by the city council such as street sweeping, area cleaning, firefighting, etc.

The following diagram shows the direction of the various expected flows.



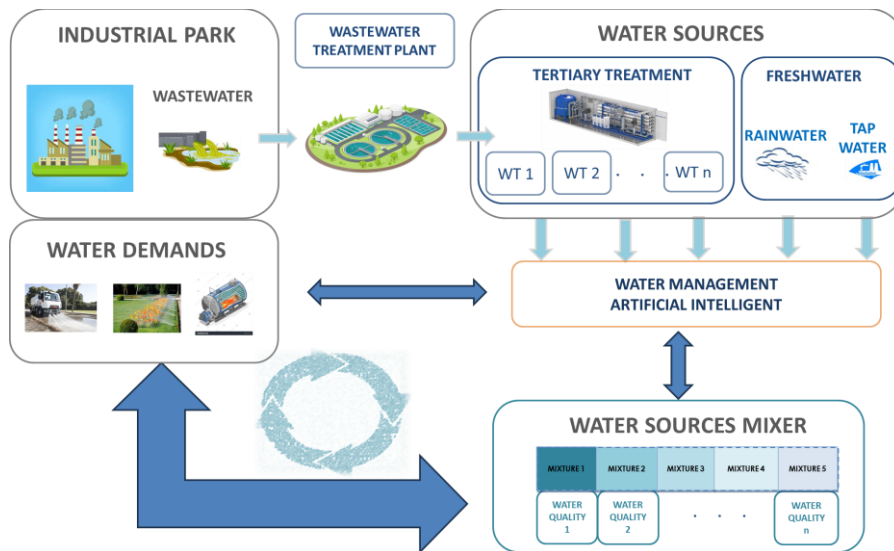


Figure 2: Simplified Metabolism Accounting Framework.

With regard to the actors present in the demonstrator and who will form part of the ecosystem, the following can be highlighted:

- The WWTP, responsible for receiving the water discharged from the different uses of the polygon. The WWTP is one of the central cores of the demonstrator, since the different treatments necessary to obtain water of different qualities and thus water for different uses will begin there.
- Industrial companies as potential recipients of the water recycled by the WWTP (for uses such as different stages of the manufacturing processes, firefighting systems, cleaning-washing, etc.).
- The city council, responsible for the industrial area and supplies related to the water resource. In addition, the city council is considered a potential demander of recycled water for use in maintenance and cleaning activities of the streets of the municipality.

The treatment of approximately more than 10% of the water treated in the treatment plant subject to the project is planned.

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

Public Administration

Public administration is directly involved in the project by providing the regulatory framework and policies that support the adoption of advanced water management technologies. Additionally, regulatory agencies oversee compliance with environmental regulations, ensuring that industrial practices are safe and responsible. EPSAR (Water Sanitation Entity of the Valencian Community, which is responsible for the operation and proper functioning of the WWTPs in the region) has a direct interest in promoting the recovery and reuse of treated wastewater. Indirectly, public administration benefits from the project through enhanced water security and reduced environmental impacts, which align with national sustainability goals and international commitments such as the European Green Deal.

Industry and Commerce

Industries and commercial enterprises are directly involved as the primary users of the CWSS. By adopting this technology, they can optimize their water use and enhance sustainability practices. The system enables industries to meet specific water quality requirements, improving their production efficiency and competitiveness. Indirectly, the wider commercial sector benefits from a more stable and reliable water supply, which supports economic growth and resilience.

Civil Society

Civil society is indirectly involved as beneficiaries of the project. Improved water management practices lead to better water availability and quality, which positively impacts public health and quality of life. Additionally, the reduction in industrial water consumption and pollution supports environmental conservation efforts, contributing to a healthier ecosystem. On the other hand, the reduction in water consumption in industrial environments would also mean a lower global water footprint, positively impacting global water consumption and reducing the frequency and intensity of possible restrictive measures on water use for society as a whole. Public awareness campaigns and community engagement initiatives can also help garner support and acceptance of the new system, highlighting its benefits for society as a whole.

Academia, Regional Technology Organizations, and NGOs

Academic institutions, regional technology organizations, and NGOs are collectively involved in advancing, implementing, and advocating for the CWSS. Academia contributes through research and development, testing, and refining the technology, while also educating future



professionals. Regional technology organizations provide the necessary technological expertise and infrastructure, facilitating collaborations and promoting knowledge sharing. NGOs advocate for sustainable water management practices, monitor environmental impacts, and raise public awareness. Indirectly, these groups benefit from increased research funding, innovation opportunities, and positive environmental outcomes that align with their respective goals.



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where does your innovation intervene in this system?

Water in Spain is a public domain asset that is available for users through an administrative concession or a legal provision. The use of water is regulated by legislation. Management is carried out by river basin organizations (in Spain the hydrographic confederations).

Water in Spain comes mainly from rainfall and inland waters. In Spain there is an uneven rainfall regime (high in the north and low in the rest of the country with punctual annual incidents of torrential rains), on the other hand, Spanish rivers have irregular courses, running through dry lands where their flow decreases, except on specific occasions that occur with large floods. This spatial and temporal irregularity has created the need for large hydraulic works (mainly dams and reservoirs) to achieve water availability of around 30-40%. Another important source is groundwater through wells and supply from desalinated water, the main resource on the islands.

The scenario varies from year to year and requires a particularized management, aimed at optimizing demand according to the available resources.

The main uses of water are urban, agricultural and industrial use, although its distribution depends on the different geographical areas.

Although the water for consumption may come from one or several sources, its quality can be considered homogeneous. This water for consumption must be collected, conveyed for drinking water treatment, stored, transported and distributed to the connections or point of delivery to the users. The users can be diverse, but they can be categorized into three main groups: agricultural, industrial, urban, etc.

In the Valencian Community, there is a public entity that manages and operates the water supply, treatment and purification and reuse of treated water.

Once used, the water is directed to the municipal sewage system and from there to the urban wastewater treatment plants. Industrial water with a high contaminant content must be treated prior to discharge into the sewer.

Wastewater treatment is performed in biological treatment plants, and it usually can include 3 types of consecutive treatments:

- Primary, reduces solids and grease content.
- Secondary, through the action of microorganisms, converts complex organic compounds into simpler and less polluting substances.



- Tertiary, it is a refining treatment that eliminates microorganisms and other substances not eliminated in the previous treatments, raising the quality of the effluents.

The treated water can be used for:

- Outfall evacuation
- Indirect reuse (recharging aquifers, rivers, etc).
- Direct reuse (productive, agricultural and industrial uses).

The percentage of reuse varies each year depending on the uses and provinces.

The wastewater treatment process also produces sewage sludge that contains organic matter and nutrients that make it a suitable organic amendment for agriculture; and if it is not suitable, it will be used for energy recovery, mainly in cement plants.



3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

The CWSS that will be deployed in the chosen wastewater treatment plant will impact both the stakeholders previously mentioned, but also some of the partners involved. Regarding the key stakeholders, it is highlightable the positive impact that it will have for EPSAR (as owner of the WWTP installations), the industries located in the industrial park (since they will be the main users of the recovered water) and the Riba-roja city council.

EPSAR (Water Sanitation Entity of the Valencian Community) owns the WWTP in the Valencian Community. Even though they delegate the WWTP management to other organizations (such as Hidraqua, who also plays a role in the project), they have a wide interest in promoting water usage sustainability, promoting treated wastewater reusage and new technologies or management techniques aimed to that purpose.

The Riba-roja municipality has been widely committed to the 2030 Agenda and the promotion of the SDGs through the management of the town; including urban planning, different awareness campaigns or the participation in projects (such as CircSyst) that are planned in that direction. The improvement in wastewater management in the selected WWTP, as well as the reduction of water consumption (by both companies and the municipality itself) or the improvement in the sustainability of the WWTP, will improve the performance of Riba-roja regarding compliance with the SDGs.

Leaving aside the main stakeholders, the proposed CWSS will also impact positively on other economic sectors (such as the agriculture sector), given the reduction of the global water footprint. On the other hand, local communities and environmental organizations will see positive environmental impacts through the water consumption reduction (improving the quality and availability of groundwater). Through this CWSS deployment, collaboration and coordination between the different actors in the Riba-roja's economical ecosystem (public administrators, industries, technological centres, etc.).

Please characterise the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

Most of the actors that are positively affected by the CWSS deployment are already involved in the project as partners. They are:

AIDIMME, as a technological and research center, plays a key role as coordinator of the CWSS. They have developed the industrial symbiosis system that will be adapted to the CWSS and will also coordinate and execute some of the sensorization needed, as well as the AI that must be deployed. They expect a successful implementation, proving the viability of the system and its scalability. AIDIMME is also an association of companies, so it will be able to transfer the good results of the project and the application of the different technologies to other companies, thus fulfilling its objective as a technological center.

Riba-roja city council will be deeply involved in supporting the CWSS deployment, since its

wide interest in the SDG implementation in the municipality. This public administration will also play a role when managing reclaimed treated wastewater for non-industrial applications (i.e. street cleaning, irrigation or firefighting), reducing therefor the pressure over the water resources in the municipality.

Hidraqua is the entity in charge of the WWTP management. They will, therefore, manage and monitorize the WWTP during the project. They expect the CWSS to help them to improve the WWTP efficiency and sustainability, as well as to improve the service they provide to the industries located in the industrial park in which the plant is located. The experience of the results obtained throughout the project can be extrapolated to other treatment plants that are operating, thus acquiring greater prestige or value, in the face of the public tenders for which it is submitted.

Aquatec, an innovation entity focused on water management and wastewater treatment, will take part in the CWSS performing and managing the WWTP sensorization. The CWSS deployment will allow them to launch and perfect the sensorization system, improving WWTP efficiency and control. In addition, they expect from the project to integrate into a cooperation framework for the replication of the CWSS in future sites.

On the other hand, some stakeholders that have shown interest in the project (or will directly participate in the CWSS) are:

EPSAR, the Water Sanitation Entity of the Valencian Community, owns the WWTP and has a high interest in sustainability and wastewater reusage. By supporting the project (and the implementation of the CWSS), they expect to obtain a system that, not only improves WWTP efficiency and enhances treated wastewater reusage, but also that is highly replicable in other WWTP that are owned by the entity.

There are 474 **industries** located in the industrial park in which the WWTP operates. Some of them will be involved in the project, since their water needs will be monitored, and they will reuse the treated wastewater produced during the CWSS deployment. They expect to be more sustainable, but also to be more competitive and resilient thanks to it.



3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

Currently the water is a scarce commodity, so wastewater treatment for reuse must be part of the solution to the problems of water scarcity and pollution.

While the reuse treated wastewater is regulated in Spain, it is not a highly extended practice. The CWSS will, through an IA-based system, adapt the wastewater treatment to the needs of those industries that will lately reuse those new resources. Therefore, the CWSS proposed enhances wastewater treatment efficiency and, on the other hand, helps the involved companies to be more sustainable and resilient.

The system mentioned above allows the reuse of water, reducing freshwater inflows and promoting sustainable consumption, in line with the principles of sustainability. This integration will minimize freshwater consumption and increase resource efficiency. In this way, a valuable resource is recovered, resulting in benefits on several fronts: economic, social and environmental, according to the principles of sustainability.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Sustainable management and integrated treatment of water resources is a priority issue our society. It is important to have water of adequate quality and in sufficient quantity to be able to support the activities derived from development, which will allow an improvement in the environment, health and quality of life.

In Spain, wastewater treatment is carried out to reduce pollution to the values allowed in the discharge limits. However, in order to recycle wastewater, it is necessary to go further and obtain a better quality of discharge.

In this way, the recycling of wastewater makes it possible to increase the guarantee of supply for already consolidated uses and to improve the use of water by replacing pre-drinking water with reused water, thus increasing the net availability of water resources in coastal areas.

With this objective, the use of reused water can be promoted as an additional resource for hydrological planning, increasing the availability of the resource and ensuring the allocation of higher quality water to more demanding uses.

The value of the solution is intended to:



- Achieve good water status
- Reduce wastewater discharges
- Promote sustainable water reuse
- Contribute to the maintenance of ecological flows
- Improve treatment and reuse systems

In summary, Circular Systemic Solutions are well designed to recover and reuse wastewater by reducing its environmental impact and aligning solutions with the principles of the circular economy.

3.4 The envisioned impact

Demonstrator 1 contemplates the design of a water management system with innovative technology that will allow linking the water needs of companies with the water treated by the WWTP, optimizing its operation. This will entail a series of potential benefits and impacts.

- Social impact, the optimization of water use will help protect the water resources of the area, favouring the well-being of the population.
- Economic impact, the reuse of treated industrial wastewater will reduce costs associated with water consumption and its subsequent treatment, which will mean a decrease in operating costs for industries.
- Environmental impact will reduce water consumption and improved wastewater management will contribute to the preservation of ecosystems and natural water bodies, ensuring more sustainable and resilient industries, especially in those areas most affected by droughts and climate change.

Regarding the KPI, the volume of water discharged and the reduction with reclaimed water will be taken into account. A 20% reduction in discharges into public waterways is expected by reclaimed water.

Other KPIs to consider:

- *Reduction in the consumption of water from the network for industrial use*
- *Volume of water used in natural spaces (irrigation water)*
- *Participation of companies and entities in the demonstrator*



4 Potential Barriers and Risks

Technological barriers

Are there any technical/technological issues hindering the application of your CSS. Do you need further research?

There can be several technological issues in implementing the treated industrial wastewater reuse system. The integration of advanced sensors and AI-based systems can present significant challenges. The calibration and maintenance of these sensors require specialized technical knowledge and may need frequent updates to maintain the system's accuracy and efficiency.

Wastewater treatment technology can also face technological barriers. It is crucial to ensure that treatment technologies can efficiently remove specific contaminants and can be scaled according to the needs of different industries. Additional research could focus on developing more effective and sustainable treatment methods, as well as improving the integration of AI-based monitoring and control systems.

The interoperability of different technological systems and integration with existing industrial infrastructures are also areas that may require further research and development. Ensuring that all system components function cohesively and efficiently is essential for successful implementation.

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

The implementation of this CSS could face several knowledge barriers. Industrial personnel must be adequately trained in the use and maintenance of advanced technologies such as sensors and AI-based systems. This training should not only cover the basic operation of the systems but also diagnostics and troubleshooting, process optimization, and compliance with environmental regulations.

Continuous training and professional development are essential to ensure that personnel are up-to-date with the latest technological and methodological advancements. Partnerships with academic institutions and research centres can facilitate access to new technologies and emerging practices.



Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

From a political perspective, several challenges may arise in the implementation of the CSS. The lack of clear policies and regulations that support and promote the reuse of industrial wastewater can be a significant barrier. Existing policies may not be up-to-date or may be insufficient to address the complexities of advanced water management using AI-based technologies.

Greater political support may be needed to establish regulatory frameworks and incentives that encourage industries to adopt water reuse practices. This could include subsidies, tax credits, or specific financing programs for projects that implement advanced water management technologies.

Furthermore, it is crucial to ensure that national and local policies actively support these initiatives, aligning them with broader goals such as the Sustainable Development Goals (SDGs) and the European Green Deal. Collaboration between different levels of government, from municipal to national, and stakeholder participation are essential to create a favourable political environment.

It is also important to consider the role of public awareness and education in promoting political support. Informing citizens and communities about the social, economic, and environmental benefits of wastewater reuse can generate public backing that influences political decisions.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

There may be regulations that hinder the adoption of the CSS. Current regulations on water quality and treatment processes may not be adapted for the reuse of treated industrial wastewater. This can create significant regulatory barriers, as industries may face uncertainty regarding legal requirements and potential penalties for non-compliance.

Reviewing and updating existing regulations is essential to allow and properly regulate the reuse of industrial wastewater. This includes establishing clear water quality standards for different industrial uses, developing technical guidelines for the implementation of advanced treatment technologies, and ensuring that regulations are consistent and applicable across different industrial sectors.

Additionally, coordination between different regulatory agencies and levels of government is crucial to ensure consistent and effective enforcement of regulations. Creating a favourable regulatory framework may also involve simplifying administrative processes and eliminating bureaucratic barriers that could discourage industries from adopting new technologies.



Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploding your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

The CSS may be perceived as risky but viable by investors due to several factors. The need for advanced technologies and the initial costs associated with implementing sensor and AI systems may make investors cautious. Additionally, the lack of precedents or successful examples of treated industrial wastewater reuse can increase the perception of risk.

To mobilize investments, it is crucial to demonstrate the profitability and long-term viability of the system. This can be achieved through pilot studies and success stories that showcase the economic and environmental benefits. Successful pilots can serve as proof of concept and reduce the perceived risk among investors.

It is also necessary to explore and develop suitable business models for exploiting this innovation. This could include public-private partnerships, innovative financing schemes such as energy performance contracts (EPC) adapted for water management, and subscription or pay-per-use models for water treatment services.

To make the CSS more profitable or less costly, it is essential to seek efficiencies in the operation and maintenance of the system, as well as to leverage economies of scale. Seeking government funding and subsidies, as well as tax incentives, can help reduce initial costs and attract investments.



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

The Circular Water Systemic Solution (CWSS) to be deployed starts from a TRL 5 (since a similar demo plant has already been tested, but not including the AI tools to be developed) and is planned to end (at the end of the project) at a TRL 7 (a demo validated in real operating and environmental conditions).

The keys for the CWSS replication in other areas to be successful will also be analysed within the project framework, in order to provide the needed guidelines to ensure its upscaling in the future. The results from the pilot plant and the economic feasibility study will be critical in assessing the system's commercial viability. Additional development efforts are needed to optimize the technology, solve upscaling issues, and ensure the CWSS meets industry standards and needs. An investment in fixed infrastructure that allows direct interconnection between the output of the WWTP and the water consuming companies will be essential for the increase in the TRL and the definitive implementation in the market of the technology to be developed.

The current pilot aims to design and validate the wastewater treatment to enable wastewater recycling. This involves determining optimal conditions for wastewater treatment and recycling.

The demonstrator will not only test its feasibility but will provide a baseline for the application of circular strategies applicable to water. Treatment systems will be continuously monitored in order to integrate circular water systemic solutions.

By applying the principles learned in this project to different wastewaters, the circular sustainability system can contribute to reducing wastewater pollution, facilitating recycling and fostering the circular economy.

In conclusion, while the CWSS to be deployed is already technologically advanced and consolidated, and will end being tested in real conditions, future economic analysis is fundamental to its upscaling, since the investment in infrastructures are key for its deployment in different WWTP and/or industrial areas.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

*As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?***

Table 2: Synergies of Demo 1

Demo Number	Synergy envisaged
DEMO 1	One of the objectives of WP2 (in which the 4 CWSS demos are included) makes special emphasis on capturing and sharing understanding around the common and overlapping areas of the demonstrator. In this way, solving common problems throughout the project through different approaches will facilitate the success of all demonstrators, and will improve their design and deployment. A constant exchange of information and visits to the different demonstrators have been planned.
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	

DEMO 2: Urban wastewater treatment for agricultural irrigation solving safety issues.



1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

The agricultural industry and the utilities used for reclaimed urban water are located in the Podravje region (Slovenia), which covers 2,170 km² (i.e. 10.7 % of national territory) and has 330,572 inhabitants (i.e. 15.6 % of the total national population). The national annual average of supplied drinking water per inhabitant is 40.6 m³, with the Podravje region consuming less than the national average (i.e. 38.6 m³ annually). At the same time, Podravje treats 81 % of communal wastewater, which places this region above the national average of 72.1 %. At the same time, Podravje accounts for 2 % of all water used for irrigation in Slovenia, which in Podravje comes from groundwater (17.3 %), rivers and similar sources (38.7 %) and 43.8 % of other sources (accumulation, lakes and public water supply systems). At the same time, Podravje is below the national average in terms of enclosed gardening (11.5 % of the total Slovenian area), while the open areas represent 21.7 % of the Slovenian total. Based on this, there is a surplus of treated wastewater in Podravje, which can be used to increase self-sufficiency of this region, by increasing production in enclosed gardening facilities or for open-air production. Therefore, Demo 2 will determine the effects of treated wastewater use in enclosed gardening spaces in order to determine the safety of the products for human consumption, which will reduce the release of treated wastewater into the environment.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

The proposed solution is to add reverse osmosis treatment to the wastewater discharged from the communal wastewater treatment plant in Ptuj (operated by CircSyst project partner Komunalno podjetje Ptuj – KPP), thus preparing water to be used in enclosed gardening testing facilities (operated by CircSyst project partner Kmetijski inštitut Slovenije – KIS), where carrots, bell peppers, onions and strawberries will be grown. The additional treated wastewater will be used for plants irrigation in the test facilities. The tests conducted by KIS will provide data on the safety of agricultural products irrigated by treated wastewater for human consumption.



Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

Water treated in wastewater treatment plants is returned to nature after the purification process as it reaches a high enough level of cleanliness to pose no threat to the environment or human health. This water could also be used for other purposes for which clean drinking water is currently used, thereby reducing the consumption of this natural resource for which people still have little respect and awareness of its importance.

Demo 2 directly contributes to the following Green Deal objectives:

- Farm to Fork,
- Preserving and restoring ecosystems and biodiversity, and
- Zero Pollution ambition.

It is also in line with:

- the Urban Waste-water Treatment Directive (91/271/EEC), determining the minimum level of wastewater treatment before discharge.
- the Water Framework Directive (2000/60/EC), advocating the sustainable use of water resources.
- EU's 8th Environmental Action Programme aims to reduce environmental and climate pressures.

Furthermore, it contributes to the following three SDG goals:



2 Scope and Territory

2.1 The territorial context

Geographical Scope: What’s the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope?

The solution of Demo 2 will take place in the Podravje region in Slovenia, more precisely in the municipality of Ptuj. As Podravje is a CCRI pilot region, the solution is also a proposed CSS which is part of the Regional Strategy for Transition of Circular Bioeconomy, with the intention of up-scaling to other communal wastewater treatment plants in the region and potentially up-scaling to the national level.



Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

The Demo 2 will affect both sectors “A – Agriculture, forestry and fishing” (more precisely A1 - Crop and animal production, hunting and related service activities) and “E

– Water supply; sewerage; waste management and remediation activities” (more precisely *E36 Water collection, treatment and supply*).

The low use of irrigation and the low use of enclosed gardening in Podravje region hinders the self-sufficiency of the region. After testing the effects of the additional wastewater treatment before release into the environment, the additionally treated wastewater will be suitable for use in agriculture. Also, it will be a readily available resource for irrigation in enclosed and controlled environments which can ensure extensive production of agricultural products for human consumption without affecting biodiversity in pristine natural environments and at the same time preserving primary water sources.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

The Urban Waste-water Treatment Directive (91/271/EEC) is a key EU document providing standards for wastewater treatment. Demo 2 will go beyond these standards and test the quality of additionally treated water at the discharge of the wastewater treatment plant for use in the irrigation of agricultural products for direct human consumption.

Within the national context, Demo 2 follows the Slovenian Development Strategy 2030, adopted by the Government of the Republic of Slovenia in December 2017, in adapting to global trends and challenges, including the pressure on the ecosystem and competition for global resources.

Demo 2 also contributes to the CSS solution as part of the Action Plan for Regional Strategy for Transition to Circular Bioeconomy, which was adopted by the Regional Council of Podravje in December 2023 and is monitored by the CircSyst project partner Regional Development Agency for Podravje – Maribor (RDAPM).

Finally, it also contributes to the European Green Deal, managed by the European commission, especially with the following three goals: (i) Farm to Fork, (ii) Preserving and restoring ecosystems and biodiversity, and (iii) Zero Pollution ambition.



2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices

Table 3: Main Regulations Framing Demo 2

Level	Regulation	Requirements
EU	Urban Waste-water Treatment Directive	Treatment of wastewater before release into the environment – Demo 2 goes beyond the minimum required treatments to ensure the safety of agricultural products irrigated with treated wastewater to be safe for human consumption.
EU	European Green Deal	(i) Supporting self-sufficiency in food production - <i>Farm to Fork strategy</i> . (ii) Reducing discharge of treated wastewater in the environment - <i>Preserving and restoring ecosystems and biodiversity</i> . (iii) Reducing pollution of the environment through extensive open-air farming - <i>Zero Pollution ambition</i>
National	Regulation on the discharge and treatment of municipal wastewater	Treatment of wastewater before release in the environment – Demo 2 goes beyond the minimum required treatments to ensure the safety of agricultural products irrigated with treated wastewater to be safe for human consumption.
Regional	Regional Strategy for Transition to Circular Bioeconomy	Action plan for implementing circular systemic solution – <i>CSS 2: Circular greenhouse and indoor farming</i> and <i>CSS 5: Re-use of water and sludge from wastewater treatment plants</i> .

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

Demo 2 uses treated wastewater to discharge it into the natural environment. The wastewater is created from municipal wastewater and industry from the city of Ptuj. Currently, the wastewater is already treated to the tertiary treatment level and is safe for release into the natural environment. However, further testing is needed to ensure the safety of agricultural products irrigated with treated wastewater.

In addition, the wastewater is treated by reverse osmosis to ensure its quality. The values of bacteria in the water are also be monitored to ensure that the permitted levels of *E. coli* bacteria in the water are not exceeded.

Kmetijski inštitut Slovenije (KIS) owns the land adjacent to the wastewater treatment plant near Ptuj. KIS will set up the testing facilities at this location and irrigate the test fields with the additionally treated wastewater from the wastewater plant. The following culture will be irrigated with this water in a controlled environment: bell peppers, onions, carrots and strawberries.

There is already interest in the Podravje region for replicating this model in the municipality of Benedikt, where they plan to use geothermal energy for heating of enclosed gardening facilities and are interested in using treated wastewater for irrigation and humidity control in production of vegetables for human consumption.



2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

The main stakeholders come from the following spheres of the quadruple helix:

- 1) Public administration:
 - a. 41 municipalities of the Podravje region (Representatives of the Regional Council that adopted the Regional Strategy for Transition to Circular Bioeconomy;
 - b. Regional Development agency for Podravje - Maribor
- 2) Companies managing wastewater treatment plants in the region:
 - a. Komunalno podjetje Ormož d.o.o.,
 - b. Komunalno podjetje Ptuj d.d.,
 - c. Vzdrževanje in gradnje, Javno podjetje Kidričevo,
 - d. Aquasystems d.o.o.,
 - e. Komunala Slovenska Bistrica Podjetje za komunalne in druge storitve d.o.o.,
 - f. Paloma Sladkogorska, Tovarna Papirja d.d.,
 - g. Občina Rače-Fram,
 - h. Komunala Odtok, Komunalne storitve d.o.o.
- 3) Agricultural ecosystem and research actors:
 - a. Kmetijski inštitut Slovenije
 - b. Kmetijsko gozdarski zavod Ptuj
 - c. Kmetijsko gozdarski zavod Maribor



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

In agriculture, water use is a critical part of the crop production value chain. It encompasses various practices such as irrigation, soil moisture management, fertilization and water conservation techniques to ensure a sustainable and efficient use of water resources for optimal agricultural output. A consistent water supply ensures a reliable source of water for crops, especially in regions with irregular or insufficient rainfall. Proper irrigation can significantly boost crop yields and improve production quality. It helps protect crops during dry periods, reducing the risk of crop failure due to drought. Irrigation helps in the efficient application and absorption of fertilizers, leading to better nutrient availability for plants. With irrigation, farmers can grow crops outside the regular rainy season, leading to multiple harvests and better land use. Reliable irrigation systems can enhance food security and provide economic stability for farming communities by ensuring continuous agricultural production. Proper irrigation practices can help maintain soil structure and health, preventing issues like soil erosion and salinization.

The global water supply for farming is a critical issue, as agriculture is the largest consumer of freshwater resources. Agriculture accounts for about 70 % of global freshwater withdrawals and this percentage can be even higher in many developing countries. Water availability for farming varies widely across regions. Areas with abundant rainfall do not require much irrigation, while arid and semi-arid regions depend heavily on irrigation systems. In many parts of the world, intensive agricultural practices have led to significant groundwater depletion, which threatens long-term water security. Rivers, lakes, and reservoirs as primary sources of irrigation water are often subject to seasonal fluctuations and competition from other sectors. Changes in climate patterns are affecting water availability, with some regions experiencing more intense droughts and others facing increased flooding, both of which can disrupt water supplies for agriculture.

Improved irrigation techniques (e.g., drip and sprinkler systems), rainwater harvesting, and water conservation practices are essential for making the most of limited water resources. Sustainable water management in agriculture includes practices like crop selection suited to local conditions, soil moisture management, and integrated water resource management to balance agricultural needs with ecosystem preservation. Advancements in technology, such as precision agriculture, can optimize water use by providing accurate data on soil moisture, weather patterns, and crop water requirements.

Effective policies and regulations are needed to manage water resources efficiently, ensuring fair distribution and preventing overuse or contamination. Overall, managing the global



water supply for farming involves balancing the demands of agricultural production with the need to conserve water resources for future generations.

Using water from wastewater facilities in agriculture is becoming an increasingly viable and important practice. It offers a sustainable, efficient, and cost-effective way to enhance water availability, improve nutrient management, and protect environmental resources. Proper treatment and management are crucial to ensuring the safety and effectiveness of this practice.

Reclaimed wastewater provides an additional water source, reducing pressure on freshwater resources and helping to meet agricultural water demands, especially in water-scarce regions. Treated wastewater often contains nutrients like nitrogen and phosphorus, which can act as fertilizers, reducing the need for chemical fertilizers and lowering agricultural costs. Recycling wastewater reduces the discharge of pollutants into natural water bodies, protecting ecosystems and improving water quality. Utilizing wastewater for irrigation promotes sustainable water management practices by reusing water and closing the loop in water resource management. It can be more cost-effective than using freshwater sources, especially in areas where freshwater is scarce or expensive to transport. Treated wastewater can be used in various irrigation methods, including drip and sprinkler systems, enhancing water use efficiency and ensuring that water is applied directly where it is needed. Using reclaimed water can help build resilience against climate change impacts, such as droughts and variable precipitation patterns, by providing a reliable water source.

Proper treatment of wastewater to meet safety standards is crucial to prevent potential health risks associated with pathogens, heavy metals, and other contaminants. Many countries, such as Israel, Spain, and parts of the United States, have successfully implemented wastewater reuse in agriculture, demonstrating its feasibility and benefits. Educating the public and farmers about the safety and benefits of using treated wastewater is essential for widespread adoption and acceptance of this practice.

Our project specifically intervenes in the waste management phase, focusing on the treatment and valorisation of the treated wastewater from the wastewater facility. The goal is to test the feasibility of using treated water from wastewater treatment plants for irrigating agricultural land. By introducing improved methods for additional water purification, we aim to enable the use of water from wastewater treatment plants and reduce the consumption of drinking water. Additionally, we seek to determine if this water can decrease the need for nutrient supplementation during the growing season.

To achieve these objectives, we plan to develop a pilot plant at an experimental level that is comparable to real production conditions on a farmers scale. Greenhouse facility planted with selected local crops will serve as a model for further on farm-implementation, allowing us to evaluate the economic and technical feasibility of our research.

Identify where your CSS is situated and how can it change the various stages. Does



it make the value chain more circular?

Our Circular Sustainability System (CSS) is strategically located in the wastewater management of crop production value chain. This stage involves the use of treated wastewater from the Ptuj wastewater treatment plant, which purifies water for the town of Ptuj and surrounding area. Specifically, our focus is on testing the possibility of reusing treated wastewater on agricultural land for irrigation of locally important crops.

By positioning our CSS at this critical point of crop production, we aim to transform what is typically considered waste into valuable resources, thereby enhancing the overall sustainability and efficiency of the value chain.

Impact on Various Stages of the Value Chain

1. Wastewater Utilization

Current Situation: Every day, 14.000 - 20.000 m³ of water flow into the Ptuj wastewater treatment plant, where it undergoes various cleaning processes. Once the water is purified to meet the cleanliness standards, it is discharged into the Drava River. Thus, the Ptuj wastewater treatment plant processes 16.000 m³ of water daily, which is then released into the Drava River with no further use.

CSS Intervention: Our CSS introduces innovative treatment technologies that convert wastewater into valuable source. This intervention could allow further utilization wastewater, minimizing its outflow and maximizing resource recovery. By reusing wastewater, we reduce the consumption of drinking water for the purpose of irrigating agricultural land, possibly reduce the use of fertilizers and ultimately, we produce food for the end consumer.

2. Production Process Optimization

Current Situation: The amount of water used for irrigating agricultural fields annually varies widely depending on the region, crop type, climate, and irrigation practices. In Europe, water use for agriculture also varies significantly. For example, in the European Union, irrigation accounts for around 20 % of total water abstraction.

In areas where water is limited, they face a shortage of water for irrigation every year, making food production impossible during certain times of the year. This often results in higher prices for agricultural products, lower quality of food on store shelves, reduced variety, and generally lower consumption of fruits and vegetables.

CSS Intervention: By integrating our CSS into the production process, we



encourage farmers to adopt a more holistic approach to resource management. Our system addresses waste reduction and optimizes the use of fertilizers, allowing producers to use less fertilizers and therefore generate additional revenue streams from by-products. The possibility to reuse water would encourage producers to re-evaluate their production practices, leading to more efficient operations and a shift towards sustainable practices.

3. Waste Management and Valorisation

Current Situation: Producers in Slovenia usually rely on water from municipal water supply or from wells. They often do not think about the waste management of the water they use for irrigation.

CSS Intervention: Our CSS revolutionizes waste management by using it for various purposes. If we could achieve to clean the water in a way that it would be useful not only for irrigation but also for cleaning (crops, product, packaging, applying fertilizer, pest protection products), this transformation enormously reduces the environmental footprint of crop production and provides technology with sustainable alternatives. By adopting our system, producers can transition from a linear waste management model to a circular one, where by-products are consistently reintegrated into the value chain.

Does the CSS Make the Value Chain More Circular?

Yes, our CSS significantly enhances the circularity of the crop production value chain. By transforming wastewater into valuable resources, our system creates a closed-loop process where waste is minimized, and resources are continually reused. This approach aligns with the principles of a circular economy, where the emphasis is on sustainable resource management and waste minimization.

Our CSS strategically positions itself within the crop production value chain to address and transform wastewater management practices. By increasing circularity through resource efficiency, waste reduction, and value creation, our system not only improves the sustainability of crop production with a reliable water source, but also sets a present pilot for other sectors to follow. The adoption of our CSS will lead to a more sustainable, economically viable, and environmentally friendly crop production, in line with global efforts to promote circular economy practices.



3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

The shift towards a Circular Sustainability System (CSS) in crop production significantly impacts key stakeholders, particularly focusing on the producers that have production areas near the wastewater treatment plant. Our stakeholders are also the government policy makers. In Slovenia, we still need to establish legislation for the reuse of treated water from wastewater treatment plants. Government decision-makers require strong and reliable studies to provide clear insights into all the impacts of such a circular economy. Another important stakeholder is also every wastewater treatment plant in the country, which processes large quantities of water daily from major cities and industrial centres. With advanced water treatment technology and ensured use of treated water for agricultural purposes, wastewater treatment plants could adopt such technology as part of their business models. These stakeholders play crucial roles in transitioning from a linear waste management model to a more circular and sustainable approach.

Please characterise the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

The demonstrator project for the Circular Sustainability System (CSS) involves several key stakeholders, each contributing to and benefiting from the initiative to revalorize wastewater. The primary actors include government, producers and wastewater treatment plants. Each has a distinct role and set of expectations from this project.

Wastewater treatment plants, as the waste management operator, is focused on utilizing the pilot technology to maximize the value of wastewater in agricultural purposes. Their interest lies in transforming this waste into valuable products, which can be sold to various end users. This shift involves integrating new technologies and processes but offers significant economic benefits by creating new revenue streams. They aim to convert wastewater from a waste disposal cost into a valuable asset. They expect that successful implementation will prove the process's viability and scalability, solidifying their role in the circular economy. Agricultural institute of Slovenia (KIS) as a link between research institutions and producers, and producers themselves are interested in reducing the environmental impact of their water resources. KIS has great interest in advancing research and demonstrating the practical applications of their pilot in sustainable



waste management. By participating in the CSS project, they aim to be able to use this waste disposal into a valuable asset with an additional value - fertilizer. This initiative is expected to improve their water supply and reduce the fertilization costs. They anticipate that the demonstrator will validate the economic and environmental benefits of a circular approach to waste management, encouraging broader adoption of such practices across the country.

The government role is essential to the project through its development of the pilot wastewater reuse technology. The pilot plant serves as a proof of concept for this kind of reuse of wastewater in agricultural purposes. They expect the demonstrator to validate their technology's scalability and impact, showcasing its potential for broader application for other wastewater treatment plants.

In summary, the demonstrator project brings together wastewater treatment plants in Slovenia, Agricultural institute of Slovenia, crop producers and government. Together, they anticipate that the demonstrator will validate the circular economy approach, demonstrating its benefits and paving the way for sustainable water management practices within the crop production and beyond.

3.3 The solution in the value chain

Describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction between actors? How does it affect material flows?

The presented solution is a circular sustainable system (CSS), which converts wastewater from the Ptuj sewage treatment plant back into a high-quality and safe water source for agricultural irrigation through a special filtering system. This practice moves from the traditional linear approach to wastewater management to a circular model where wastewater is reused for irrigation in agriculture.

This system changes the interaction between stakeholders by creating a framework for cooperation. Komunala Ptuj integrates the technology of an additional filtration system into its water treatment plant, so that instead of draining it into the Drava River, some of it is diverted into a system for irrigating various crops in the greenhouses of the Agricultural Institute of Slovenia (KIS). KIS will monitor and evaluate the growth of the plants and, in cooperation with other institutions, analyse their safety for consumers. RRA Podravje, with the help of other partners, will inform and raise awareness among interested groups about the use of purified water for irrigation in agriculture in case of favourable results.



Wastewater also contains several non-renewable nutrients such as phosphorus and potassium. By using this water to irrigate plants, we reduce the need for additional fertilization and thus have a sustainable impact on primary resources (nutrients and water) in nature. This ensures a circular system.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

The current solution for handling wastewater from municipal sewage treatment plants in Slovenia is to discharge the water into rivers and streams. This results in the loss of a potential source of irrigation water during dry periods when the need for irrigation water is high.

In contrast, the Circular Sustainability System (CSS) offers a sustainable approach. This process not only reduces the load on primary water resources but also reduces the need to fertilize with non-renewable nutrients.

We will focus on the removal of heavy metals and other pollutants (e.g., medicines, pesticides) that can represent an obstacle in the use of treated wastewater.

Enhancements offered by CSS:

- Improved use of resources: CSS enables reuse of water and naturally renewable nutrients.
- Economic benefits: CSS reduces the need to fertilize plants, which means savings for growers on fertilizing with mineral fertilizers.
- Support for a circular economy: CSS is aligned with the principles of a circular economy by reducing dependence on primary water sources during dry periods. Current solutions typically follow a linear model where treated water flows from a municipal treatment plant into rivers and streams.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

The Circular Sustainability System (CSS) is particularly suitable for solving the challenges associated with handling treated wastewater from municipal wastewater treatment plants. In a context where efficient wastewater management and environmental impact reduction are key priorities, CSS offers a solution with additional wastewater treatment that can be an important water source for irrigation in agriculture.

The main advantage of CSS is its ability to reduce the load on primary water



sources, especially during dry periods.

CSS is also known for its alignment with circular economy principles. Unlike linear wastewater management methods that simply flow into rivers without considering its potential for reuse, CSS keeps water within the economic cycle and reduces the need for primary water resources. This integration of additional wastewater treatment contributes to a more sustainable and circular economy.

In summary, CSS is well suited to the challenge of managing treated wastewater from municipal wastewater treatment plants by transforming wastewater into a valuable source of water and nutrients for irrigation in agriculture. It offers a superstructure of existing wastewater management solutions with the principles of a circular economy.

3.5 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

A circular sustainability system (CSS) is designed to achieve a range of objectives in social, ecological and economic dimensions. From a social perspective, CSS aims to increase community participation and awareness of sustainable practices in the use of irrigation water. By involving local communities, CSS aims to promote greater commitment to sustainability.

From an ecological perspective, CSS aims to significantly reduce the dependence of agricultural irrigation on primary water sources.

From an economic perspective, CSS aims to create new revenue streams for municipal wastewater treatment plants by converting wastewater into an important source of water for irrigation. It will provide agricultural producers with constant production and less dependence on primary water sources. Thereby driving economic growth and supporting circular economy principles.

The demonstrator is expected to have several positive social impacts, including increasing community awareness of sustainable wastewater management practices, which will not be easy given public concerns about the use of treated water for irrigation in agricultural. From an ecological point of view, CSS offers an improvement in the efficiency of water resources.

Economically, CSS provides benefits by creating new revenue streams for the wastewater treatment system. Despite the advantages, the initial installation and operating costs of a pilot plant can present short-term financial challenges.



In conclusion, CSS is well positioned to achieve its social, ecological, and economic goals through effective municipal wastewater revalorization and sustainable practices.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

To effectively gauge the success of the Circular Sustainability System (CSS) pilot demonstration, a range of Key Performance Indicators (KPIs) is essential, addressing environmental, societal, and economic aspects.

From an environmental perspective, the increase in the use of treated water from municipal wastewater treatment plants for irrigation purposes is crucial. This indicator helps to assess how effectively CSS reduces the amount of irrigation water used from primary water sources. In addition, the efficiency of the use of purified water measures the amount of non-renewable natural nutrients that the plants receive from the use of this water for irrigation, which indicates a better environmental efficiency.

In terms of social impact, the level of community involvement and awareness is a key KPI that measures the extent of local awareness and involvement in CSS through surveys and feedback. This reflects the system's success in fostering community support. Community support is key in reducing people's concerns about using treated wastewater for agricultural irrigation.

From an economic point of view, revenue from the sale of purified water can provide an additional source of income for municipal water treatment plants, while for the farmer a stable and environmentally efficient source of water means consistent production and thus a guaranteed cash flow.



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

NO

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

NO

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

Since it is an economically low-profit activity, it would be reasonable to consider the introduction of financial incentives for the construction of filtration and distribution systems at larger water treatment plants near the fields for irrigation.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

The current basic legislative framework regarding the quality of treated wastewater for irrigation is set by the Regulation of the European Parliament on minimum requirements for water reuse (EU 2020/741).

The research findings of this project may help policy makers to adopt national legislation for the use of treated water for irrigation in agriculture.

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

A certain risk definitely exists, as the filtration system is quite expensive as well as distribution system from wastewater treatment plant to growers fields. A critical mass of growers must be reached to use purified water.

One way to make our CSS less costly is described under "Policy barriers"

5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

The market for agricultural products already exists, so it is expected that replication of the methods used for the demonstration site will not be a problem. There is already interest to replicate the agricultural production using treated wastewater in another municipality in the region.

Before the replication, it is necessary to test the safety of agricultural products irrigated with treated wastewater for human consumption, which is part of the Demo2.

Once the conditions for ensuring the safety for human consumption are established and confirmed, no further research is needed and the solution is ready for replication or up-scaling.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?**

Table 4: Synergies of Demo 2

Demo Number	Synergy envisaged
DEMO 1	As the quantities of discharged wastewater from the treatment plants are higher than the expected demand of water for irrigation, other possible use determined in DEMO 1 would be of interest if such use could also be applied in the Podravje region.
DEMO 2	
DEMO 3	Demo 3 is also using Reverse Osmosis for water treatment, therefore there is opportunity for comparing data on treatment of different quality of water.
DEMO 4	The water quality results of stored treated wastewater can help set up storage facilities for treated wastewater, as the demand for irrigation is not constant throughout the year.
DEMO 5	
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	

DEMO 3: Addressing the seasonal water demand variability involving nature-based solutions.



1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

Koksijde is a small city located in the coast region of Belgium, in which the intermunicipal water company, Aquaduin, serves about 62,000 people living permanently in the distribution area. However, water supply becomes challenging during summer due to a massive increase in the population due to tourism, causing a big difference between the minimal and maximum daily demand. The existing installation of Aquaduin (WPC Torreele) treats domestic wastewater effluent from the wastewater treatment plant of Wulpen, operated by Aquafin. The treatment consists of a pre-screen followed by ultrafiltration (UF) as pretreatment for reverse osmosis (RO). The current recovery ratio of this set up is 70%. The filtrate of the RO is infiltrated in a dune aquifer, which is in turn is used as source for drinking water production. The dune aquifer serves as a buffer in time to match the seasonal variability of demand and supply, but also offers an additional safety barrier.

The concentrate of the RO membrane filtration step was originally discharged in a nearby canal. To minimize the environmental impact and treat this concentrate stream before this discharge, a 0.8-ha horizontal subsurface flow (HSSF) constructed wetland, designated as willow field, was built in the FRESH4Cs project (Interreg 2 Seas program, 2014-2020, co-funded by the European Regional Development Fund under subsidy contract No 2S06-028). The existing willow field has a gravel substrate and a fraction of <10% was constructed with wood chips (not mixed with gravel), with focus on removal of nutrients, nitrogen and phosphorus, as well as residual heavy metals (Zinc). This project was dedicated mainly to the building the infrastructure, lacking means and time for an in-depth evaluation of the constructed wetland performance.

Wetlands are widely used for applications in treatment of domestic wastewater, agricultural effluents, drainage waters, and industrial effluents. The use of wetlands for concentrate management has only recently been proposed (Scholes et al., 2021). The site under study in this project is reportedly one of the few cases where this has been tested on reverse osmosis concentrates from domestic wastewater. The available literature on reverse osmosis concentrates treatment in wetlands is limited, and the present case remains largely unique. Nonetheless, some parallels can be drawn with the use of wetlands for the post treatment of conventional activated sludge (CAS) effluents. Toet et al. (2005) carried out a polishing treatment of a CAS using a wetland, in which they observe an increase in the COD in the effluent and could show that the composition of the COD changed from the influent of the wetland to the effluent. They did also observe a good denitrification of 60% of the influent



that mainly occurred on the front section of the wetland (due to high nitrate loading rates, large substrate area for periphyton and associated microbial communities, and low oxygen concentrations during the growing season). They also observed that biomass harvesting (*Phragmites australis* or *Typha latifolia*) contributed only 2–3% to the total N removal in the ditches, whereas sedimentation and adsorption contributed to 7%. Chakraborti and Bays (2020) also found good N removal of wetlands from RO concentrates, although, on the contrary to the studied case at Aquaduin, their effluent contains a lot of NH₃-N (i.e. 121 mg/L). Thus, their influent seems to be not comparable to the influent for the present case. Improved treatment of the concentrates in the wetland will likely also increase the opportunity to recover water from the treated concentrates. A novel technology that is available is direct nanofiltration (hollow fibre nanofiltration), which has the advantage of handle feed streams with much higher levels of suspended solids than spiral wound nanofiltration and reverse osmosis, matching or even surpassing ultrafiltration (UF) membranes. Thus, it reduces the pretreatment requirements and energy requirements compared to these technologies, and should hence be easily integrated into existing technology trains.

Finally, successful operation of the water UF-RO water recovery system relies on an adequate treatment of the incoming wastewater by the wastewater treatment company (i.e. Aquafin). Rain events in the catchment can severely affect that treatment performance of the wastewater treatment plant through dilution and, more importantly, by passes or overflows during large storm events. Therefore, there is an interest to create catchments that act as sponge, by draining the water slowing to the wastewater treatment. A novel concept is to use existing pipes, pump storage reservoirs or small rainwater storage basins to detain the rainwater in the catchment. These systems will however only effectively work when they are ‘smartly’ managed. These systems work based on predictive algorithms that allow a filling and drainage of the buffers in accordance with expected rain events in combination with the situation downstream (e.g. at the wastewater treatment site, demand of the customer).

The objectives of the demo research carried out in CircSyst are therefore two-fold:

- **Increase water recovery:** Improve the removal of nitrogen, phosphorus, and COD to reduce the impact of the discharge into the environment and lower the levies to be paid by Aquaduin. Provide an influent to a membrane filtration unit that will maximize the recovery of water, leading to an overall increased water recovery ratio of the UF-RO unit.
- **Increased water reuse:** Model the effect of combination of smart water buffering systems of sewer overflows and performance of the wastewater treatment installation.



2 Scope and Territory

2.1 The territorial context

Geographical Scope:

Aquaduïn, formerly known as Intermunicipal Water Company of Veurne-Ambacht (IWVA), is responsible for the distribution of drinking water in the western part of the Flemish coastal plain. The distribution pattern is mainly related to tourism seasonality: on a daily basis the water demand in summer doubles compared to that of winter.

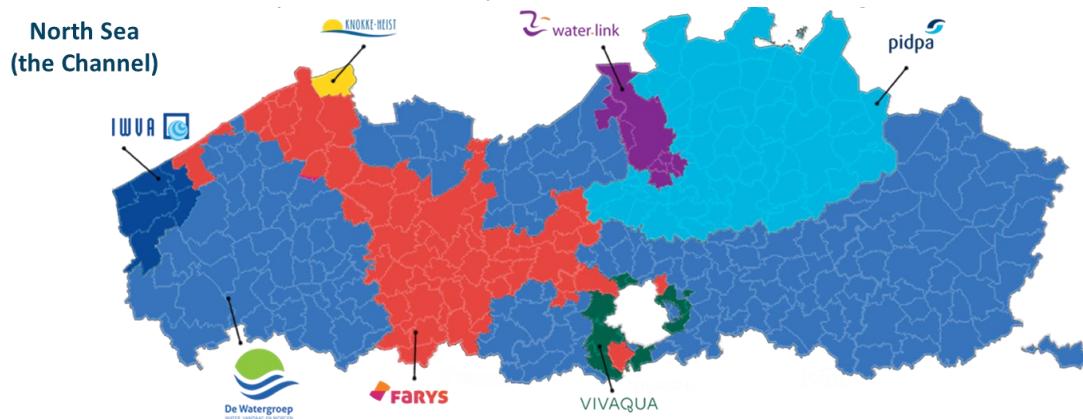


Figure 3: Water companies in Flanders.

Historically, Aquaduïn produced drinking water out of the dunes. Under the dunes, a freshwater lens is formed by infiltrating rainwater. In natural conditions, groundwater flows from the dunes towards the polder area (south of the dunes) and the seaside (north of the dunes), preventing intrusion of saline water (¡Error! No se encuentra el origen de la referencia.2).

To obtain sustainable groundwater management and thus keep the natural flow, in 2002, Aquaduïn implemented the reuse of local treated wastewater of the Wastewater Treatment Plan (WWTP) Wulpen (Aquafin, 2) and infiltration in the existing dune water catchment of St-André. This enabled Aquaduïn to keep its existing infrastructure for treatment of dune water, which is based on aeration and sand filtration.

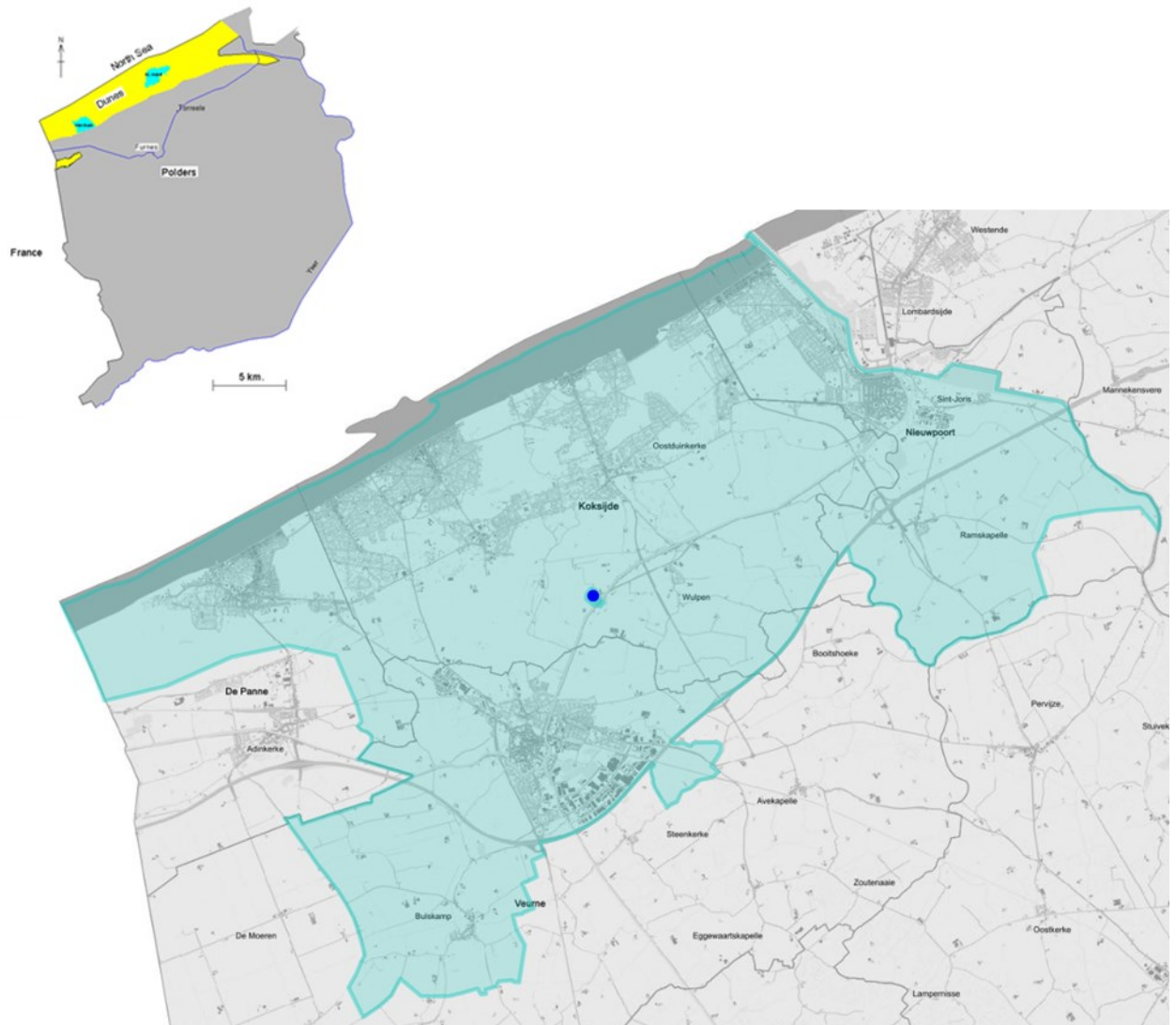


Figure 4: Top left: water supply area of the IWWA and Dune aquifer. Bottom: Treatment area (in light blue) of the wastewater treatment plant Wulpen (dark blue dot) of Aquafin near the Belgian municipality Koksijde.

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

The water and wastewater treatment sectors are affected by the project innovations.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations)? Please, list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

The key drivers for the development of Aquaduin’s indirect potable water reuse operations is a regional water shortage due to the small coastal aquifer that is surrounded by salt and brackish water. More recently, in 2020, the Flemish Blue Deal was launched by the Flemish regional government that contains more than 70 ambitious actions to structurally tackle drought and water scarcity. Such priority is areas for action include ‘circular water’ or, in other words, the recovery and reuse of water as well as increased water efficiency. Over the course of the legislative period, more than 500 million euro have been invested in these and other actions.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices.

Table 5: Policies that acted as a driver for this Project.

Level	Regulation	Requirements
EU		
National		
Regional	Flemish Blue Deal – it is not a regulation but a program of specific actions.	Water efficiency and water recovery
Regional	Drinking-water permits are regional matter	Infiltration water has to meet drinking-water standards except for nitrate, nitrite, ammonia and phosphor. Separate discharge parameters for WPC Torreele.
Sectorial		

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

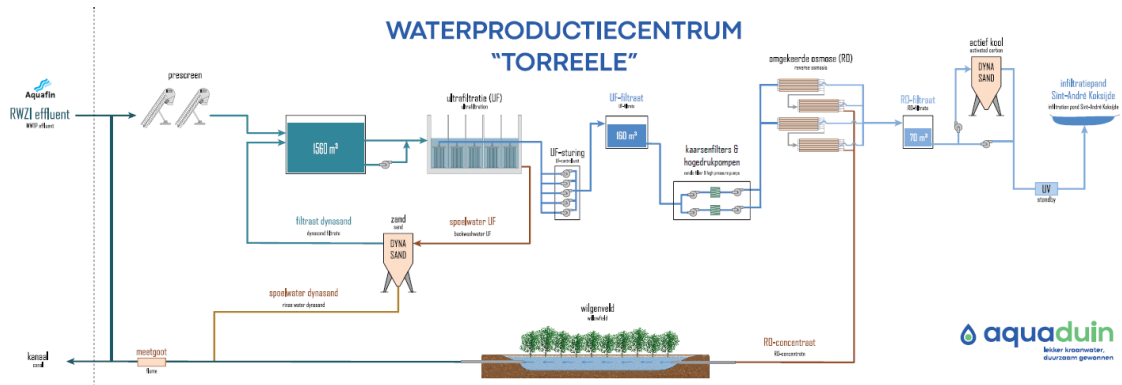


Figure 5: Treatment scheme of the water production system of Aquaduin (called WPC Torreele)

The water production system at Aquaduin (called Torreele) operates on incoming treated effluent from the domestic wastewater treatment plant ‘Wulpen’ of Aquafin, which has a capacity of 105,144 m³/day and is treating the wastewater of an agglomeration with the size of 95,700 PE (population equivalent) (Figure 4). The treatment area of this facility is shown in **¡Error! No se encuentra el origen de la referencia.2**. In practice, the incoming wastewater flow can vary a lot due to rain events and coastal tourism, with an average of 21,200 m³/day, a minimum of 2,700 m³/day and a maximum of 103,500 m³/day (data of 2020-2023).

The current production capacity of Aquaduin water treatment installation amounts 2.4 million m³/year, whereas the permitted volume corresponds to 2.9 m³/year with an extra groundwater extraction capacity of 1.5 million m³/year.

Over the past 5 years (2019-2023) 2.32 million m³/year was infiltrated. With an average intake of effluent of 3,21 million m³/year WPC Torreele reaches a recovery of 72,3%. This means that on average 0.9 million m³/year is discharged of which 74,5% is RO-concentrate. Since 2022 almost all RO-concentrate has been treated by the NBS willow-field.

In 2019, a year with an average annual rainfall, Aquaduin took 50% of the total amount of effluent Aquafin produced. This amount will vary according to meteorological circumstances. To produce infiltration water chemicals are needed in the process, mostly to avoid biofouling and scaling. In the period 2019-2023 on average yearly 288.8 tons were used, 60.3% being sulphuric acid and 32.6% sodiumhypochlorite.

Since the combination of water reuse and managed aquifer recharge started (2002) the extraction of natural groundwater substantially lowered (44% or 1.2 million m³ year⁻¹ in the 2 existing dune water catchments St-André and Westhoek).

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

The key stakeholders with an interest are:

Table 6: Stakeholders in Demo 3

	Aquaduin	AquaFin	Civil society
Increased water recovery and reuse	Cost savings in higher process efficiencies	Higher treatment efficiencies of the STP and fewer sewer overflows	Improved water quality due to lower amounts for combined overflows and better discharge quality Potential reduction of water price for Aquaduin's users
Improved concentrate treatment	Cost savings in discharge levies (e.g., lower nutrient levels for improved removal efficiencies in willow field) Social responsibility toward environment		Improved water quality in the canal that discharges to the sea and overall environmental quality of the surroundings
Harvest biomass from willow field	Potential use of the willow biomass for agricultural uses, water treatment (e.g. as biochar) or construction (willows as a protection to erosion)		
	Aquaduin	AquaFin	Civil society
Increased water recovery and reuse	Cost savings in higher process efficiencies	Higher treatment efficiencies of the STP and fewer sewer overflows	Improved water quality due to lower amounts for combined overflows and better discharge quality Potential reduction of water price for Aquaduin's users

3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

The value chain under study is the flow of water from the water user to wastewater treatment and then to recovery of water for potable use. The key challenge in this value chain is the management of the concentrate that comes from the reverse osmosis filtration step. Through studying improvement option of the existing wetland that is currently treating the concentrate, the project will: I) reduce the environmental burdens for the discharge of the concentrates; II) potentially increase the water recovery when the effluent is coupled to a novel direct nanofiltration technology.

The options of smart buffering within the RWZI Wulpen catchment will be investigated in silico. This modelling will highlight options for reduction of sewer overflows and a more homogeneous influent to the wastewater treatment, which will improve treatment performance and, hence, effluent quality and potable water recovery via the UF-RO installation.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

Please characterise the main actors and their interests in the demonstrator. How are they affected.

What are their expectations.

See section 2.5

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

No change in the interaction between stakeholders compared to the current state is expected.



3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

Currently there is no solution to the treatment of reverse osmosis concentrates. A more dedicated design proposal of the wetland has the potential to further improve the efficiency of the current wetland, mainly in terms of removal of nutrients, which for example for N has an efficiency of about 30% and a negligible efficiency for P removal.

The smart buffering solution is a novel concept that relies on digital technologies and existing infrastructure. Alternative solutions for buffering would rather require infrastructural investment, which is not desired.

3.4 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

The KPIs for the demo are the following:

- The target is to improve the potable water recovery from currently 70% to 80%.
- The target is to improve the removal capacity for N and P in the wetland from 30% to 50% (N) and from nearly 0% to 25% (P).
- The target is to find economic practice for the harvest of willow biomass and processing to wood chips.
- The target is to half the incidence of overflows in the catchment.



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

N/A

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

The performance of the technologies (direct nanofiltration, constructed wetland) in the specific context of reverse osmosis concentrate treatment is not known and needs to be investigated. The concept of smart buffering is novel and novel algorithms and concepts need to be developed first.

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

N/A

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

N/A

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

N/A



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?
Post project further technology development will be required.

Currently no aims nor goals defined



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

*As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?***

Table 7: Synergies of Demo 3

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	

None identified at this stage

7 References

- Chakraborti, R.K. and Bays, J.S. 2020. Natural Treatment of High-Strength Reverse Osmosis Concentrate by Constructed Wetlands for Reclaimed Water Use. *Water* 12(1), 158.10.3390/w12010158
- Scholes, R.C., Stiegler, A.N., Anderson, C.M. and Sedlak, D.L. 2021. Enabling Water Reuse by Treatment of Reverse Osmosis Concentrate: The Promise of Constructed Wetlands. *ACS Environmental Au* 1(1), 7-17.10.1021/acsenvironau.1c00013
- Toet, S., Van Logtestijn, R.S.P., Schreijer, M., Kampf, R. and Verhoeven, J.T.A. 2005. The functioning of a wetland system used for polishing effluent from a sewage treatment plant. *Ecological Engineering* 25(1), 101-124.<https://doi.org/10.1016/j.ecoleng.2005.03.004>



DEMO 4:

Water Flows modelling as a decision-support tool in water symbiosis.



1. The idea in brief

The Swedish demonstration project will consist of a symbiosis between several industrial actors in the municipality of Visby, Sweden.

Within Visby, drinking water that is used by both the local population and industry is mainly sourced from limited groundwater reservoirs. This poses a risk of water shortage during summer months due to both the impact of climate change and increased tourism in this period (Nicolaidis Lindqvist et al. 2021; Nicolaidis Lindqvist et al. 2022). Given this, and despite efforts to reduce water consumption, it is difficult for the municipality to support expansion of existing industries, attract new businesses, and increase residents and tourism.

Several potential water symbiosis scenarios have already been identified between industrial actors in the area to reduce overall freshwater consumption and subsequently reduce the risk of water shortage. Further development and implementation of these scenarios, however, is limited by several factors such as a lack of:

- Technoeconomic assessment tools for assessing symbiosis options that consider flow variations between actors, water quality, resource demands, storage requirements and costs.
- Techniques to address problems around long term governance and ownership, shared costs, and economic risks.
- Techniques for developing symbiosis configurations where microbiological safe water-buffering equipment is needed to overcome time differences in water availability for reuse and demand for water of reuse quality.
- Techniques for developing cost-efficient and microbiological safe distribution-handling-solutions that could handle different water qualities.

This project will demonstrate a set of integrated tools and methodologies that can be used to address these current limitations in establishing water symbiosis networks. These integrated tools will centre around dynamic modelling and simulation of water flows at company up to municipal/regional scale, coupled to the application of dynamic marginal cost curves (dynamic MCC) that allow actors to search for and test different water symbiosis configurations within a cluster. Water safety aspects will also be captured through pilots for testing storage of water of different qualities. This will be used to form the basis of industry guidelines as well as being integrated into the decision support tool.



2 Scope and Territory

2.1 The territorial context

The demonstration area will be in Visby on the island of Gotland, Sweden. The nature of the toolbox being developed allows for expansions to a regional, national and international scope where necessary, but the local scope is prioritised. Successful demonstration would allow for applications of this approach for decision support in other local areas or regions. The sectorial scope is both industrial and residential water users (via municipalities). The work on microbial risks for storing water of different water qualities can be applied to dairy industry generally and with adjustment to other industries or users.

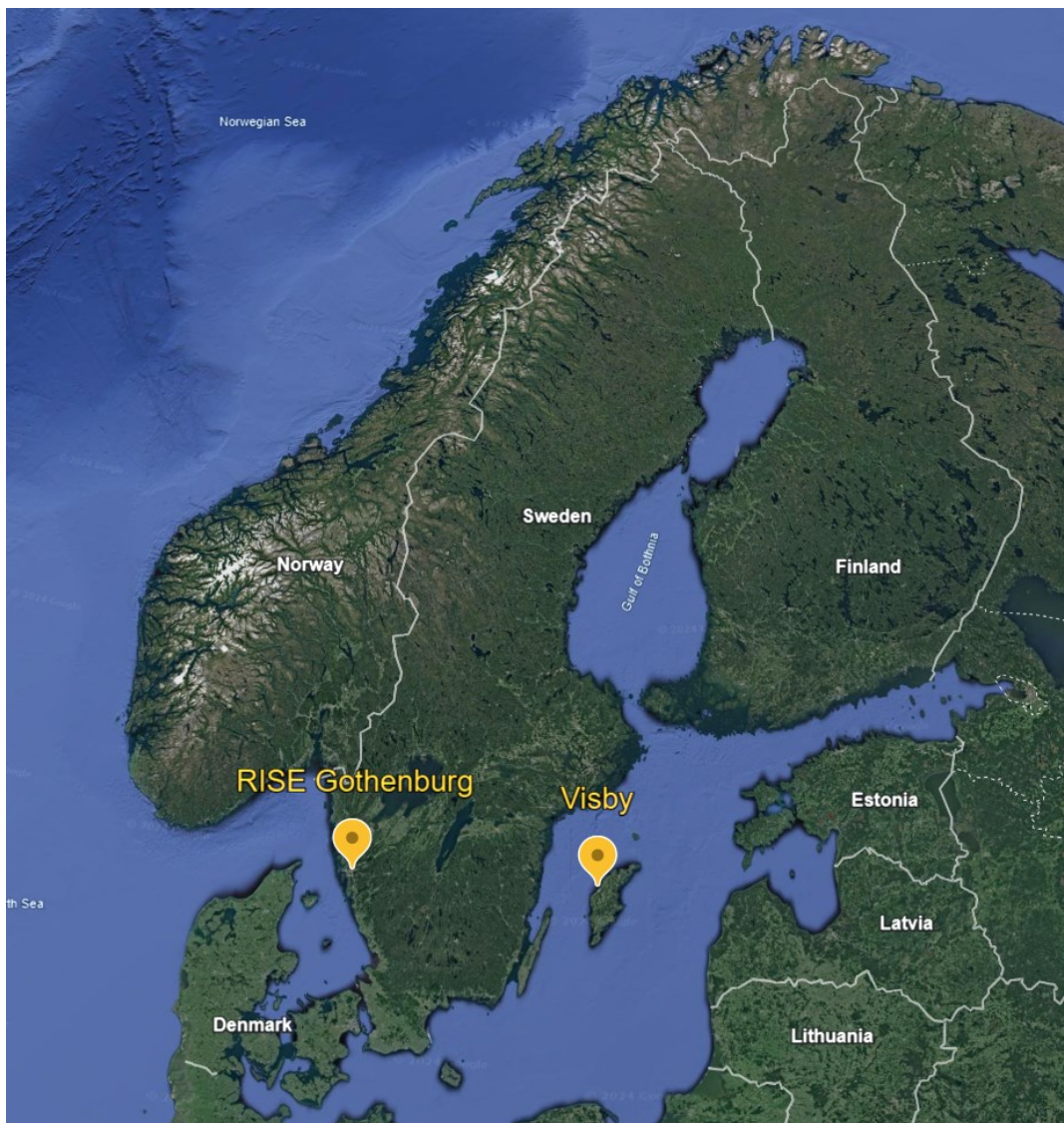


Figure 6 Map of Sweden showing the Demo 4 test case (Visby) and location of the biological risk testing pilot (Gothenburg). Google Earth data attribution: Google Landsat / Copernicus Data SIO, NOAA, U.S. Navy, NGA, GEBCO/BCAO GeoBase-DE/BKG (©2009)

2.2 The territorial policy framework

[Sweden's Climate Act and Climate Policy Framework \(naturvardsverket.se\)](https://naturvardsverket.se)

[Swedish environmental objectives \(naturvardsverket.se\)](https://naturvardsverket.se)

Region Gotland: Mål 8 Tillgången till vatten av god kvalitet är långsiktigt säkrad

P62 [Årsredovisning 2023 \(gotland.se\)](https://gotland.se)

Sector guidelines in the dairy industry

2.3 Territorial Regulatory Framework

Level	Regulation	Requirements
EU	Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste (Text with EEA relevance)	Defines requirements for industries to reduce and reuse water as per that industries Best Available Technology (BAT) conclusions.
EU	Commission Implementing Decision (EU) 2019/2031 of 12 November 2019 establishing best available techniques (BAT) conclusions for the food, drink and milk industries, under Directive 2010/75/EU of the European Parliament and of the Council (notified under document C(2019) 7989)	Best Available Techniques (BAT) for food, drink and dairy industries. Captures water efficiency and reuse.
EU	Commission Implementing Decision (EU) 2023/2749 of 11 December 2023 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions, for slaughterhouses, animal by-products and/or edible co-products industries (notified under document C(2023) 8434)	Best Available Techniques (BAT) for slaughterhouses, animal by-products and/or edible co-products industries. Captures water efficiency and reuse.
National	LIVSFS 2022:12 The Swedish Food Agency's regulations on drinking water In Swedish: Lag (2006:412) om allmänna vattentjänster	Laws related to the supply of drinking water and wastewater handling in Sweden. Includes responsibilities of stakeholders such as the municipality. Establishes rules

		around costs and profits in supply of water.
National	Act (2006:412) on public water services In Swedish: Lag (2006:412) om allmänna vattentjänster	Laws related to the supply of drinking water and wastewater handling in Sweden. Includes responsibilities of stakeholders such as the municipality. Establishes rules around costs and profits in supply of water.
Regional	Constitution collection for Region Gotland: VA tariff for Region Gotland's public water and sewage plant In Swedish: Författningssamling för Region Gotland: VA-taxa för Region Gotlands allmänna vatten- och avloppsanläggning	Regional rules for charging for water use and wastewater treatment. Based on Act 2006:412.
Regional	Guidelines for discharge of waste water from industry and other activities. Document: STY-19312 v 6.0. In Swedish: Riktlinjer för utsläpp av avloppsvatten från industri och annan verksamhet.	Regional guidelines for industrial wastewater discharged into the municipal wastewater system.
Sectorial	ISO 22447:2019 Industrial wastewater classification	ISO Standards related to water and water reuse in various contexts.
	ISO 22449-1:2020 Use of reclaimed water in cooling systems	
	ISO 23043:2021 Evaluation methods for industrial wastewater treatment reuse processes	
	ISO 23044:2020 Guidelines for softening and desalination of industrial water for reuse	
	SS-EN 16941-1:2018 Systems for the use of rainwater	
	SS-EN 16941-2:2021 Non-potable water systems pt 2 use of treated greywater	
	ISO 22524:2020 Pilot plan for industrial wastewater treatment with the objective of reuse	



2.4 The territorial metabolism

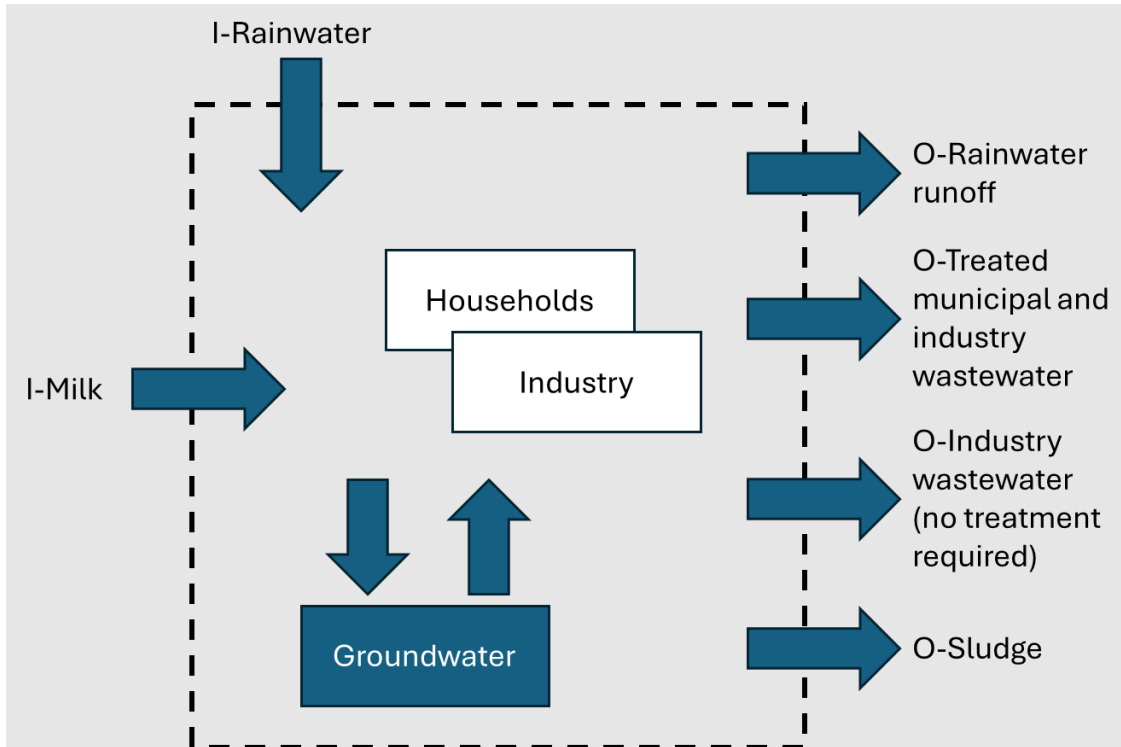


Figure 7 Territorial metabolism for water in Visby. I are inflows, O are outflows. Volumes are to be quantified in the project.

2.5 The territorial stakeholders

Public administration

Region Gotland (Municipality) is the key stakeholder as the owner of the water infrastructure in Visby and the responsible party for providing drinking water to residents. Given this, Region Gotland has a large influence on shaping the requirements from the demo tools. The region drives awareness activities about the water situation on the island.

Industry and business

There are numerous industries that rely on the availability of drinking water for their continued operation in Visby. Three key stakeholders in this project are Arla Foods AB (Dairy), Protos AB (Food) and GotlandsHem AB (Housing). As users they influence decisions around water quality requirements and also set the level of risk tolerance both with respect to water safety and business aspects.

Civil society

The limited availability of groundwater in the region affects the local population both through the risks associated with water scarcity and the inability for expansions and growth.

Academia, RTOs and NGOs

RISE, as Sweden's state owned research institute, has a strong interest in developing techniques to foster water stewardship in Swedish society and industry. Projects such as this one allow for the development of learnings that RISE can then transfer to other locations in Sweden. Tillväxt Gotland as an NGO supporting the growth of businesses at Gotland.



3 The Circular Systemic Solution

3.1 The intervention in a value chain

The Demo 4 CSS is concerned with decision support around water reduction and reuse. Given the nature of this the approach, all aspects of the value chain tied to water use are important to capture. For example; the source, uses, recirculation and final discharge of wastewaters.

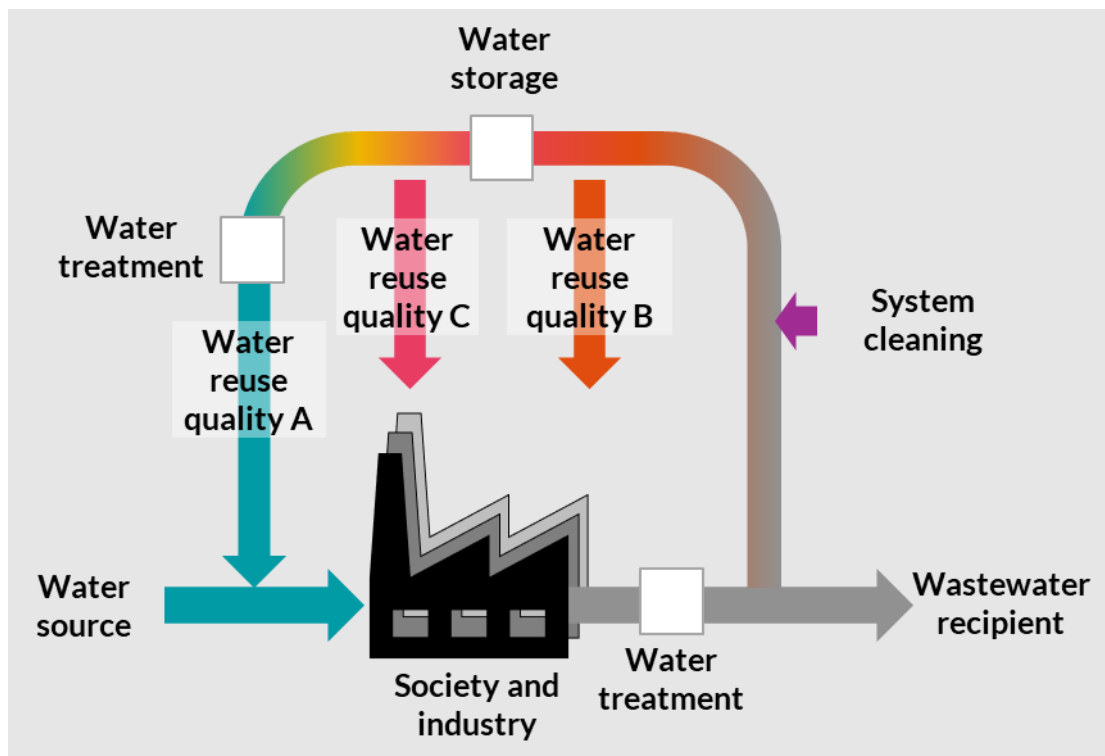


Figure 8 Water value chain with implementation of water reuse.

3.2 Value Chain Overview and Stakeholders' Identification

All actors along the water value chain are impacted. Namely the municipality who produces drinking water, the residents and industry that use the water, and finally the municipality again who treats wastewater to a quality acceptable for discharge. All stakeholders are particularly concerned with how water reuse and symbiosis impact:

- Cost aspects such as who pays for both upfront and ongoing costs
- Responsibility for safety considering that drinking water and the food industry are involved in the project

3.3 The solution in the value chain

The solution proposed will offer a way for stakeholders to come together and evaluate different options for water reuse in an area. Through the tools developed stakeholders will better be able to assess cost and risk aspects over the long-term including issues such as structural changes in the actors in the symbiosis, changes in regulation, and climate impacts.

3.4 The Value of your solution

Many solutions to water reuse focus on the technical aspects only and do not consider aspects such as safety risks, risk perceptions or long-term governance. The CSS proposed will evaluate such aspects to help actors make decisions beyond technical aspects alone.



4 Potential Barriers and Risks

Technological barriers

No.

Knowledge barriers

No.

Policy barriers

As the involved partners are in the food industry and housing there are risk related to water safety. This CSS will develop tools and approaches to rectify this.

Nonetheless there is a risk that even with decision support actors may see implementation too risk. This could occur, for example, if there is low trust in the tool. The project will seek to create guidelines for food industry around water reuse in an attempt to reduce policy risk.

Regulatory Barriers

Act (2006:412) on public water services (In Swedish: Lag (2006:412) om allmänna vattentjänster) sets what is legally required from municipalities and water companies in terms of water services. There may be conditions made in agreements that allow the municipality to stop supply to industry under water shortage scenarios. This may be limiting around forming symbiosis where the municipality or water company is involved, but it is unclear.

Business barriers

The CSS toolbox will consider business aspects as part of the decision support process. Nonetheless, the outcomes from the decision support process need to be trusted by the user in order for them to implement any changes in the future. To reduce this risk the toolbox must be kept transparent and allow for stakeholders to independently verify results.



5 Aims and Goals

A key part of this project is to work towards the development of guidelines for water reuse in the food industry and society. By design, these guidelines should reduce the liability for that industry when reducing water use and encourage the uptake of circular water solutions. From the perspective of the decision support tool, expansion of the tool to encapsulate a larger variety of situations will likely be needed to improve acceptance and application. Tied to this is a need for results to be interpretable and relatable. For example, simply showing results from a model does not necessarily create “buy-in” from stakeholders about the need or trustworthiness of the outcomes. To minimise this problem, we will utilise engagement techniques such as exploratory dashboards so potential users can better see what the tools developed can offer.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

For demo 1, 2, and 3 the synergies will be captured through the structuring of WP 2 which includes a task and deliverable to gather joint learning (T 2.3).

Table 8: Synergies of Demo 2

Demo Number	Synergy envisaged
DEMO 1	<p>The Demo 1 approach could be added and tested in the decision support tool. For example, a user could understand how effective an AI based control is when it operates at different degrees of accuracy vs a non-AI solution.</p> <p>The biological risk work in Demo 4 can be used in this demo to support understanding of allowable storage times for water of different qualities.</p>
DEMO 2	<p>As with Demo 1 the learnings from Demo 2 can be captured in the decision support tool to be developed.</p> <p>The biological risk work in Demo 4 can also aid in safety aspects for this demo.</p>
DEMO 3	<p>Demo 3 will build on a previous circular water solution involving infiltration. This could be an option in Gotland and hence the knowledge from this project could be included in the decision support tool.</p>
DEMO 4	
DEMO 5	<p>The biological risk work in Demo 4 can also aid in safety aspects for this demo.</p>
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	

DEMO 5:

Flexible and intelligent biorefinery for bio-waste circularity.



1. The idea in brief

The demonstration will focus on the recovery of valuable materials and components from waste to produce polyhydroxyalkanoate (PHA) biopolymer and to extract fertilizers and other value components, while also considering CO² recovery routes. The aim is also in further development of a pilot scale biorefinery utilizing waste and side streams from agriculture; food, beverage, and forest industry; and municipal sources. The pilot plant will be a mobile container located at the Lahti Aqua Ltd wastewater treatment facility (Päijät-Häme) in the initial phase of the project.

The production process will be an alternative to conventional biogas production, improving energy efficiency and enabling recovery of various high-value components like PHAs, key nutrients and chemicals from wastewater treatment. The demonstration also includes assessment of potentially hazardous chemical and biological contaminants, as well as defining and testing methods to remove them. The properties of PHAs from different sources will be evaluated and the most sustainable and economically feasible potential end products will be selected. The piloted PHA-production model is applicable to different raw materials and production environments. Scaling and optimization of the process will be done by utilizing digital modelling.

***Problem Addressed or Need Detected:** Briefly describe the problem or need addressed by your CSS.*

Growing amount of plastic pollution is a significant global challenge which causes damages to ecosystems while also inflicting diseases. Majority of the used plastics are synthetic and produced by using fossil raw materials and fuels, which contributes to global warming. In addition to reducing the use of plastic products, biobased alternative raw materials are needed. These can be e.g., cultivated plants or waste or side streams. When using virgin raw materials, the production costs are usually high and can be seen as a barrier, in addition to sustainability issues related to e.g., land use. A more circular solution is to use waste materials, such as sludge obtained from municipal or industrial wastewater treatment processes. Sludge also contains various other value components, but currently its reuse is very limited, consisting mainly of biogas production and using the digestate for landscaping. Another important aspect is related to reducing the nutrient load of water bodies and the security of nutrient/fertilizer and energy supply. Currently, the production and use of nitrogen (N) and phosphorus (P), which are essential nutrients for food production, are not at a sustainable level. The production of ammonium nitrate, the most commonly used nitrogen source in Europe, is very energy-intensive and often tied to the use of fossil fuels. Manufacturing also produces nitrogen oxide emissions that intensify the greenhouse effect. In current wastewater treatment processes, ammonia is recycled back to atmospheric N₂ through nitrification and denitrification, instead of being recovered and used as a fertilizer. The mining of mineral P burdens the environment, and it is also a non-renewable natural resource that has been added to the EU's list of critical substances. Environmental problems



are also caused by the use of fertilizers, when part of the N applied to the field evaporates into the air. N and P are leached into waterways not only from fields, but also with industrial and urban wastewater, causing eutrophication and oxygen loss. The problem is also that a considerable part of the inorganic fertilizers is imported from outside Europe, which weakens the security of supply, especially due to the prevailing world political situation. The valuable nutrients contained in municipal wastewater should be utilized much more efficiently than at present. However, the currently used processing technologies are poorly suited for this purpose. During the chemical treatment process, P precipitates in a sparingly soluble form and is thus poorly usable for plants. There are also other challenges related to the use of sewage sludge as a fertilizer product, such as the harmful substances it may contain (e.g., heavy metals, pharmaceuticals and microplastics). Cleaning methods are being developed, but more research information is needed on their cost-effectiveness and the safety of the final products. Based on the latest research results, pyrolysis of sludge into biochar has proven to be an effective method for removing harmful organic substances.

***Solution Proposed:** Briefly describe what is your solution and how does it solve the Problem/need addressed.*

The cost-effectiveness of sludge treatment could be improved by utilizing the various value components it contains in products with a higher degree of processing, such as bioplastics. Sustainability challenges related to plastics produced from fossil raw materials can be solved by switching to recyclable and bio-based plastics, which is also emphasized in the EU's strategy for plastic products. Polyhydroxyalkanoates (PHAs) can be produced from sewage sludge as a raw material for bioplastics. In the process, the organic compounds contained in the sludge are converted into short-chain fatty acids (VFAs), which are further converted into PHAs by microorganisms. The method has been piloted in a five-liter fermenter. Based on the results, the production of PHA from sewage sludge was found to be economically viable compared to the world market price of PHA. The following step is to increase the scale of PHA production to 500-1000 liters in a portable container, which will be placed in connection with the wastewater treatment plant. At the same time, a PHA isolation method will be developed based on solvent extraction, following the goals of green chemistry. Alternatively, sludge can be utilized by producing biogas, e.g. into energy (district heating, decentralized power generation, solvent or transport fuel). In addition, other high-value components (e.g., metals, VFAs, lignin, cellulose, nutrients) can be recovered. Methods for P recovery and recycling of precipitating chemical FeSO_4 are developed. After PHA production or anaerobic digestion, the solid residue will be pyrolyzed to produce biochar for soil improvement use or other purposes.

The main goal of this pilot is to develop a smart bio-based industry that aims for added-value products through multiple and interconnected processes. The piloted biorefinery aims to produce a variety of bio-based products and digital solutions creating new business opportunities with reduced environmental impacts and enhanced carbon sequestration. Production lines can be directed, optimized and scaled utilizing digital modelling, e.g.,



creating a digital twin. The resources recovered from wastewater sludge can either be sold as raw materials or could be processed further, depending on the current market value.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

This pilot aims to develop multidisciplinary and value adding circular economy (CE) ecosystems around a biorefinery based on a wastewater or other sludge-based waste or side stream as a resource material and its processes are utilizing high-level digitalization. It will combine the CE interests of business enterprises, industry, cities, and communities together with high-level research and development by research institutes, emphasis being on the improved competence of small and medium size enterprises. The stakeholders of the project will be e.g., processes producing biobased side and waste streams, including communities, primary producers, manufacturing, local research actors and local authorities. The goal of the proposed pilot project is to reduce the dependence on fossil oil and fossil-based fertilizers of natural resources and to increase the level of material recycling and self-sufficiency. This systemic perspective innovation pilot focuses on unlocking the full potential of biomass by cascading optimized valorization of all (or at least several parts of) of local biomass resources.

From a societal perspective, food security will be improved due to the enhanced nutrient recovery and locally produced, affordable and bio-based fertilizing products. Furthermore, the negative health impacts caused by plastic pollution and emissions can be reduced. Ensuring the safety of the end-products will be a priority and thus the social acceptance of using waste and side streams as raw materials will be promoted.

From an economic perspective, using waste and side streams as raw materials will help to reduce the production costs of plastic manufacturing, as well as create new business opportunities and new sources of income for companies. The economic efficiency of nutrient recycling from wastewater sludge can also be improved by producing simultaneously other added-value products.

From environmental perspective, the amount of plastic waste will be reduced due to replacing fossil raw materials with renewables and producing biodegradable products. Improved recovery of nutrients from wastewater reduces the emissions to air, land and water bodies.

The demonstrator has direct link to several Sustainable Development Goals (SDGs). With SDG 2: Zero hunger, it contributes to improving nutrient recovery from waste and side streams thus enhancing food security and self-sufficiency in food production. With SDG 6: Clean water and sanitation, it produces clean water from wastewater and value-added products are extracted at the same time. With SDG 7: Affordable and clean energy, it aims at improving the efficiency of renewable energy production from waste and side streams. With SDG 8: Decent work and economic growth, it creates new circular economy-based business opportunities while also improving companies' economy. With SDG 9: Industry, innovation



and infrastructure, it positively effects on several industries and supports their transition towards more circular economy. With SDG 12: Responsible consumption and production, it encourages companies to replace fossil raw materials with renewables and to bring more sustainable and affordable products to markets. With SDG 13: Climate action, it reduces the dependence on fossil fuels and raw materials in the production of e.g., plastics, fertilizers and energy. With SDG 14: Life below water and SDG 15: Life on land, it contributes to reducing the damages to ecosystems caused by plastic pollution and leaching of nutrients.



2 Scope and Territory

2.1 The territorial context

***Geographical Scope:** What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope? If possible, add a map.*

In the first stage, the geographical scope of the solution will be local (Lahti) and regional (Päijät-Häme). The aim is to develop scalable biorefinery concept which can be transferred to other regions in Finland and in EU countries.

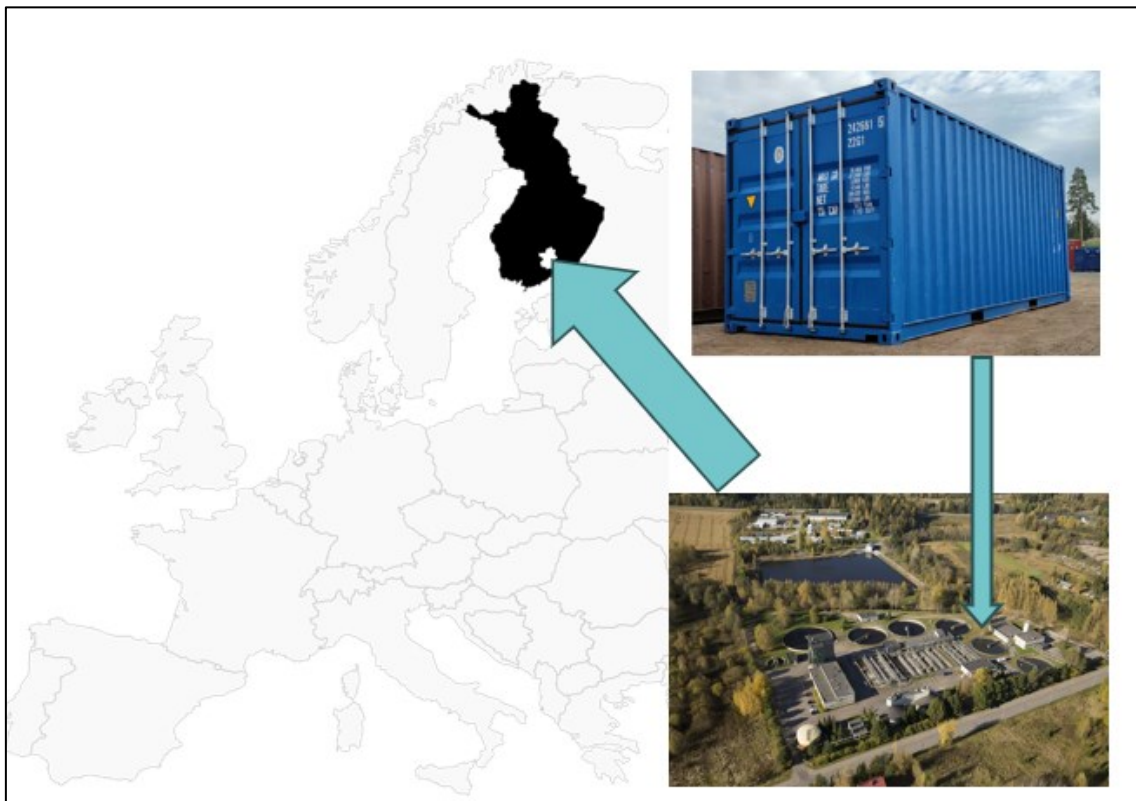


Fig. 1. The location of the pilot plant in Lahti, Finland.

The city of Lahti, in southern Finland (European Green Capital, 2021), is known for its environmental expertise and for being an internationally renowned design center. The surrounding Päijät-Häme region is known as the Finnish “Waterland” (¼ of the surface area is waterbodies). This emphasizes the role of “water” also in the strategic spearheads of the region: “Manufacturing” and “Food & drink” (i.e., Water & Grain) with a strong emphasis on sustainable development. Päijät-Häme is Finland’s 2nd largest clean tech business centre, internationally known for its expertise and solutions. The region has a high level of R&D in environmental technology by academic and applied research institutes as well as a strong

business sector, including medium to international size food- and wood refining industries as well as SME technology producers.

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

The innovation is related to wastewater and biowaste management, as well as several industries (forest, food & beverage, plastics, fertilizers), energy, and agriculture. The aim is to increase the valorization of wastewater sludge and biowaste, while improving energy efficiency of biogas production. Waste and side streams will be turned into value-added products which will have a direct impact on companies' economy. The production costs and environmental impacts of biobased plastics are reduced by using secondary raw materials that are otherwise difficult to utilize. The innovation also contributes to more efficient nutrient recovery providing safe and affordable fertilizing products for agricultural use.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban). Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

With the circular economy goals set by the European Union, the EU Commission wants to promote research and innovation in plastics that are safe and durable, enable reusability and recycling and are biodegradable. According to the EU plastics strategy, plastic products in Europe should be developed in a renewable and recyclable direction. In addition, the European Commission has set the recycling target of 50% for plastic packaging. Finland's plastic road map, drawn up by the Ministry of the Environment, is aimed at by 2030 circular economy breakthrough. In order to reach the goal, the aim is to reduce environmental harm caused by plastic, promote reuse, enhance the recycling of plastic and recyclability of the products, and to replace virgin plastic produced from fossil raw materials with recycled and renewable alternatives.

The Plastics Regulation applies to the following materials and products placed on the EU market: materials and accessories consisting of plastic, multi-layered plastic materials and accessories that have used binders, etc., products and accessories made of plastic with coating or printing, plastic layers or plastic coatings, plastic layers of multilayer materials consisting of different materials. The regulation specifies that the substances used must be suitable to its quality and purity for its intended use. There must be sufficient information on the composition of the substance and their decomposition products, and they must be provided on request to the authorities. The regulation mentions which materials plastic



products are allowed to be manufactured from, as well as set limit values for the extent to which different substances may be released of the product. It is also important to ensure the environmental and health effects of decomposition products, as well as recyclability, biodegradability, compostability and functionality.

National legislation in Finland does not set specific restrictions for PHA-based plastics made from sewage sludge. However, they must comply with current EU legislation and guidelines. Quality, safety and fit for purpose, as well as the degradation of bioplastics, must be taken into account. It is also important to ensure the environmental and health effects of decomposition products, as well as recyclability, biodegradability, compostability and functionality.

Fertilizer legislation on national and EU levels is also relevant for CSS. Considering the use of wastewater sludge in fertilizing products, there are remarkable differences. According to the current fertilizer legislation in Finland, sewage sludge can be utilized as a fertilizing product when it is properly treated (i.e., composting, digestion, stabilization, pyrolysis), and the utilization is only allowed in the cultivation of plants that are not directly used for human consumption or animal feed. In the EU Fertilizing Products Regulation (2019/1009/EC), wastewater sludge is excluded from the allowed raw materials for CE-marked fertilizing products, thus limiting the markets. As a result, Finnish farmers comply with EU legislation due to international markets.

At the national level, the Finnish Ministry of the Environment has a specific funding program for promoting nutrient recycling, from which the co-project *PULINA – Value components of sewage sludge* is funded. The Päijät-Häme Regional CE strategy, i.e. The CE Roadmap defines the objectives and actions for achieving CE and has been compiled in collaboration with stakeholders in the region. The roadmap was supplemented in 2019 with the Päijät-Häme Bio-based CE Action Plan. The vision of the Päijät-Häme regional CE is “a success that will not waste resources in 2030”. This pilot will strongly promote the implementation of this roadmap.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices.



Table 9: Legal Framework for Demo 5

Level	Regulation	Requirements
EU	EU Circular Economy Action Plan (European Commission).	Promoting the transition to a circular economy, and the reuse and recycling of materials.
EU	Waste Framework Directive (2008/98/EC) (European Parliament and Council of the EU).	Establishing the waste hierarchy, prioritizing prevention and recycling.
EU	Fertilizing Products Regulation (2019/1009/EC)	Regulates the requirements for treatment processes and techniques, and requirements for CE-marked EU fertilizing products.
EU	Plastic Regulation (EU) 10/2011	Establishing specific measures and serving as an example of the criteria to be defined also for other materials.
EU	Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment	Reducing the impact of certain (single use) plastic products on the environment.
National	Ministry of Agriculture and Forestry's regulation on fertilizing products (964/2023)	Regulates the categories of the fertilizing products and specific requirements for those; the requirements for quality, labeling, packaging, transporting, storage, application of fertilizing products; the allowed raw material for fertilizing products.

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

Material flows in the demonstration:

Inflow (biomass): Biomass transported for PHAs and biogas production

- Source-separated biowaste, woody biomass, sewage sludge.
- Municipal waste 3.3 Mt in 2020 in Finland.
- 67 600 t/year of sludge generated by the Finnish food industry.
- Forest industry produced biodegradable waste 3.0-3.5 MT in 2014-2016.
- Export of Finnish forest industry products was 13.2 billion euros in 2021.
- 30 Mm³/year of livestock manure sludge in Finland.

Inflow (energy): Electricity, biomass for biogas production.

Inflow (water): Wastewater, rainfall (stormwater), flowing water in waterbodies.

- 169 100 t of sewage sludge produced in Finland in 2021.

Inflow (minerals): Minerals of sewage sludge and other waste materials.

Internal flow: sewage sludge, other waste.

- PHAs, biogas, P and N fertilizers, biochar, energy recovery from the sewage and waste treatment processes.
- Plastic products produced globally 390.7 Mt, of which 1.5% only were bioplastic).
- Biogas produced 50 GWh.

Production (biomass): Biomass waste can be recycled to PHAs, biogas and compost.

- 22 000 t of compost/year (landscaping, organic fertilizer).

Production (minerals): P and N minerals recovered from sewage sludge.

Storage (water): treated wastewater, and rainfall water (stormwater) to waterbodies.

- Wastewater treated 35 000 m³/d (Lahti, Nastola, Hämeenkoski).

Storage (minerals): Wastewater sludge minerals (other than P and N) can be stored for further mineral extraction.

Outflow (energy): Excess energy (biogas, recovered process energy) can be utilized also outside urban system.

Outflow (water): Treated wastewater released to waterbodies flows out of the urban system.

Outflow (minerals): P and N fertilizers transported to other regions.

Outflow (biomass): Organic carbon exported in the form of PHAs/plastic products.

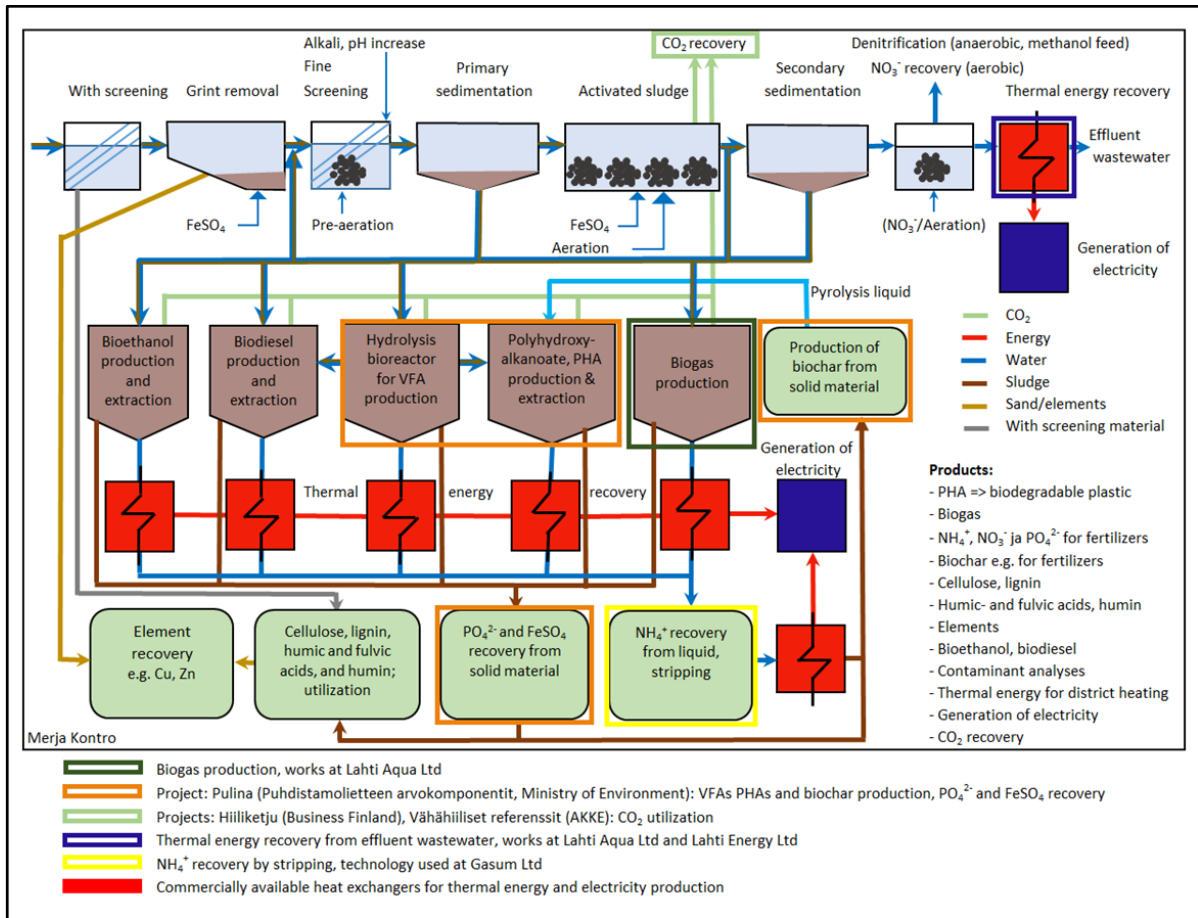


Figure 9: The development of the biorefinery at the wastewater treatment plant, and related projects.

The demonstration is concerned with municipal and industrial wastewater sludge and other waste originated from waste treatment plants. Municipal wastewater sludge is commonly utilized in biogas production, and the digestate is used for landscaping, or as a soil improver in horticulture and agriculture, with some restrictions. Industrial wastewater sludge is more commonly used as a raw material for fertilizing products or incinerated with energy recovery. During the project, sludge is utilized by producing different value-added products, while also aiming for more efficient nutrient recovery and renewable energy production. The main actors in the value chain in the first stage are research and education institutes, and waste producing and treating companies.

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

The stakeholders of the project will be e.g., processes producing biobased side and waste streams, including communities, primary producers, manufacturing, local research actors and local authorities.

Public administration

Public administration has a key role in promoting and regulating new practices related to wastewater utilization. The Ministry of Environment and the Centre for Economic Development, Transport and the Environment (ELY Centre) are important stakeholders on national and regional level. Close cooperation with local municipalities/communities is also required.

Industry and companies

The main stakeholders regarding industries and companies are waste management companies and biogas producers Lahti Aqua Ltd, Labio Ltd, Salpakierto Ltd in addition to forest industry and food industry companies who are providing raw materials for the biorefinery. Plastic manufacturing companies are the main consumers of the produced PHA, whereas companies operating in agriculture and forestry sectors are utilizing the developed fertilizing products.

Civil society

Consumers have strong influence as their choices and preferences directly impact on companies' business activities. There is a growing demand for sustainable and circular products, but they will also have to be affordable for a large group of end users.

Academia, RTOs and NGOs

Academic institutions are needed for research, technology development and sharing information to promote the new innovations related to wastewater sludge valorization. The main stakeholders of this CSS are LAB University of Applied Sciences, University of Helsinki and LUT University. Also, Salpaus Further Education which is one of the biggest vocational education providers in Finland, can be identified as important stakeholder.



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

In our wastewater treatment the cleaning process starts with a mechanical step where coarse solid is removed. After that, sand, gravel, grease and other mixed waste are removed from the wastewater. In the next phase, the phosphorus contained in the wastewater is chemically removed. Iron salt, or ferrous sulfate, is added to the wastewater, which precipitates the phosphorus in the water into a separable form. In the third stage of the cleaning process, the bacteria contained in the wastewater are responsible for the biological cleaning. The biological phase takes place at wastewater treatment plants in aeration basins, where the aim is to create optimal conditions for bacteria to grow and reproduce. Activated sludge is formed from bacteria, which consume organic substances from wastewater. At the same time, more than 70% of the wastewater nitrogen and more than 98% of organics and phosphorus are removed as a result of the growth and activity of bacteria. and chemical precipitation. As the last step in the wastewater treatment process, the discharged water is effectively sanitized to the level that meets the requirements of the Bathing Water Directive. This is done by disinfecting the outgoing water with ultraviolet light.

Sewage sludge refers to settled solid matter generated in the wastewater treatment process. In the first stage of sludge treatment, sewage sludge is first concentrated mechanically and then led to digesters. In digestion, the organic matter of the sewage sludge is digested in oxygen-free conditions. Biogas, or methane, and carbon dioxide are produced during the process. At Lahti Aqua's wastewater treatment plant, biogas is used for heat by burning it in gas boilers. The heat produced is used for heating both the treatment plant buildings and the premises. The surplus is sold to Lahti Energia's district heating network.

After digestion, water is mechanically separated water from the sludge. The sludge is transported to Labio's composting facility for further processing. When composting sludge and biowaste, mulch is produced, which is used in the construction of green areas. Biowaste-based compost is also used as an organic fertilizer.

Salpakierto Ltd is a waste treatment station located in Lahti, which also recycles waste with varying concentrations of organic materials, such as sawdust, lake reed, and other organic materials, including organic soil. The possibilities of recycling their carbon to PHAs will be evaluated.

Our CSS makes the value chain more circular in many ways. It enables wider utilization of waste organics and wastewater sludge for various purposes, one being PHA production for biodegradable plastic, and thus it is interconnected with all phases of the plastics value chain.



In the raw material production phase, the aim is to replace the fossil raw materials sourced from oil with biobased waste materials obtained from municipal and industrial wastewater sludges. In the manufacturing phase, processing methods for the extracted PHA are evaluated in addition to developing material properties and providing feedback for PHA production. PHA plastics are biodegradable, which significantly reduces the amount of plastic waste generation. Another possible use of biomass is the production of biochar. Moreover, phosphorus and nitrogen will be recovered for use as fertilizers. In general, ammonia recovery from wastewater by stripping is already an industrial process, but the recovery of chemically precipitated phosphorus has not yet been developed.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

Please characterize the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

This demonstrator aims at turning waste and wastewater treatment plants into biorefineries, where waste, wastewater and sludge are seen as versatile and valuable resources. More versatile utilization of waste and sludge raw materials promotes transition towards fossil neutral society, as self-sufficiency is increased by reducing dependence on imported oil and fossil-based products, such as plastics, fuels and fertilizers. Moreover, the development can improve economic viability of waste treatment plant investments, including sewage sludge treatment, and create new business opportunities based on the circular economy. Hence, there are several stakeholders who will benefit from this CSS shift.

Waste and wastewater management companies, such as Lahti Aqua Ltd, Labio Ltd, and Salpakierto Ltd, become raw material producers. Currently, wastewater sludge is utilized in biogas production and the digestate is used in landscaping. Source-separated biowaste is composted and used as a fertilizer. This CSS creates new business opportunities and new sources of income based on utilization of bio- and mineral waste, the overall biorefinery process being controlled using artificial intelligence (AI). Using the same approach, forest and food industry companies can turn their waste streams into value-added products. Although the residue sludges can be utilized e.g., as soil improvers or in energy production, there is a great potential for more valorization options.

Plastic manufacturers consider increasing the circular economy as a necessary opportunity and there is a great interest in finding secondary raw materials for producing biobased plastics. For example, the high production costs can be a major barrier for wider use of PHAs. Using waste as raw material and mixed microbial cultures instead of pure culture technologies would help to improve the economic profitability and sustainability of the companies' operation.

Consumers of the end products are also important stakeholders. Due to the increased knowledge about the negative impacts of synthetic fossil-based plastics, there is a growing interest towards recycled and biodegradable alternatives. Farmers are the end users of



fertilizing products, and they are interested in finding cost effective and safe alternatives for mineral fertilizers. However, there can be concerns about wastewater sludge or biowaste as raw materials. Biochar is one of the end products of the biorefinery developed in this demonstration. Pyrolysis has been shown to efficiently destroy many harmful substances and micro plastics from sludge.

Furthermore, there are various other industries that can utilize the value components made from waste materials processed in the biorefinery.

The main actors of this demonstration are University of Helsinki, LAB University of Applied Sciences and Lahti Aqua.

University of Helsinki is focusing on production and extraction of PHAs. Small pilots of biomass hydrolysis and PHA accumulation are currently ongoing in the laboratory, and they will be upscaled to 500-1000 l containers in a portable research unit which will be placed in **Lahti Aqua** wastewater treatment plant. In addition, the technologies for recovery of P and recycling of FeSO₄ used in P precipitation are developed, while also aiming to improve the energy efficiency of biogas production from sludge.

LAB University of Applied Sciences is focusing on material and product demonstrations. Multiple processing methods for the extracted PHAs are evaluated. The tasks also include developing material properties and providing feedback for PHA production. LAB is utilizing AI to create a digital twin of the process, aiming for optimization and scalability. Industrial usability of PHAs is observed holistically from raw material into the product level, also carrying out techno-economic evaluation.

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

Currently, wastewater sludge is utilized in anaerobic digestion, and the digestate is used in landscaping. In this demonstration, the production of PHAs from wastewater sludge is being piloted as an alternative process for digestion and biogas production. In both cases, other high-value components (e.g., metals, VFAs, lignin, cellulose, nutrients) will also be recovered. The economic efficiency, technical flexibility (inc. ICT solutions) and sustainability of the recovery processes will be assessed. Furthermore, the presence of potentially harmful organic substances will be evaluated, and purification methods to remove them will be defined and tested to ensure the safety of the products. The described pilot process is not restricted on municipal wastewater sludge, as water and other waste materials are available from the region's strong food and forest industry sectors. As a result, a scalable and reproducible bio-refinery concept that can be transferred into various environments is developed.

The material flows in the plastic value chain are changed, as fossil raw materials in manufacturing are replaced with PHAs to produce biodegradable plastics. Furthermore, the



recovered nutrients and produced biochar can be used in agriculture to replace synthetic fertilizing products. The main change is, that wastewater sludge can be turned into valuable resource instead of waste. This CSS supports transition towards circular economy and has multiple various impacts on environmental, economic and social sustainability. It helps to decrease the industries' dependence on fossil raw materials and fuels, while reducing the generation of plastic pollution and emissions that contribute to global warming, eutrophication.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

Commercial production of PHAs is currently done using pure cultures. However, technology has been developed to enrich PHAs accumulating bacteria and accumulate PHAs from processes using microbial phosphorus recovery. As phosphorus is precipitated with FeSO_4 in Finland, the process requirements change, and such process has not yet been piloted. Furthermore, the recovery of precipitated phosphorus has not yet been developed. Large-scale phosphorus and ammonia recovery has been developed for processes that utilize the microbial accumulation of phosphorus, which is then released into the liquid phase during biogas production. When both ammonia and phosphorus are in the liquid phase, they readily react and form struvite after adding magnesium. Finally, all biowaste contains so called difficult to digest material, including especially cellulolytic materials and lignin. The hydrolysis of these materials to VFAs is also considered.

3.4 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

The main impacts include added value for waste, circular use of an alternative fertilizer product and improved self-sufficiency, best available technologies for nutrient recovery from wastewater sludge (inc. policy recommendations), in addition to replacement of fossil-based materials.

The measures promote circular economy and green transition, while creating new business opportunities. With the help of the concept being developed, the wastewater treatment plant can be transformed into a multi-product biorefinery, which allows the valuable materials contained in the sewage sludge to be collected and used more efficiently. More efficient



recovery of nutrients from wastewater reduces the nutrient loading of water bodies, eutrophication and the occurrence of oxygen loss. By replacing industrially produced mineral fertilizers with recycled fertilizers, emissions are reduced. The need for fossil raw materials decreases when wastewater can be used to produce raw materials to produce bioplastics at a competitive price. Increasing the use of bioplastics, on the other hand, reduces the amount of plastic waste generated. The container piloted in the project can be easily moved and duplicated. In addition, bioplastics and biochar produced from sewage sludge can be seen as carbon sinks.



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

Several issues must be resolved in the development of PHA production for large-scale pilots. However, they are not considered to be impossible to solve, and therefore all technological barriers should be possible to solve. Transitioning from piloting to full-scale processes requires quite large investments. The same applies to phosphorus recovery. Several options have already been studied, where the connection to the real industrial full-scale processes has not been made well enough. Several methods are already available for phosphorus recovery from the liquid phase, but a suitable approach to recover the precipitated phosphorus has not yet been solved. Therefore, the development of this process requires all stages from the laboratory to small pilots, and finally to large-scale pilots and industrial processes.

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

There are no knowledge barriers, which prevent the implementation of the research.

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

There are no policy barriers. However, for full-scale processes, quite large investments are required.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

The utilization of wastewater sludge in fertilizer products is not as strictly regulated in Finnish legislation as in EU legislation. In the EU Fertilizing Products Regulation, sludge is excluded from the permitted raw materials, which is a barrier to entering the EU markets. Therefore, sludge is not used as a fertilizer in Finland, and sludge-based products that are considered safe can also be difficult to sell.

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploding your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

One of the barriers can be related to the social acceptance of using wastewater sludge as raw material, especially for fertilizing products. Farmers and consumers may have precautions about the safety of the products, and grain industry companies can be concerned about the image disadvantage that using such products would cause. Large investments are required to build full-scale processes.

5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

Production of PHAs has been demonstrated on a pilot-scale at wastewater treatment plants utilizing biological phosphorus recovery. The product purification and quality would need improvement, although the quality requirements for technical plastics are lower than for food-based materials. In terms of market readiness, it is not yet fully prepared to enter the market. The economic feasibility has been assessed, and it was positive. Additional research may be needed to develop a full-scale process, for example continuous process development.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos?

Table 10: Demo 4 Identified Synergies

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	
DEMO 6	The fermentation processes will be validated with biowaste (brewer's spent grain) from Demonstrator 6.
DEMO 7	
DEMO 8	
DEMO 9	

How do you plan to test and develop those synergies?

Brewer's spent grain, or bagasse, which is a by-product from brewing industries, is characterized to its nutrient and fiber content, determining which fractions are most suitable for fermentation and PHA production. Bagasse is then incorporated as part of the substrate in the biowaste plant's fermenters, evaluating parameters such as conversion rate, PHA productivity, and the properties of the resulting biopolymer. It is expected that this would increase the efficiency and yield of the fermentation process. Furthermore, the properties of bioplastics could be improved by the active compounds extracted from the bagasse. Thus, there are potentially several synergies due to the more efficient utilization of waste and side streams as well as reduced raw material costs. Digital modelling will be utilized for process optimization and scalability. Close collaboration between the experts and multidisciplinary teamwork will be needed to enable the potential synergies.

Demo 6: Beer bagasse waste as a source of high value-added substances and as a filler in plastic matrices



1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

The beer sector in Spain has a production of around 40 million hectolitres. While there are large national producers such as Mahou San Miguel, Grupo DAMM and Heineken España, there are more and more initiatives to produce craft beers. The annual quantity of malting barley in Spain is around 700,000 tonnes, which, together with some 860 tonnes of flowering hops, feeds beer production in Spain. It is obvious that a large part of these materials is left as waste at the end of the fermentation and beer production process.

Beer production in the European Union generates more than 6 million tonnes of bagasse and 1 million tonnes of yeast. Currently, in most cases, the yeast is managed together with the wastewater, while the bagasse is used fresh for animal feed and biogas production, while the remaining fraction (about 20%) is landfilled, leading to the loss of a product with high potential for other applications.

In beer bagasse residue we can find between 15 and 26% of proteins, 70% of fibres (cellulose, hemicellulose and lignin) and between 4 and 15% of polyphenols, polysaccharides and lipids. The project presents a great opportunity to boost circular economies.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

The proposed solution is to use beer bagasse waste as a source of high value-added substances and as a filler in plastic matrices. The project will make it possible to develop laboratory-scale processes to obtain the different target products (polyphenols, proteins and fibre). The active principles obtained will be of great use in certain biotechnological sectors and the residual plant fibres obtained will be incorporated as a natural filler in plastic products. In this way, a waste with a high potential will be put to good use while reducing the environmental impact at the same time.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?



The use of beer bagasse residue as a source of high value-added substances and as a filler in plastic matrices represents a significant change with multiple benefits from environmental, economic and social perspectives. On the environmental side, one of the main benefits is the reduction of waste. Beer bagasse is an abundant by-product of the brewing industry that, if not reused, contributes to the accumulation of organic waste. By using it as a source of value, the amount of waste sent to landfill is reduced, thus minimising its environmental impact. In addition, this approach promotes recycling and sustainability, fostering a circular economy where waste is reused rather than discarded, which in turn reduces reliance on virgin materials and consumption of natural resources. By reducing the need for new fossil fuel-based plastics by adding the fibres as a filler, it also reduces the greenhouse gas emissions associated with their production.

From an economic perspective, the incorporation of bagasse into plastic matrices can generate cost savings, as industries can benefit from partially replacing conventional plastic materials with a low-cost by-product such as beer bagasse, thus reducing production costs. This type of innovation increases the competitiveness of companies adopting sustainable practices and opens up new markets for innovative products. Furthermore, the valorisation of bagasse could generate new sources of income for breweries and companies involved in the production of composite materials by developing new lines of business.

At the societal level, the implementation of technologies that transform waste into high value-added products has the potential to generate new jobs in research, development and manufacturing sectors. Furthermore, promoting the use of industrial by-products in sustainable applications can raise awareness of the importance of waste management and sustainability. This contributes to improving the quality of life, as more sustainable and cost-effective products can be more accessible and environmentally responsible.

This approach has a direct connection with several Sustainable Development Goals (SDGs) and the European Green Pact. With SDG 12: Responsible Consumption and Production, it aligns with promoting recycling and reuse of materials, ensuring sustainable consumption and production patterns. With SDG 9: Industry, Innovation and Infrastructure, it encourages innovation in the use of recycled materials and the development of sustainable infrastructure. With SDG 13: Climate Action, it contributes to combating climate change by reducing CO₂ emissions and promoting sustainable practices. Finally, it aligns with the European Green Pact, which seeks to transform the EU into a modern, resource-efficient and competitive economy, ensuring no net greenhouse gas emissions by 2050 and decoupling economic growth from resource use.



2 Scope and Territory

2.1 The territorial context

Geographical Scope: What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope?

If possible, add a map.

In the first stage, the project will have a local (Alicante), regional (Valencian Community) and national (Spain) scope. Once the project is developed, it could be transferred to any of the EU countries.

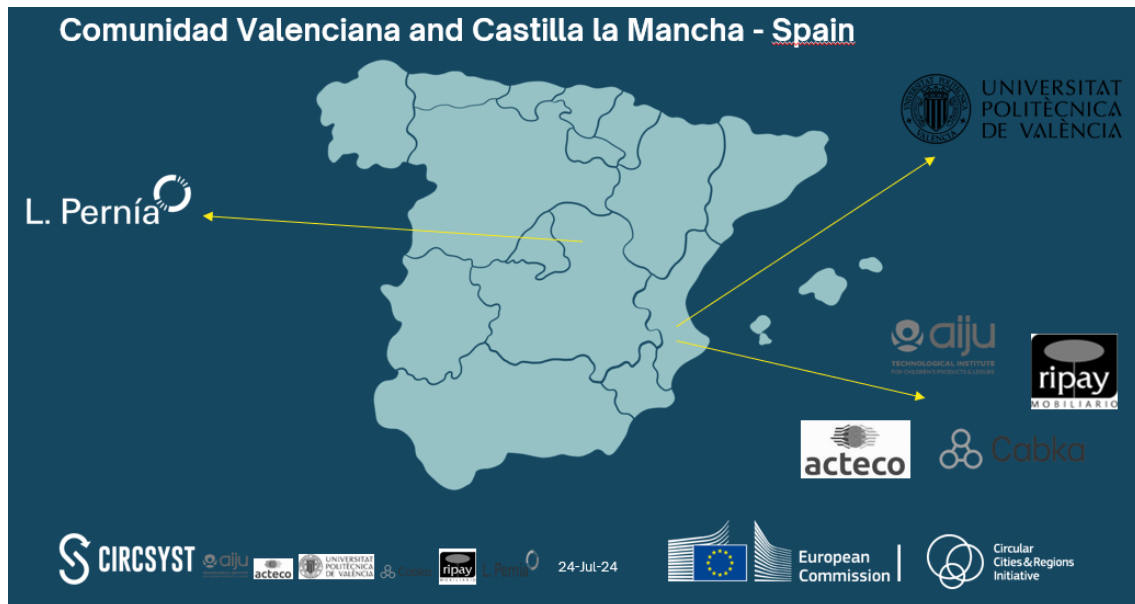


Figure 10: Demo 6 Location

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

The project of using beer bagasse as a source of high value-added substances and as a filler in plastic matrices can positively affect several sectors. Firstly, the beer industry is directly impacted, as it finds an innovative use for its main byproduct, bagasse. This not only reduces the cost associated with managing this waste, but also opens up new income opportunities by selling the bagasse to companies that transform it into valuable materials.

On the other hand, the plastics and composite materials industry will benefit significantly by incorporating bagasse as a filler material in the production of bioplastics and other materials. This innovation allows the development of more sustainable products, reducing dependence on materials based on fossil fuels and

promoting the use of renewable sources.

The project is closely related to waste management, as it focuses on the valorization of a by-product that is traditionally considered waste. By creating a market for beer bagasse, the circular economy is promoted and the amount of organic waste sent to landfills is reduced.

Although the project does not impact water use very directly, it may have positive indirect effects on the water sector. The reduction of organic waste and its correct management reduces the possibility of contamination of water sources. Furthermore, by reducing the production of traditional plastics, the use of water in related industrial processes is also reduced.

The chemical industry and the agri-food sector can also benefit, since beer bagasse contains bioactive compounds that can be extracted and used to manufacture pharmaceutical, cosmetic or nutraceutical products. This opens new avenues for the development of innovative products from natural sources.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Try to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

In the context of the project that uses beer bagasse as a source of high value-added substances and filler in plastic matrices, there are several policy instruments that promote the circular economy at European, national and regional level. One of the most relevant is the Action Plan for the Circular Economy of the European Union, which seeks to facilitate the transition to a circular economy in Europe. This plan, administered by the European Commission, promotes the efficient use of resources and the reduction of waste, establishing legal and financial measures that encourage innovation and the use of recycled materials.

The Waste Framework Directive (2008/98/EC) is another key instrument that establishes a legal framework for waste treatment in the EU. Its objective is to promote the prevention, recycling and reuse of waste, as well as the reduction of landfilling. This directive, managed by the European Parliament and the Council of the EU, obliges Member States to implement waste management plans and promote the waste hierarchy, which favors the recovery of by-products such as beer bagasse.



At the national level, the National Circular Economy Strategy in Spain, led by the Ministry for the Ecological Transition and the Demographic Challenge, seeks to integrate the principles of the circular economy into economic policies, reducing waste generation and promoting sustainability. In addition, the Waste and Contaminated Soil Law, also under the same ministry, establishes standards for waste management, promoting reuse and recycling.

The Spanish Bioeconomy Strategy, managed by the Ministry of Agriculture, Fisheries and Food, promotes the development of a sustainable bioeconomy, encouraging the use of renewable biological resources in the production of food, energy and industrial products. This strategy encourages the use of residual biomass, such as beer bagasse, in innovative industrial applications.

The Rural Development Program (PDR), administered by the Ministries of Agriculture and regional governments, supports sustainable development in rural areas, encouraging circular economy projects that use agricultural and industrial waste.

Finally, the European Green Deal, managed by the European Commission, establishes a framework to transform the EU economy towards sustainability and climate neutrality by 2050, promoting the circular economy in all sectors and providing funds for technological innovations that reduce the environmental impact.

These policy instruments are essential to promote the circular economy, encouraging innovation and the efficient use of resources in projects such as the use of beer bagasse. Through regulations, financial incentives and support for research, the aim is to transform production systems towards more sustainable models, aligned with the sustainable development objectives and the goals of the European Green Deal.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices.



Level	Regulation	Requirements
EU	EU Circular Economy Action Plan (European Commission).	It promotes the transition to a circular economy. Promotes the reuse and recycling of materials, which is essential for the valorisation of bagasse as a secondary raw material.
EU	Waste Framework Directive (2008/98/EC) (European Parliament and Council of the EU).	It establishes the waste hierarchy, prioritising prevention and recycling. It is key to encouraging the recovery of waste such as bagasse instead of disposal.
National (Spain)	National Circular Economy Strategy (Ministry for Ecological Transition and the Demographic Challenge).	It seeks to reduce waste generation and promote sustainability in production processes, supporting initiatives that reuse organic waste such as beer bagasse.
National (Spain)	Waste and Contaminated Soil Act (Ministry for Ecological Transition and the Demographic Challenge).	It regulates waste management and promotes selective collection and recycling, which favours the creation of value from bagasse rather than its disposal as waste.
National (Spain)	Spanish Bioeconomy Strategy (Ministry of Agriculture, Fisheries and Food).	Promotes the use of renewable biological resources in industry, supporting innovation in the use of bagasse as a raw material for bio-based products and sustainable materials.
Regional/Local	Regional Circular Economy and Sustainability Programmes (depending on each Autonomous Community) (Regional and local governments).	The Autonomous Communities can implement specific plans that encourage the reuse of industrial by-products, such as bagasse, in circular economy projects at regional and local level.



2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

Beer bagasse, a byproduct of beer production, originates during the malting and mashing process. In this process, fermentable sugars are extracted from barley grains, generating approximately 20 kg of bagasse for every 100 litres of beer produced. At European level, this represents about 6 million tons of bagasse annually.

Once generated, bagasse is collected and transported from breweries to processing facilities by waste management companies and recycling cooperatives. These logistics may involve handling several tons daily, depending on the size of the brewery and the capacity of the receiving plants.

In the proposed project, in processing facilities, biotechnology and recycling companies will transform bagasse into high-value components, such as proteins and fibres, in addition to drying and grinding it for use as filler in plastic matrices. Bagasse contains between 15% and 26% protein and up to 70% fibre.

Subsequently, plastic manufacturers will incorporate the processed bagasse into bio-composites, which are mixtures of plastic resins and bagasse. These bio-composites can replace between 10% and 30% of conventional plastic material in final products, depending on the application and material requirements. The resulting products, such as packaging, furniture and automotive components, will be marketed by consumer product manufacturers and distributors as sustainable alternatives to traditional plastic products.

At the end of their useful life, these products can be recycled, thus closing the cycle of the circular economy. Recycling plants and waste managers will manage this process, which will contribute to further reducing the environmental impact. The recycling rate of bio-composites depends on the available local waste management infrastructure.

In summary, the value chain of this project integrates several actors: breweries that generate the bagasse, waste management companies that transport it, biotechnology industries that valorise it, manufacturers that incorporate it into bio-composites, and distributors that market the final products. This flow of materials illustrates a system that leverages beer bagasse as a valuable resource, driving the circular economy and reducing the environmental impact of the beer and plastic industry.



2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

Public administration.

The public administration will play a crucial role in regulating and promoting sustainable practices in the management of beer waste. Local, regional and national governments, as well as the European Union, are key actors that establish policies, regulations and standards that drive the circular economy. The Ministries of Environment and Agriculture, in particular, have a direct interest in promoting the recycling and recovery of organic waste, providing subsidies and tax incentives for projects that develop sustainable technologies. Additionally, regulatory agencies oversee compliance with environmental regulations, ensuring that industrial practices are safe and responsible.

Industry and Companies.

Within the industrial sector, breweries are the main generators of bagasse and, therefore, will be the fundamental actors in the supply chain. These companies are interested in reducing their operating costs and improving their environmental sustainability, which will encourage them to collaborate in initiatives to valorize bagasse. Additionally, biotechnology and recycling companies will be crucial, as they will develop and apply technologies to transform bagasse into high-value products. Plastics manufacturers are also interested parties, as they will seek to integrate sustainable materials into their products to meet consumer demand and comply with environmental regulations.

Civil society.

Civil society, including consumers and community groups, will influence the SSC of bagasse through demand for more sustainable and environmentally responsible products. Consumers are increasingly interested in purchasing products that reduce environmental impact, motivating companies to adopt sustainable practices. Civil society organizations and environmental NGOs also play an important role in advocating for stricter waste management policies and raising awareness of the benefits of the circular economy. Its influence extends through awareness campaigns and public education.

Academia, RTOs and NGOs.

Academic institutions and research and technology organizations (RTO) will play an essential role in the development of new technologies and processes that facilitate



the valorization of bagasse. Universities and research institutes will carry out studies that will improve the efficiency of converting bagasse into useful products and contribute to the advancement of knowledge in biotechnology and sustainability. On the other hand, NGOs, both locally and internationally, act as mediators and facilitators of collaborative projects between the different actors of the quadruple helix, promoting sustainable practices and participating in the implementation of circular economy projects.

The interaction between public administration, industry, civil society and academia will be essential to develop an integrated approach that maximizes the economic, social and environmental benefits of bagasse valorization.



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

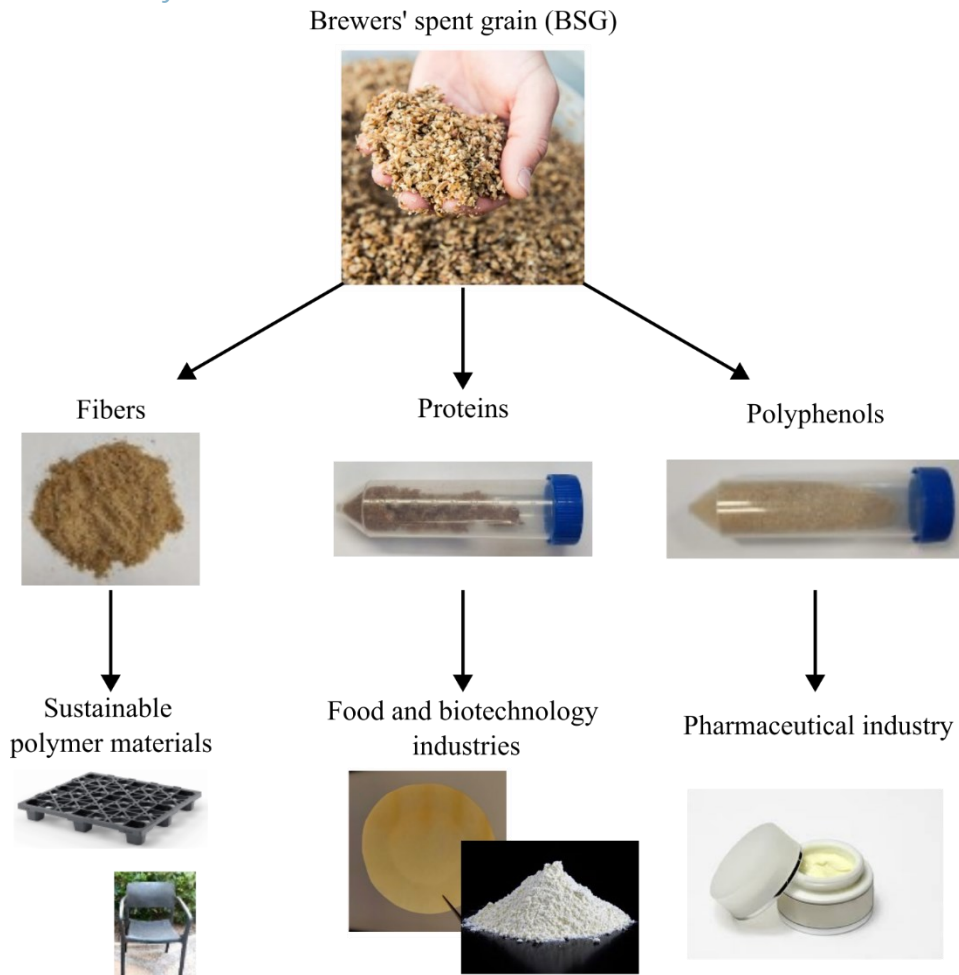


Figure 11: Demo 6 Value Chain

The value chain in the brewing industry begins with the cultivation and supply of raw materials, primarily malted barley, water, hops, and yeast, which are sourced from agricultural suppliers. Farmers grow and supply these essential ingredients to breweries where they undergo a series of transformation processes. The beer production process starts with malting, where barley is prepared for fermentation. This is followed by mashing and boiling, where the malted grain is mixed with hot water to release sugars. Hops are added for flavor, and the mixture is boiled to produce wort. The next stage is fermentation, where yeast is introduced to convert sugars into alcohol and carbon dioxide, resulting in the creation of beer. Clarification and filtration are conducted to remove solids and achieve a clear liquid ready for

consumption.

During beer production, a significant byproduct known as brewers' spent grain (BSG) is generated. This residue consists of the leftover grain after the mashing process. While some of this spent grain is currently used as animal feed or composted, a substantial amount remains underutilized despite its potential for valuable compound extraction.

Following production, the beer is packaged in bottles, cans, or kegs and distributed to retailers, bars, and restaurants for final consumption by consumers. Material flows within this chain involve the transportation of ingredients to breweries, followed by the distribution of packaged beer to various points of sale.

Our project specifically intervenes in the waste management phase, focusing on the treatment and valorization of brewers' spent grain. The goal is to transform this byproduct into a valuable source of proteins, polyphenols, and natural fibers, maximizing its potential within a circular economy framework. By implementing innovative extraction technologies, we aim to utilize the spent grain fully, turning it into a resource that can benefit various industries.

The intervention involves extracting proteins, which can be employed in the food and biotechnology industries, as well as polyphenols, which are antioxidants with promising applications in the pharmaceutical industry. Furthermore, the natural fibers extracted from the spent grain can be utilized in the transformation of plastics and the production of biopolymers, contributing to the development of sustainable materials.

To achieve these objectives, we plan to develop a pilot plant at an experimental level. This facility will serve as a model for future industrial-scale implementations, allowing us to evaluate the economic and technical feasibility of our extraction processes. By converting spent grain into useful inputs, we reduce waste and contribute to creating a more sustainable system that lessens the environmental impact of the brewing industry.

Our project aims to extend the impact of this transformation to adjacent sectors, including the biotechnology sector, where proteins and polyphenols can be applied in creating innovative biotechnological products. The pharmaceutical industry also stands to benefit from natural antioxidants extracted from spent grain, which can be used in dietary supplements and medicinal formulations. Additionally, the plastics transformation industry can integrate the natural fibers from spent grain into the manufacturing of bioplastics, supporting the shift toward more sustainable



materials.

By embracing the principles of a circular economy, our intervention views waste as a valuable resource. Converting brewers' spent grain into multifunctional materials promotes sustainability and opens new business opportunities in key sectors. The proposed pilot plant represents a crucial step toward implementing large-scale circular economy practices, demonstrating the feasibility of integrating industrial waste into a more responsible and efficient economic model.

In summary, this project seeks to innovate within the brewing industry's value chain by valorizing spent grain, transforming it into a multifunctional resource. This approach not only promotes sustainability but also creates new business opportunities across various sectors, contributing to a more sustainable and environmentally friendly brewing industry.

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

Our Circular Sustainability System (CSS) is strategically situated in the waste management and valorization stage of the brewing industry's value chain. This stage traditionally involves handling byproducts and waste materials that result from the beer production process. Specifically, our focus is on the brewers' spent grain (BSG), a substantial byproduct generated during mashing. By positioning our CSS at this critical point, we aim to transform what is typically considered waste into valuable resources, thereby enhancing the overall sustainability and efficiency of the value chain.

Impact on Various Stages of the Value Chain

1. Raw Material Utilization

Current Situation: In the conventional brewing process, raw materials such as barley and hops are used to produce beer, resulting in significant amounts of spent grain as a byproduct. Typically, this byproduct is used as animal feed or discarded, leading to limited resource recovery.

CSS Intervention: Our CSS introduces innovative extraction technologies that convert BSG into valuable compounds like proteins, polyphenols, and natural fibers. This intervention allows for the complete utilization of raw materials, minimizing waste and maximizing resource recovery. By extracting these compounds, we reduce the reliance on additional raw materials for industries that can benefit from



these extracted elements, such as food, biotechnology, and pharmaceuticals.

2. Production Process Optimization

Current Situation: The production process in breweries is primarily focused on beer creation, with byproducts viewed as secondary outputs. This often results in inefficiencies and missed opportunities for resource optimization.

CSS Intervention: By integrating our CSS into the production process, we encourage breweries to adopt a more holistic approach to resource management. Our system not only addresses waste reduction but also optimizes the extraction process, allowing breweries to generate additional revenue streams from byproducts. The ability to extract and repurpose compounds from BSG encourages breweries to re-evaluate their production practices, leading to more efficient operations and a shift towards sustainable practices.

3. Waste Management and Valorization

Current Situation: Brewers' spent grain is commonly used as livestock feed or discarded, which does not fully capitalize on its potential as a valuable resource.

CSS Intervention: Our CSS revolutionizes waste management by transforming BSG into a multifunctional resource. This transformation reduces the environmental footprint of breweries and provides industries with sustainable alternatives. By adopting our system, breweries can transition from a linear waste management model to a circular one, where byproducts are consistently reintegrated into the value chain.

Does the CSS Make the Value Chain More Circular?

Yes, our CSS significantly enhances the circularity of the brewing industry's value chain. By transforming BSG into valuable resources, our system creates a closed-loop process where waste is minimized, and resources are continually reused and repurposed. This approach aligns with the principles of a circular economy, where the emphasis is on sustainable resource management and waste minimization.

Key Contributions to Circularity:

Resource Efficiency: Our CSS maximizes the use of raw materials by extracting valuable compounds from spent grain, reducing the need for additional inputs in various industries.

Waste Reduction: By converting what was previously considered waste into valuable products, our CSS minimizes the environmental impact of breweries and promotes sustainable waste management practices.

Value Creation: The extracted compounds from BSG open up new business opportunities across sectors such as food, pharmaceuticals, and bioplastics, demonstrating that waste can indeed be a valuable resource.



Economic Sustainability: By integrating CSS, breweries can diversify their revenue streams, contributing to economic sustainability and resilience.

Environmental Impact: The shift from a linear to a circular model reduces landfill waste, lowers carbon emissions, and supports the sustainable use of natural resources.

Our CSS strategically situates itself within the value chain of the brewing industry to address and transform waste management practices. By enhancing circularity through resource efficiency, waste reduction, and value creation, our system not only improves the sustainability of the brewing industry but also sets a precedent for other sectors to follow. The adoption of our CSS will lead to a more sustainable, economically viable, and environmentally friendly brewing process, aligning with global efforts to promote circular economy practices.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

The shift towards a Circular Sustainability System (CSS) in the brewing industry significantly impacts key stakeholders, particularly focusing on the roles of L. Pernía as a waste management operator, and Heineken and Estrella Galicia as major breweries and suppliers of brewers' spent grain (BSG). These stakeholders play crucial roles in transitioning from a linear waste management model to a more circular and sustainable approach.

L. Pernía is instrumental in managing and transforming the byproduct of brewers' spent grain into valuable resources such as proteins, polyphenols, and fibers. This transition not only enhances waste valorization but also creates new business opportunities by offering high-quality raw materials for industries seeking sustainable inputs. As a result, L. Pernía can position itself as a leader in sustainable waste management, aligning with global trends towards circular economy practices. The company will need to adapt its operations and invest in new technologies to handle the increased complexity of resource extraction, but this shift will ultimately lead to an enhanced reputation and potential new revenue streams.

Heineken and Estrella Galicia are pivotal in supplying the brewers' spent grain essential for this transformation. By adopting the CSS, these breweries can significantly improve their resource efficiency and sustainability profiles. The system allows them to convert what was previously waste into profitable products, thereby opening up new revenue streams. This enhances their brand image as environmentally responsible companies, appealing to eco-conscious consumers and partners. Furthermore, by collaborating with L. Pernía, Heineken and Estrella Galicia can drive innovation and explore novel applications for the extracted



compounds, thereby gaining a competitive edge in the market.

In addition to the primary stakeholders, the CSS shift also affects biotechnology, pharmaceutical, and plastic manufacturing industries. These sectors stand to benefit from the sustainable materials sourced from BSG, enabling them to meet the growing consumer demand for environmentally friendly products. Regulatory bodies and government agencies are also impacted as they will need to adapt policies and provide incentives to support these circular economy initiatives. Moreover, local communities and environmental organizations will see positive environmental impacts through reduced waste and pollution, further enhancing the brewing industry's sustainability.

In conclusion, the transition to a Circular Sustainability System in the brewing industry is a transformative step that affects various stakeholders, particularly highlighting the roles of L. Pernía, Heineken, and Estrella Galicia. By adopting CSS practices, these companies are not only driving innovation and sustainability within their operations but also setting a standard for responsible resource management. This shift not only enhances the circularity of the value chain but also positions the involved parties as leaders in promoting a more sustainable and eco-friendly brewing industry. Through this collaboration and commitment to sustainability, the stakeholders contribute to creating a more resilient and sustainable ecosystem that benefits all involved and paves the way for a sustainable future.

Please characterise the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

The demonstrator project for the Circular Sustainability System (CSS) involves several key stakeholders, each contributing to and benefiting from the initiative to revalorize brewers' spent grain (BSG) and other byproducts. The primary actors include L. Pernía, Heineken, Estrella Galicia, the Universidad Politécnica de Valencia (UPV), and AIJU. Each has a distinct role and set of expectations from this project.

L. Pernía, as the waste management operator, is focused on utilizing the pilot plant technology developed by UPV to maximize the value extracted from BSG. Their interest lies in transforming this waste into valuable products, such as proteins, polyphenols, and fibers, which can be sold to various industries. This shift involves integrating new technologies and processes but offers significant economic benefits by creating new revenue streams and enhancing L. Pernía's reputation as a leader in sustainable waste management. They expect that successful implementation will prove the process's viability and scalability, solidifying their role in the circular economy.



Heineken and Estrella Galicia, major breweries and suppliers of BSG, are interested in reducing the environmental impact of their operations. By participating in the CSS project, they aim to convert BSG from a waste disposal cost into a valuable asset. The CSS enables them to sell or repurpose BSG, thus enhancing profitability and sustainability. This initiative is expected to improve their brand image and attract eco-conscious consumers and partners. They anticipate that the demonstrator will validate the economic and environmental benefits of a circular approach to waste management, encouraging broader adoption of such practices across the industry.

The **Universidad Politécnica de Valencia (UPV)** is integral to the project through its development of the pilot plant technology. Their interest is in advancing research and demonstrating the practical applications of their innovations in sustainable waste management. The pilot plant serves as a proof of concept for UPV's technology, reinforcing their leadership in environmental engineering and fostering opportunities for future research and industry collaboration. They expect the demonstrator to validate their technology's scalability and impact, showcasing its potential for broader industrial application.

AIJU (Instituto Tecnológico del Juguete) plays a key role by utilizing the revalorized BSG and other waste products to develop new plastics with high renewable content. AIJU's focus is on integrating these sustainable materials into the production of innovative, eco-friendly plastics. By doing so, AIJU supports the circular economy by creating products that reduce reliance on fossil fuels and minimize environmental impact. Their interest is in demonstrating the feasibility of using waste-derived materials in plastic manufacturing and contributing to a sustainable, circular economy. AIJU expects that the project will showcase the viability of these materials for high-quality, renewable plastics, paving the way for more sustainable plastic solutions in various industries.

In summary, the demonstrator project brings together L. Pernía, Heineken, Estrella Galicia, UPV, and AIJU in a collaborative effort to implement a Circular Sustainability System for brewers' spent grain and other byproducts. Each stakeholder has unique interests and expectations: L. Pernía aims to profit from waste revalorization, Heineken and Estrella Galicia seek to enhance sustainability and profitability, UPV focuses on validating their technology, and AIJU is committed to creating innovative, renewable plastics. Together, they anticipate that the demonstrator will validate the circular economy approach, demonstrating its benefits and paving the way for sustainable practices within the brewing industry and beyond.



3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

The solution introduced is a Circular Sustainability System (CSS) that transforms brewers' spent grain (BSG) from a waste product into valuable resources through an innovative pilot plant developed by the Universidad Politécnica de Valencia (UPV). This new practice shifts from a traditional linear waste management approach to a circular model, where waste is revalorized rather than discarded. The pilot plant employs advanced extraction technology to obtain proteins, polyphenols, and fibers from BSG, which can then be used in biotechnology, pharmaceuticals, and plastic manufacturing.

This technology changes interactions among stakeholders by creating a collaborative framework. L. Pernía integrates the pilot plant technology into its operations, shifting from waste disposal to processing BSG into high-value products. Heineken and Estrella Galicia, as suppliers of BSG, move from merely disposing of waste to actively participating in a system that generates economic value from their byproducts. UPV supports the practical application and scaling of their technology, while AIJU uses the revalorized materials to develop new plastics with high renewable content, contributing to a circular economy.

The new technology significantly impacts material flows by redirecting BSG from waste management to resource extraction, creating new flows of valuable materials for various applications. These flows reduce waste disposal needs and promote the use of sustainable materials in plastic production, aligning with circular economy principles. This integration not only provides economic benefits but also advances environmental sustainability by minimizing waste and enhancing resource efficiency.

In summary, the CSS and pilot plant technology represent a major shift towards sustainability in the brewing industry, transforming waste into valuable resources and altering material flows to support a circular economy. This collaborative approach among stakeholders facilitates innovation, enhances resource utilization, and contributes to a more sustainable future.



3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Current waste management solutions in the brewing industry typically involve the disposal of brewers' spent grain (BSG) through methods such as landfilling, incineration, or animal feed. These approaches often treat BSG as a waste product with limited economic value, resulting in environmental impacts and missed opportunities for resource recovery.

In contrast, the Circular Sustainability System (CSS) offers a more innovative and sustainable approach. Unlike traditional methods, the CSS focuses on revalorizing BSG to extract valuable compounds like proteins, polyphenols, and fibers. This process not only reduces the environmental impact of waste disposal but also transforms BSG into high-value resources that can be used in biotechnology, pharmaceuticals, and plastic manufacturing.

Improvements Offered by CSS:

- **Enhanced Resource Utilization:** The CSS converts BSG from a waste product into valuable materials, creating new revenue streams and reducing the need for disposal. This contrasts with current solutions that often overlook the potential value of BSG.
- **Reduced Environmental Impact:** By eliminating or significantly reducing waste through the extraction of useful compounds, the CSS minimizes environmental impacts associated with landfilling and incineration. This leads to a more sustainable waste management practice.
- **Economic Benefits:** The CSS provides economic advantages by turning waste into high-value products. This creates new market opportunities and can lead to cost savings on waste disposal. Traditional methods, by focusing on disposal, do not leverage the economic potential of BSG.
- **Support for Circular Economy:** The CSS aligns with circular economy principles by keeping materials in use and reducing the reliance on virgin resources. Current solutions typically follow a linear model, where waste is simply removed from the system without contributing to circularity.

In summary, while existing waste management solutions primarily focus on disposal, the CSS improves upon these methods by revalorizing BSG into valuable resources, reducing environmental impact, and supporting a circular economy. This approach not only enhances resource efficiency but also offers significant economic and sustainability benefits.



Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

The Circular Sustainability System (CSS) is particularly well-suited to address the challenges associated with managing brewers' spent grain (BSG) and other byproducts from the brewing industry. In a context where efficient waste management and minimizing environmental impact are key priorities, the CSS offers an innovative solution by transforming BSG, traditionally viewed as waste, into high-value resources.

The primary advantage of the CSS lies in its ability to reduce the environmental burden of waste. Instead of relying on traditional disposal methods such as landfilling or incineration, which contribute to pollution and resource loss, the CSS diverts BSG from these processes, converting it into valuable compounds like proteins, polyphenols, and fibers. This transformation not only minimizes waste but also maximizes the use of byproducts, meeting the demand for sustainable solutions in biotechnology, pharmaceuticals, and plastic manufacturing.

Moreover, the CSS addresses economic challenges by turning waste into marketable products, creating new revenue streams, and converting disposal costs into economic benefits. This contrasts with traditional methods that often view BSG as a problem to be solved rather than a business opportunity. By offering an approach that transforms waste into economic value, the CSS provides financial incentives for both breweries and waste management companies.

The CSS is also notable for its alignment with circular economy principles. Unlike linear waste management methods that simply remove material without considering its potential for reuse, the CSS keeps materials within the economic cycle, reducing the need for virgin resources and promoting greater material efficiency. This integration of waste into the production cycle contributes to a more sustainable and circular economy.

The use of advanced technology from the pilot plant developed by the Universidad Politècnica de València (UPV) is another strength of the CSS. This innovative technology enables efficient extraction of resources from BSG, offering a significant improvement over traditional waste management technologies. The CSS's ability to effectively utilize these new extraction processes not only enhances operational viability but also provides scalability that existing methods cannot match.

In summary, the CSS is well-suited to the challenge of managing brewing byproducts by transforming waste into valuable resources, reducing environmental impact, and creating economic benefits. It outperforms existing solutions by improving resource recovery, aligning with circular economy principles, and leveraging innovative



technologies that provide both operational and financial advantages.

3.5 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

The Circular Sustainability System (CSS) is designed to achieve a range of targets across social, ecological, and economic dimensions. Socially, the CSS aims to enhance community engagement and awareness of sustainable practices while also creating new employment opportunities. By involving local communities and generating jobs in the operation of the pilot plant and related industries, the CSS seeks to foster a greater commitment to sustainability.

Ecologically, the CSS targets significant reductions in waste and improvements in resource efficiency. The system is focused on minimizing the volume of brewers' spent grain (BSG) that ends up in landfills or incineration. Instead, it repurposes this byproduct into valuable compounds such as proteins, polyphenols, and fibers. This approach not only conserves resources but also lowers greenhouse gas emissions and other pollutants associated with traditional waste management methods.

Economically, the CSS aims to create new revenue streams by transforming waste into high-value products. It also seeks to reduce waste disposal costs for breweries and waste management companies, thus providing financial benefits. Additionally, the CSS endeavours to open new markets for products derived from BSG, such as sustainable plastics and biotechnological applications, thereby driving economic growth and supporting circular economy principles.

To monitor these targets effectively, various methods are employed. Social impacts are tracked through community surveys that assess awareness and engagement with the CSS, alongside employment statistics that measure job creation linked to the pilot plant and associated industries. Ecological impacts are monitored by keeping detailed records of the volume of BSG diverted from landfills, measuring the quantities of valuable compounds extracted, and conducting periodic environmental assessments to evaluate reductions in greenhouse gas emissions and other pollutants.

Economic impacts are assessed by analysing financial reports to track revenue generated from new products and markets. Cost savings related to reduced waste disposal and operational efficiencies are also evaluated, along with market growth and expansion for products derived from BSG. These monitoring methods provide a comprehensive view of how well the CSS is meeting its targets and ensuring its overall effectiveness.



The demonstrator is expected to have several positive social impacts, including increased community awareness of sustainable practices and job creation in technology and plant operation sectors. However, challenges may arise, such as the need for workforce training and adaptation to new technologies. Ecologically, the CSS offers significant benefits by reducing waste and improving resource efficiency, though it is essential to manage the environmental impact of the pilot plant's operation, including its energy and resource use.

Economically, the CSS provides substantial advantages by creating new revenue streams and reducing waste disposal costs. It also supports the development of new markets for sustainable materials. Despite these benefits, the initial setup and operational costs of the pilot plant and technology development may present short-term financial challenges.

In conclusion, the CSS is well-positioned to achieve its social, ecological, and economic targets through effective waste revalorization and sustainable practices. By employing comprehensive monitoring methods, the demonstrator ensures that it meets its objectives while addressing potential challenges to maximize its positive outcomes.

What are the main KPIs for the Demo considering also these three key aspects (environment, society, economy).

To effectively gauge the success of the Circular Sustainability System (CSS) pilot demonstration, a range of Key Performance Indicators (KPIs) is essential, addressing environmental, societal, and economic aspects.

From an environmental perspective, the waste reduction rate is a crucial KPI, measuring the percentage of brewers' spent grain (BSG) diverted from landfills or incineration. This indicator helps evaluate how effectively the CSS reduces waste. Complementing this, the resource recovery efficiency measures the amount of valuable compounds extracted from BSG compared to the total processed, reflecting the system's effectiveness in utilizing byproducts. Additionally, tracking the reduction in greenhouse gas emissions helps assess the ecological benefits by comparing emissions before and after implementing the CSS. The energy consumption per unit of output is another key metric, indicating how efficiently the system uses energy relative to the quantity of valuable compounds produced, with lower energy use suggesting better environmental performance.

In terms of societal impacts, the community engagement level is a vital KPI, gauging the extent of local awareness and involvement in the CSS through surveys and feedback. This reflects the system's success in fostering community support. The job



creation KPI tracks the number of new positions created as a result of the pilot plant and associated activities, highlighting the economic benefits to the local community. Additionally, the training and development opportunities provided are measured to ensure effective skill-building for employees and stakeholders involved in the CSS, which is essential for its successful implementation.

Economically, the revenue from byproducts assesses the financial gains from selling the valuable compounds extracted from BSG, indicating the system's profitability. The cost savings on waste disposal measures the reduction in expenses related to waste management achieved by the CSS, showcasing its economic efficiency. Evaluating the return on investment (ROI) provides insight into the financial return compared to the initial investment, with a higher ROI reflecting economic success. Finally, market expansion and growth are monitored to understand the development of new markets and applications for the products derived from BSG, illustrating the CSS's potential to drive economic growth.

In summary, these KPIs collectively offer a comprehensive view of the CSS pilot demonstration's effectiveness and impact across environmental, societal, and economic dimensions, ensuring a well-rounded assessment of its success and benefits.



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

One of the main technological challenges we face in the development of the project is related to scaling up the pilot plant we have developed at the laboratory scale to an industrial size. The transition from a pilot plant to a large-scale industrial facility presents several significant difficulties. These include engineering problems related to optimizing processes, controlling quality, and ensuring operational efficiency in an industrial setting.

Specifically, extrapolating the results obtained from the pilot plant to an industrial scale could involve issues such as adapting equipment, managing larger production volumes, and ensuring that processes remain stable and efficient at a larger scale. Additionally, unforeseen challenges may arise related to integrating new technologies and adapting operational procedures to meet industrial standards. Therefore, further research and continued development are likely required to address these issues. This may include detailed studies on process scalability, conducting larger-scale pilot tests, and implementing innovative technological solutions to ensure the system operates efficiently in an industrial environment.

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

No.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

No

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more



profitable or less costly so it can reach a market exploitation stage?

No



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

To advance the Circular Sustainability System (CSS) to a higher level of acceptance and application, several key steps must be undertaken. The current pilot project's primary focus is to design and validate a treatment plant that transforms brewers' spent grain (BSG) waste from the beer manufacturing sector into high-value materials for the plastics and healthcare industries. This involves determining the optimal conditions for extracting active compounds such as hydrolysed proteins, arabinoxylans, polyphenols, and lignin, and assessing the suitability of these fibers for integration into plastic matrices. The demonstrator will initially construct pilot plants at a laboratory scale to extract phenolic compounds and proteins, and to separate and extract lignocellulosic compounds from BSG. These results will then be scaled up to an industrial level following the biorefinery concept, aiming to efficiently process waste and by-products from the brewing sector. An accompanying economic study will evaluate the feasibility of industrial-scale implementation.

To further elevate the CSS, future steps should include refining the extraction methodology for proteins, polyphenols, and fibers, scaling up from laboratory-scale results to a fully operational pilot plant, and addressing any technical challenges. Additionally, further technology research is required to enhance the CSS, focusing on optimizing extraction processes, improving the quality and consistency of the extracted compounds, and developing advanced biobased and recycled plastic formulations. This involves validating these formulations in industrial sectors such as furniture and pallets and understanding how BSG fiber content affects the final material properties, compatibility, and processing. Moreover, a significant future direction is to extend the CSS methodology to other types of agro-food residues. By applying the learned principles and technologies from this project to different waste streams, the CSS can contribute to reducing overall waste generation and fostering a broader circular economy. This expansion will involve adapting the extraction processes and formulations for various types of agro-food byproducts, maximizing resource recovery, and minimizing waste across different industries.

Regarding market readiness, while the CSS is progressing towards industrial application, it is not yet fully prepared for market penetration. The results from the pilot plant and the economic feasibility study will be critical in assessing the system's commercial viability. Additional research and development efforts are needed to finalize the technology, resolve scalability issues, and ensure the CSS meets market



requirements and industry standards.

In summary, advancing the CSS involves optimizing current processes, scaling up pilot plant operations, and conducting further research on material formulations. Future efforts should also include applying the CSS to other agro-food residues to promote waste reduction and a circular economy. While the CSS shows promise, ongoing development is necessary to achieve full market readiness and widespread acceptance.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?**

Table 11: Demo 4 Identified Synergies

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	The vaporization of brewer's spent grain and the pilot plant that processes biowaste has several potential synergies that can be leveraged to optimize both processes. Firstly, the fibrous components and nutrients in the spent grain can serve as an additional source of substrates for the production of polyhydroxyalkanoates (PHA) in the pilot plant, potentially increasing the efficiency and yield of the fermentation process. The spent grain can supplement the volatile solids load, enhancing PHA production, which already has yields of 40% to 70%. Additionally, the active compounds extracted from the spent grain could have applications as additives to improve the properties of bioplastics, or the extraction residues could be processed in the plant to obtain PHA. This not only maximizes the utilization of agro-industrial waste but can also reduce raw material costs by integrating both processes, creating a more sustainable and efficient circular economy system.
DEMO 6	
DEMO 7	
DEMO 8	
DEMO 9	

How do you plan to test and develop those synergies?

To test and develop the synergies between the valorization of brewer's spent grain and the biowaste pilot plant, an experimental approach and collaboration among multidisciplinary teams can be followed. First, a comprehensive characterization of the brewer's spent grain should be conducted to identify its nutrient and fiber content, determining which fractions are most suitable for fermentation and PHA production. Next, pilot experiments can be carried out where the spent grain is incorporated as part of the substrate in the biowaste plant's fermenters, evaluating parameters such as conversion rate, PHA productivity, and the properties of the resulting biopolymer. Simultaneously, methods for extracting active compounds from the spent grain can be tested, analyzing residual by-products for their use in fermentation. It would be important to establish a robust experimental design with appropriate controls to assess the impact of adding spent grain to existing processes. Additionally, the development of simulation models can help predict results on a larger scale. Finally, collaboration with experts in bioprocessing and polymer materials can facilitate the optimization and scaling of these synergies, adjusting operating conditions to maximize the efficiency and sustainability of the integrated process.



Demo 7: Multilayer PET recycling as a secondary raw material for plastics manufacturing.

1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

m-PET is rarely recycled due to the incompatibility between layers and their lack of homogeneity. Now, this waste is delaminated (which entails high environmental problems) and, mostly buried or incinerated, as far as it is selectively collected.

Estimations establish that around 650 K tones m-PET are generated in EU, from which 1'87 Kt would entail the one generated in the Valencian Community.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

Demonstrate a solution to enhance recyclability of food packaging m-PET, in a real environment.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

Mechanical retrieve system for m-PET recycling that boosts its circularity. It acts as a replacement for polyolefin material, thus replacing virgin materials from natural resources.

2. Scope and Territory

2.1 The territorial context

Geographical Scope: What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope?

This solution will be implemented in the Valencian Community (Figure 12). Also, Masoutis (Greece) and Ugrinpack (Hungary) are related to this demo, as they will respectively provide post-consumer and post-industrial packaging material.

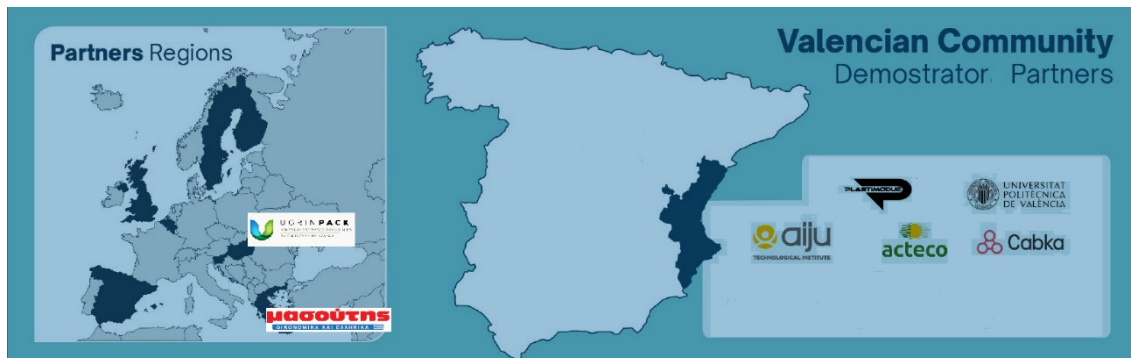


Figure 12 Demo 7 location and partners

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

- m-PET Packaging waste management
- Plastic industry.

2.2 The territorial policy framework

What are the main **policy instruments** for circular economy and the specific **context** of the CSS (e.g., waste regulations). Please list the **main policy instruments**, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin

(EU/national/regional/local).

Derived from the [European Circular Economy Action Plan](#) and the [EU Green Deal](#), Spanish government implemented the **Circular Economy Action Plan 2021-2023: Spanish strategy**¹. Its objective is to increase the recycling and reuse rate of plastics and promote subsequent uses of plastics through recycling and placing them on the market, as well as reducing dependence on virgin fossil raw materials. In terms of waste, it establishes a new regulatory framework through the **Law on Waste and Contaminated Soil**². The Law implements the modifications introduced by [Directive \(EU\) 2018/851 of the European Parliament and of the Council of 30 May 2018](#), which amended Directive 2008/98/EC on waste as well as the so-called Directive on single-use plastics, i.e. [Directive \(EU\) 2019/904 of the European Parliament and the Council of 5 June 2019 on reducing the impact of certain plastic products on the environment](#). This focuses on waste reduction, increased recycling rates, and the promotion of a circular economy.

Another law, in which this Demo is based, is the **Packaging and Packaging Waste Directive (PPWD) - Directive (EU) 2018/852**, updated measures designed to:

- prevent the production of packaging waste, and

¹ Plan de Acción de Economía Circular 2021-2023: Estrategia española de economía circular, Ministerio para la transición ecológica y el reto demográfico (MITECO), mayo 2021, NIPO: 665-21-071-3 [online: https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/economia-circular/plan_accion_eco_circular_def_nipo_tcm30-529618.pdf]

² Ley 7/2022, de 8 de abril, de residuos y suelos contaminados para una economía circular, «BOE» núm. 85, de 09/04/2022. Entrada en vigor: 10/04/2022, BOE-A-2022-5809 [online: <https://www.boe.es/eli/es/l/2022/04/08/7/con>]

- promote the reuse, recycling and other forms of recovering of packaging waste, instead of its final disposal, thus contributing to the transition towards a circular economy*.

Additionally, Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishes a framework for the setting of eco-design requirements for energy-related products.

These policies are tailored to the specific needs and circumstances of the region. Here are some of the main policy instruments and initiatives pertinent to circular economy and plastics in the **Valencian Community**³:

1. Legislation and Regulations:

- Law 5/2022, of November 29, on **waste and contaminated soils for the promotion of the circular economy in the Valencian Community** [<https://www.boe.es/buscar/doc.php?id=BOE-A-2023-3348>].
 - Derived from this: the **Comprehensive waste plan of the Valencian Community (PIRCV)**⁴, constitutes the instrument director and coordinator of all actions carried out in the Valencian Community in terms of waste management. At present, it is in the process of public consultation for review.
- Law 6/2022, of December 5, on **climate change and ecological transition**, establish the necessary legal framework that allows guarantee, in the medium and long term, an orderly transition of the Valencian economy 'towards a low-carbon economy, competitive, innovative, efficient in the use of resources and resilient to climate'

2. Extended Producer Responsibility (EPR):

- This is regulated in the "*Special tax on non-reusable plastic containers*", established in the law on Waste and Contaminated Soil^[2].
- In the Valencian Community, it is collectively managed mainly through [Ecoembes](#). Although currently other companies are being

³ Rosa Moreno, Juan, Valencian Community: new legal framework of the ecological transition, Yearbook. Environmental Policy Observatory 2023 [Online: https://www.boe.es/biblioteca_juridica/anuarios_derecho/abrir_pdf.php?id=ANU-O-2023-10083900866]

⁴ DECRETO 55/2019, de 5 de abril, del Consell, por el que se aprueba la revisión del Plan integral de residuos de la Comunitat Valenciana. [2019/4208]. DOGV No. 8536, of April 26, 2019. (Department of Agriculture, Environment, Climate Change and Rural Development) [online: https://dogv.gva.es/datos/2019/04/26/pdf/2019_4208.pdf].



formalized such as CSEPR (Collective Systems of Extended Producer Responsibility, SCRAP in Spanish).

3. Economic Instruments:

- **Taxes and Levies:** *Special tax on non-reusable plastic packaging*^[2].

Subsidies and Grants: There are Four main organisms, apart from being a **CCRI Fellow**, aiming the consolidation of the Valencian Community as a circular economy leader, and the **European Commission** co-founding:

- **Valencian Institute of Competitiveness and Innovation** (IVACE+i) which has, among others, the aim of establishing and managing the support for the creation, modernization and internationalization of companies and the Network of Technological Institutes of the Valencian Community, in business R&D&I.
 - Merged with the previous the **Valencian Innovation Agency** (AVI) constituted an innovation Strategic Innovation Committee in the Circular Economy. It is made up of independent experts from the business, scientific and technological sector of the Valencian Community, and whose purpose is to study and prioritize the challenges and opportunities that the Circular Economy model harbours for the productive system of the Valencian Community.
- The **Department of Innovation, Industry, Commerce and Tourism**
- The **Climate-KIC Spain:** Creation of the group of Innovation and Circular Economy Leaders of the Valencian Community, and whose purpose is to make visible, promote and generate awareness about the sustainability and benefits for society and the environment of the new circular economy model, and in particular, in the Valencian Community.

4. Public Procurement Policies:

- The law 5/2022 of November 2022, in its article 34, establish the requirement for approving a sustainable public procurement plan with the objectives of preventing waste and promoting the circular economy.
- Regulated in the Decree 118/2022, of August 5, of the Consell, by which regulates the inclusion of social responsibility clauses in public procurement and in calls for aid.



5. Research and Innovation:

The Smart specialization strategy of the Valencian community, RIS3, is a regional strategic plan for development that is characterized by:

- Focus political support and regional investments on key priorities, challenges and needs for knowledge-based development;
- Build on the strengths of each region, competitive advantages and potential for excellence;
- Support both technological innovation and practice-focused innovation, and aim to stimulate private investment;
- Fully involve all stakeholders and stimulate innovation and experimentation.
- Be evidence-based, and include robust monitoring and evaluation systems

Additionally, the [Valencian Community Industry 4.0 Agenda](#) is built as a regional strategy, coordinated by the IVACE. It aims to evolve the productive model of the Valencian Community towards the concept of a new sustainable, intelligent and integrative industry. It will be achieved through digitalization and through the aligned action and effective collaboration of the key agents of the Valencian Innovation System, public and private, in a context of global action.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices.

Described in the section above

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

The material concerned in this demo is m-PET (multilayer PET) from food packaging. This waste is mainly generated such as urban waste. Nowadays, ECOEMBES is the main recycler that carries out a selective collection of this waste. Subsequently this material is delivered to other companies that try to recover this polymer.

Currently the main system to recover it is a mechanical process (delamination) or a thermal



process (incineration).

Related to quantification, estimations establish that around 650 K tones m-PET are generated in EU, from which 1'87 Kt would entail the one generated in the Valencian Community.

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

- Public administrations:

Within Europe, we can find the following:

1. [European Circular Economy Stakeholder Platform](#)

The main related public organisms of the Valencian Community are:

1. [Valencian Community Foundation European Region](#)
2. [Economic and social committee](#) (DESCV)
3. [Valencian energy use of waste](#) (VAERSA)
4. [Mediterranean Environmental Studies Centre](#)
5. [Valencian Foundation for Excellence in Research](#).
6. [Strategic Committee for Innovation in Circular Economy](#)
7. [Innovation and Circular Economy Leaders of the Valencian Community](#) (Climate-KIC)

- Industry & Business:

On the European and National Panorama, we can find initiatives such as, that provide a holistic view on the circular economy and I+D+I activities performance:

1. [European Commission: Closing the loop - An EU action plan for the Circular Economy](#).
2. [COTEC Foundation](#).

Focusing on the Valencian Community panorama, we can find groups and companies as the related in the following **¡Error! No se encuentra el origen de la referencia..**



Table 12: Industry & Business Stakeholders within the Valencian Community

Plastic Recyclers:	ACTECO IBERRESINAS A selection of those .
Plastic products Manufacturers:	U's database (109 plastic processing industries, 125 toys manufacturers, 30 childcare companies, 10 raw materials providers) Others arising.
Federations & Associations	Petcore Europe. ; Spanish Association of Industrial Plastics (ANAIP) ; Spanish Plastic Centre (CEP) ; CEOE; National Association of Public Environmental Companies.(ANEMPA) ; Business confederation of the Valencian community (CEV) ; Valencian association of plastic entrepreneurs – AVEP ; Packaging Innovation Cluster ; Spanish Association of Toy Manufacturers (AEFJ) ; Foia de Castalla Business Association (IBIAE) ; Valencian Association of Entrepreneurs (AVE) ; Alicante Provincial Plastics Association (A.P.P.A) ; Economy of the common good – Valencian Association

- Civil Society

Awareness actions taken by environmental organisations may be taken into account for collaboration with Demo 7.

1. [Ecoembes](#) - non-profit environmental organization- develops campaigns addressed to the civil society related to domestic packaging.
2. The "[Environmental Education Centre of the Valencian Community](#)" (CEACV) make awareness campaigns within the "[European waste prevention week](#)". They also have a [campaign called "Fent Camí"](#) (making way) addressed to public employees that have as a reference de Sustainable Development Objectives (ODS) of the Agenda 2030. Others addressed to [schools as Zero waste or consumers such as "with great pleasure, I consume just enough"](#).
3. "[Crea: consorci de residuos](#) – waste consortium-" is the public entity responsible for the treatment, recovery and elimination of waste generated in the 14 municipalities (not AIJU's but surrounding area). They perform [specific awareness campaigns](#).
4. [Silvoturismo](#) is a company dedicated, among others, to environmental education, environmental marketing, environmental volunteering and the organization of activities related to the environment. Within environmental marketing, since they design communication, awareness and environmental education strategies, and implement environmental improvement plans in companies. They perform activities with schoolchildren and support Town Halls to develop their environmental improvement plans and local waste plans.



- Academia

The main universities within the Valencian Community are the following:

1. Valencian University
2. Polytechnic University of Valencia
3. University of Alicante
4. Jaume I University
5. Miguel Hernandez University of Elche

- RTOs

The Technology Institutes Network of the Valencian Community ([REDIT](#)) collaborates with companies through their associated Technology Institutes (among which AIJU is included) to generate R&D&I and enhance competitiveness. We provide companies with advice on innovation and external support.

The partner AIDIMME is researching on the **TRIS project**. Transition Regions towards Industrial Symbiosis. European Interreg project in which AIDIMME and IVACE participate together with other European partners, whose objective is to share the best practices in Industrial Symbiosis and support public authorities and organizations in the efficiency of use of resources and competitiveness of their SMEs.

- NGOs

ONGs that could be related to the Demo could be the following:

1. [Waste and Resources Action Programme](#) (WRAP)
2. [Amigos de la Tierra](#).
3. [ONGAWA. Engineering for human development](#).
4. [REEDES. Spanish network of development studies](#).



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

The current value chain of these materials is the established in the following Figure 13. As can be seen in red, this project addresses the mechanical reprocessing of the recyclates to check their suitability in the manufacturing of specific products. In an indirect way this Demo circularity can also contribute to the inconsistencies in the collection, sorting and recycling of PET around Europe, as having additional economic value will enhance and improve it.

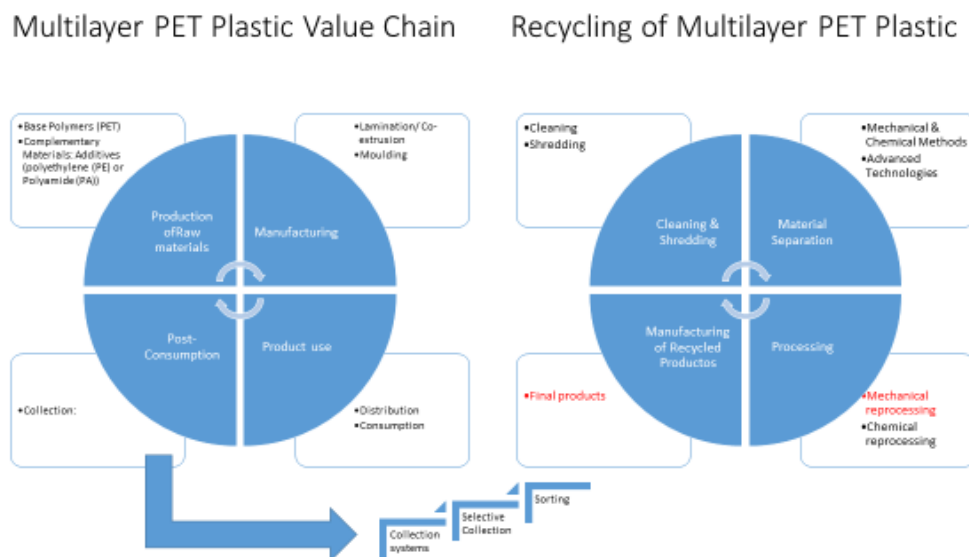


Figure 13 Current Value Chain for m-PET materials

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

The base-materials used for this Demo 7, at this stage of the state-of-the-art lays on upcycling the value of the m-PET recycling, most of which is incinerated and/or landfilled.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift. Please characterise the main actors and their interests in the demonstrator. How are they affected? What are their expectations?

The following Figure 14 displays the main stakeholders of the CircSyst Demo 7, their interests, potential affections and expectations they may have from this Demo outputs.



Figure 14 Main Demo 7 stakeholders, a) their interest, b) affections and c) expectations

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

The solution provided by this Demo is a mechanical recycling system for recycling m-PET that enhances the circularity of this waste, acting as a substitute for polyolefin material. This promotes recycling and replaces virgin materials derived from natural resources.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

Recycling multilayer PET is challenging due to its composite structure. Solutions being developed, include **Mechanical Recycling**, using selective dissolution or mechanical delamination technologies, **Chemical Recycling** through: Glycolysis, methanolysis or hydrolysis, **Solvent-Based Recycling, Pyrolysis, Depolymerization & Repolymerization** or the use **Compatibilizers** and therefore the usual process. Some **Hybrid Approaches** combining mechanical and chemical methods are also applied. **R&D Efforts** are focusing on developing new, easier-to-recycle products and materials and biodegradables.

Pros & cons of previous methodologies are based in providing a value to this m-PET that is difficult to recycle, although environmental inefficient performance of the delamination processes are relevant.

This methodology takes profit of the previous established pros, upcycling the waste derived from m-PET, while providing a recycling methodology that avoids the use of solvents or other products for their recycling. The resultant material performs as polyolefins, thus avoiding the use as raw material of non-renewable materials.

3.4 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

Environmental Impact

In 2020, Europe collected 208 kilotons (Kt) of PET tray waste, with 47% being multilayer PET (m-PET). This results in a 21% recycling rate, translating to approximately 470 Kt of m-PET available for recycling.

In the Valencian Community in 2018, the average packaging waste collected per person was 11.2 kg, with 21.6% deemed unsuitable. About 4.28% of total waste was m-PET, totalling around 1.869 tons.

A 75% implementation rate of blending m-PET with virgin polyolefins could provide 627 Kt of feedstock, reducing dependence on fossil fuels.

Potential m-PET Value Chain Turnover:

- **Short-term (Valencian Community/year):** 1.87 Kt m-PET leading to 2.49 Kt total.
- **Medium-term (Consortium countries/year):** 139.26 Kt m-PET leading to 185.68 Kt total.
- **Long-term (Europe/year):** 470.00 Kt m-PET leading to 626.67 Kt total.

ANARPLA's report shows Europe consumed 4.99 Mt of post-consumer recycles, with 2.122 Mt coming from packaging. The reported recycling capacity is 8.5 Mt, indicating room for improvement.

Economic Impact

Economic potential and broader benefits of substituting polypropylene (PP) with a new material (m-PET), by September 2023 it was priced at 1,580 €/ton. Economic estimations suggest substantial financial gains and job creation at different implementation stages:

1. **Economic Impact:**

- **Short-Term:** €9.2 million
- **Medium-Term:** €108.6 million
- **Long-Term:** €494.2 million

2. **Job Creation:**

- Approximately 2,358 jobs (direct and indirect) are projected due to the economic multiplier effects detailed in Table IV.



Social impact

Broader social benefits include:

- Enhanced participation in circular economy practices and an increased recycling rate, especially through targeted citizen involvement in waste collection.
- Improved knowledge transfer across EU cities and regions, facilitating easier replication and scalability of circular economic solutions.
- Contribution to European environmental initiatives including the Circular Economy Action Plan and European Green Deal, by reducing dependence on virgin materials and increasing recycling rates.

In summary, the CSS not only promises significant economic and job growth but also aligns with broader environmental and policy objectives.



4 Potential Barriers and Risks

General barriers for the CSS are established in Table 9 of the Grant Agreement. Specifically for this project

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

The main technological barrier of this Demo is the material compatibility. It should be ensured that the formulations developed are able to adapt to current processes and machinery, while the final product achieves a good performance and the required mechanical properties.

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

The main barrier within this demonstrator is the performance of the products manufactured with the new materials. It is expected to be overcome within Result 1 (R1).

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

Policy barriers would be set on the policy trend addressed to the simplification of the materials. In this case, the m-PET is fully employed, what would be a potential constrain for waste management policies and regulatory compliance.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

Regulatory barriers would be related to standardisation and certification issues.

Extensive testing to check the meeting of the demonstrators and process specifications and requirements are applied.

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

Business barriers are set on the materials price viability, raw material availability and technical performance.



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

TRL, MRL, BRL

The increasing of the TRL within the proposal will improve the materials and related products performance. The market acceptance is also addressed while the potential business model is set in R22, within WP7 will contribute to that.

Transversal WPs such as LCA within W1, WP5 & WP6 will support the spread of the knowledge and the awareness, co-creation, etc. of the results of the demo.



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos?

How do you plan to test and develop those synergies?

Table 13: Demo 7 Identified Synergies

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	.
DEMO 6	
DEMO 7	Addressing the mechanical recycling of m-PET
DEMO 8	Providing post-consumer m-PET
DEMO 9	Re-Designing products with m-PET

DEMO 8: Enhancing Packaging recycling processes by involving consumers.



1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

EU member states have increased plastic waste recycling but also production. In 2021, the average EU resident generated 36.1 kg of plastic packaging waste. Overall, 16.13 million tons of plastic waste were produced in the EU, with 6.56 million tons recycled. Non-recycled plastics cause significant economic and environmental damage, with 22 million tons ending up in land, rivers, and oceans in 2019. The EU aims to reduce plastic waste by setting goals for recycled content in plastic bottles (25% by 2025, 30% by 2030) and reducing packaging waste by 5% by 2030, 10% by 2035, and 15% by 2040. Despite these efforts, much collected plastic waste is exported for processing outside the EU due to local capacity, technology, and funding shortages. Demo 8 gives communities initiatives to recycle plastic waste and contribute to the co-development and co-design of secondary life products, while developing social manufacturing concepts under circular economy models.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

To address the vast plastic waste and help increase recycling quantities, Demo 8 aims to initiate circular approaches to the sustainable valorization of food waste plastics through social inclusion. This involves including consumers in a circular economy approach by recycling their plastic waste and creating secondary life products, allowing them to become prosumers with their own plastic trash.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

Demo 8 envisions transforming plastic waste management by engaging consumers in recycling and creating secondary life products, thus promoting a circular economy. This change is crucial for reducing environmental pollution, conserving resources, and fostering sustainable consumption patterns. It will be achieved by leveraging MASOYTIS, one of the largest retail companies in Greece, and its logistics for collecting and recycling plastic food packaging. Consumers will deposit their plastic waste in designated bins and earn credits on their loyalty cards. They can then use these credits to access CERTH's additive manufacturing lab, where they can receive 3D-printed parts made from their recycled plastic waste. This initiative directly supports SDGs such as Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), and Life Below Water (SDG 14), aligning with the EU Green Deal's objectives of waste reduction and resource efficiency.



2 Scope and Territory

2.1 The territorial context

Geographical Scope: What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope?

Locally, regionally, and nationwide, MASOYTIS will leverage its extensive supermarket network and partnerships with food industries and associations to transfer knowledge of best practices to consumers, empowering them to become prosumers.

Demo 8 aims to increase community initiatives for recycling key plastics such as LDPE, PP, PET, and m-PET, while reinforcing digital manufacturing through 3D printing technologies.



Figure 15: Geographical Scope of 8

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

The innovation proposed in Demo 8 significantly impacts multiple sectors, particularly the food packaging industry, the plastic industry, and ICT-digital manufacturing. By focusing on plastics such as LDPE, PP, PET, and m-PET, the initiative mainly addresses waste management within the food packaging sector. Additionally, it encourages sustainable practices within the plastic industry by promoting the circular economy and reducing plastic pollution. Furthermore, the integration of digital manufacturing through 3D printing technologies enhances the potential for creating new products from recycled materials, thus fostering innovation and efficiency in manufacturing processes.

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

The main policy instruments supporting the circular economy actions that Demo 8 represents include The European Green Deal, the EU Waste Framework Directive (2008/98/EC) which prioritizes waste prevention and recycling, the EU Plastic Strategy (2018), aimed at reducing plastic waste and promoting sustainable alternatives, the Circular Economy Action Plan (CEAP) (2020) that accelerates the transition by encouraging innovative circular business models and establishing regulatory measures, the National Waste Management Plans (NWMP) which set specific recycling targets, the Extended Producer Responsibility (EPR) Schemes that hold producers accountable for product lifecycle management and finally the Green Public Procurement (GPP) which promotes sustainable purchasing by public authorities, and Regional Circular Economy Strategies tailor initiatives to local needs. For the implementation of policies mentioned above, the following national laws come into play

- National Law 4819/2021 – Complete framework for waste management. Integration of Directives 2018/851 and 2018/852 of the European Parliament and the Council of the European Union (30/05/2018) for the amendment of Directive 2008/98/EC on waste and the Directive 94/62/EC on packaging and packaging waste, organizing framework of the Hellenic Recycling Agency (HRA/EOAN), provisions for plastic products and the protection of the environment.
- National Law 4685/2020 – Modernisation of environmental legislation, integration of Directives 2018/844 and 2019/692 of the European Parliament and the Council of the European Union, and other provisions.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices



Level	Regulation	Requirements
EU	EU Circular Economy Action Plan (European Commission).	It promotes the transition to a circular economy. Promotes the reuse and recycling of materials, which is essential for the valorisation of bagasse as a secondary raw material.
EU	Waste Framework Directive (2008/98/EC) (European Parliament and Council of the EU).	It establishes the waste hierarchy, prioritising prevention and recycling. It is key to encouraging the recovery of waste such as bagasse instead of disposal.
National	Law 4819/2021	Complete waste management framework. Integration of EU Directives.
National	Law 4685/2020	Modernisation of environmental legislation.
National	Circular ΥΠΕΝ/ΔΔΑ/8437/176	Implementation of article 85, paragraph 1, of Law 4685/2020 for the collection and transportation of non-dangerous waste.
EU	EU Circular Economy Action Plan (European Commission).	It promotes the transition to a circular economy. Promotes the reuse and recycling of materials, which is essential for the valorisation of bagasse as a secondary raw material.

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

The demo focuses on the material flow of plastic waste generated from food packaging, specifically targeting plastics such as LDPE, PP, PET, and m-PET. The flow begins at supermarkets, where consumers deposit their plastic waste into specific recycling bins tailored to the requirements of Demo 8. This waste is then collected and transported to recycling facilities. MASOYTIS will utilize its logistics to transport this plastic waste to the recycling facilities. At these facilities, the plastic waste is sorted, cleaned, and processed into high-quality recycled pellets and granules. These new forms of recycled plastic will be used by CERTH to create new products for MASOYTIS consumers, contributing to the recycling process. The goal is to promote a circular economy. The processed plastics can be employed in various applications, such as manufacturing new supermarket trolleys, baskets, and more.



The main actors involved along the value chain include consumers (as prosumers), supermarkets (like MASOYTIS), waste management companies, recycling facilities, and product manufacturers. This integrated system not only reduces plastic waste but also fosters sustainable consumption and responsible production practices.

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

Recyclers and recycling companies (DION S.A., ELDIA S.A., etc.), as well as academics involved in formulation research, such as chemical engineers, chemists, and environmental engineers, play crucial roles in this initiative. Additionally, stakeholders can include professionals related to information technologies, innovation spaces, and actions, including makerspaces (e.g., OK!Thess), competence centres (e.g., I4byDesign Competence Centre), the chemical and food packaging industry (e.g., Hatzopoulos S.A., Thrace Plastics Holding and Commercial S.A.), 3D printing labs, consumers who will act as prosumers, supermarket chains, and store chains.

3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

The existing value chain for plastic waste, particularly from food packaging, typically follows these stages: 1) Generation: Plastic waste is generated at the consumer level, 2) Collection: Consumers deposit their plastic waste into recycling bins, 3) Transportation: The collected waste is transported to recycling facilities, 4) Recycling: At recycling facilities, the plastic waste is sorted, cleaned, and processed into high-quality recycled pellets or granules, 5) Manufacturing: These recycled materials are then used by manufacturers to produce new products.

Our intervention occurs primarily at the collection and recycling stages of this value

chain. By engaging consumers as prosumers, we facilitate the direct deposit of plastic waste into customized recycling bins at supermarkets. Additionally, our initiative proposes creating opportunities for consumers to contribute to the recycling process in places such as open innovation centers, open maker spaces, one-stop shops, competence centers, and digital hubs. This approach encourages active participation and collaboration in the recycling process, fostering a more sustainable circular economy.

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

Our Circular Sustainability System (CSS) is situated primarily at the collection and recycling stages of the plastic waste value chain, particularly focusing on plastic waste from food packaging. By engaging consumers as prosumers, we facilitate direct deposits of plastic waste into customized recycling bins at supermarkets and create initiatives within open innovation centers and maker spaces. This involvement not only enhances the efficiency of waste collection and processing but also encourages sustainable behaviors among consumers. As a result, our CSS significantly contributes to making the value chain more circular by ensuring that more plastic waste is recycled and repurposed into new products, thus reducing environmental impact and promoting resource efficiency.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

Please characterise the main actors and their interests in the demonstrator. How are they affected. What are their expectations.

The stakeholders involved in the Circular Sustainability System (CSS) shift include:

Consumers (Prosumers): These individuals play a dual role by both consuming and contributing to the recycling process. Their interest lies in sustainable practices and the opportunity to earn rewards (such as loyalty points) for recycling.

Supermarkets (e.g., MASOYTIS): As collection points for plastic waste, supermarkets have a vested interest in promoting sustainable practices to enhance their corporate social responsibility (CSR) image. They benefit from increased foot traffic and customer loyalty as consumers engage in recycling initiatives.

Waste Management Companies: These entities are responsible for collecting and transporting plastic waste to recycling facilities. Their interest is in efficiently managing the logistics of plastic waste, maximizing recycling rates, and reducing contamination in collected materials.

Recycling Facilities: These facilities focus on processing collected plastic waste into high-quality recycled materials.

Manufacturers (e.g., DION S.A., ELDIA S.A., Thrace Plastics Holding and

Commercial S.A., etc.): Companies that produce new products from recycled materials.

Academic Institutions (e.g., AUTH) and Research Organizations (e.g., CERTH): These entities can provide expertise in material science, recycling technologies, and sustainability practices.

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

The solution introduces a new practice where consumers become prosumers, actively participating in the recycling process by depositing plastic waste into specialized bins and creating secondary life products through 3D printing. The technology involved includes recycling systems and 3D printing labs, promoting at the same time circular economy.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

Our Circular Sustainability System (CSS) improves upon existing solutions by actively engaging consumers as prosumers, allowing them to participate in recycling and product manufacturing. Unlike traditional methods, our approach integrates advanced recycling technologies and 3D printing, resulting in higher recycling rates and the creation of secondary life products. Consumers are also motivated by the benefits of digital manufacturing and 3D printing in the recycling process, such as customization, waste reduction, cost-effectiveness, material recovery, and design innovation. Additionally, they are motivated through the use of digital technologies, such as the MASOYTIS loyalty card, which allows them to collect points as rewards for their participation.



3.5 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

Demo 8 aims to increase recycling rates, reduce plastic waste, and promote sustainable consumption practices. Monitoring can be achieved through key performance indicators (KPIs) such as the volume of plastic waste recycled and the number of consumers participating as prosumers. Social impacts include enhanced consumer awareness and engagement regarding waste management, increased environmental consciousness, and demand for recycled products. Demo 8 focuses on reinforcing recycling of plastic materials at both regional and national levels while motivating consumers to embrace new creative manufacturing methodologies through rapid prototyping. This initiative will strengthen the recycling industry by utilizing advanced materials and enabling complex designs.

4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

Regarding our CSS, one significant issue is the need for collecting, sorting, and processing technologies to efficiently handle various types of plastic waste (LDPE, PP, PET, m-PET) and ensure high-quality recycling outputs. Additionally, integrating 3D printing technology for manufacturing secondary life products from recycled plastics requires further research to optimize material properties and ensure proper printability with the desired mechanical properties. To overcome these barriers, further research and development are essential, particularly in enhancing recycling processes, materials processing, and 3D printing parameters.

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

No.

Policy barriers



What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

No.

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

Marking of packaging regarding recyclability is not mandatory and is not regulated by any legislation, so it may lack reliability on some occasions. Consequently, collection and sorting of different types of plastic packaging by consumers will be restricted in a proportion of the available products distributed on the market and an additional sorting process by specialized machines will be required.

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

Considering circular economy policies in EU, exploitation of plastic waste could not be regarded as a too risky investment, but profitability mostly depends on the market value of the new products that are going to emerge through this process.



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

To bring our CSS to a higher level, the following steps are needed:

Further Technology Research: We need to advance technologies for collecting, sorting, and processing various types of plastic waste (LDPE, PP, PET, m-PET) to ensure efficient recycling and high-quality outputs.

Stakeholder Engagement: Actively engaging with stakeholders, including consumers, industry partners, and policymakers, to educate them on the benefits of our CSS and promote the concept of consumers becoming prosumers who create secondary life products.

Reward System: Development of a reward system to motivate consumers to participate in our CSS.

The product aims to improve Masoutis Cycling Economy Performance, by creating a new methodology that encloses new recycling processes that involves products with difficulties in recycling, as well as a significantly higher consumer involvement. At the end of the demo 8 we aim to:

- Educate European consumers about recycling
- Improve our technical experience in multiple plastic type recycling
- Find new strategical partnerships in recycling, sorting, and pellet regeneration
- Engage our customers in cycling economy activities through campaigns in our stores
- Endorse consumers with novel useful materials from their own plastic waste
- Create knowledge and technical about 3D printing of recycled materials



6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? **How do you plan to test and develop those synergies?**

Table 14: Demo 8 Identified Synergies

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	
DEMO 6	
DEMO 7	A part of the post-consumer m-PET fraction will be transferred to Dem ES-7 for mechanical recycling, where it will be cleaned, shredded, melted, and extruded into new pellets. These high-quality recycled m-PET pellets can be used for various applications, such as producing new plastic baskets. Some of the processed m-PET will be sent to CERTH for use as a feedstock material for 3D printing or as an additive in other plastics to improve their mechanical properties. This process not only reduces waste but also supports a circular economy by continuously repurposing materials.
DEMO 8	
DEMO 9	

How do you plan to test and develop those synergies?

MASOYTIS logistics center supports the company's 379 stores and 339 supermarkets with an on-site packaging recycling center. This enables MASOYTIS to collect and manage large quantities of various plastics, such as m-PET. CERTH will perform the recycling processes, develop 3D polymer filament from the produced plastic pellets, and support the creation of 3D-printed parts in supermarkets in cooperation with customers.

Demo 9:

Implementing sustainable packaging solutions by eco- design



1. The idea in brief

Problem Addressed or Need Detected: Briefly describe the problem or need addressed by your CSS.

Packaging is needed to maintain the quality and safety of food products to ensure their protection during transport/logistics, to extend shelf life and to reduce (food) waste. This is the key point to keep in mind.

However, due to the amount of packaging (thus the amount of waste) used, it is a must to look for sustainable, eco-friendly solutions. More producers have realized this fostering eco-innovation in the packaging industry.

Hungary has a well-developed policy and legal framework for waste management, mainly driven by EU requirements. It has taken steps to improve material management, but still has a lot to do to foster the transition to a circular economy. There are positive waste management trends: decoupling of waste generation from economic growth, increased recycling and recovery rates, and decreased use of landfilling. Hungary, despite some changes in the waste management systems, still landfill relatively large amounts of municipal waste (50% or more), and their recycling rates are lagging behind the EU-27 average.

Moreover, the use of plastics plays a significant role in the packaging industry in Hungary, plastic packaging waste is more than 30 % (47.5 kg per capita) of all packaging waste. The recycling rate of plastic packaging was only 24.9 % (2020) compared to the 50 % to be reached by 2025 and 55 % by 2030. In Hungary each year more than 5800 t of composite packaging waste is generated which currently could not be recycled due to the complexity of the materials.

However, due to the challenges we face globally (increasing amount of packaging waste, overuse of primary resources, loss of biodiversity, climate change etc.) and due to the stricter regulations, EU directives affecting the companies' directly (extended producers' responsibility, new packaging and eco-design directive, SUP directive, ESG related obligations) it is already a must to look for sustainable, eco-friendly solutions. More producers have realized this fostering eco-innovation in the packaging industry.

Solution Proposed: Briefly describe what is your solution and how does it solve the Problem/need addressed.

Taking into consideration the aforementioned issues, the solution proposed by the Hungarian DEMO initiative is to help the packaging sector and the food producer companies finding those sustainable packaging solutions that provide maximum protection for the food covered with it, and are totally recyclable and contain only the necessarily needed amount of material.



So during our DEMO9 activities, the design phase of packaging will be in the centre of attention. 10 food producer companies are currently involved as stakeholders in co-designing, simplifying, and greening their food packaging. During the project the working groups will focus on a minimum of 15 selected products whose packaging will be eco-designed.

The objectives of DEMO9 are the followings:

- Demonstrating alternatives to plastic food contact packaging materials
- Simplification of food contact packaging to promote mono-material solutions instead of multilayer plastics. With this concept in line with the circular economy related principles – packaging will be lighter (less material used) and recycling rates could be also increased – avoiding the waste of secondary raw materials.
- Identifying commercially viable solutions that could be applied in the whole value chain (from production, through retail, till waste treatment)

Since the analysis and redesign of the value chain of production, packaging, logistics and retail sales of critical food products might be needed in this respect, close cooperation with the pilot companies is crucial during the whole duration of the project.

Based on the criteria defined by the food producers – the alternative packaging material is demonstrated, then comes the complex testing and validation process:

- Economic analysis,
- Test rolls durability test (length depending on the shelf life of the products),
- Test production – inner pilot analysing the effect on producing capacities (like production lines, scrap proportion, maintenance need)
- Production optimization
- Communication towards customers & retail

By the end of the project, at least 2-3 (out of the 15) products will use the suggested new packaging material in actual production also appearing on the shelves of the supermarkets. The results and the acceptance by the customers & the retail sector could be analysed as well.

Short introduction to the demonstrator: What is the change that you envision and why is it important to achieve that from a societal/economic/environmental perspective. Does it have a direct link to specific SDGs or Green Deal objectives?

Since in Demo9 Hungarian partners will work together with the business sector (namely food producer companies), the societal, economic and environmental perspectives should be identified on company level, as well.

There are many benefits for food production companies to participate in the Demo relevant from both sustainability and economic perspectives.



Innovation and Competitiveness

Within the framework of the project, by testing recyclable, sustainable raw materials, innovative products can be developed that can provide a competitive advantage meeting the ever-increasing sustainability related demands and can contribute to the company's innovation potential.

Cost reduction

The use of recycled raw materials and alternative packaging materials can reduce raw material procurement costs in the long term. In addition, the lighter packaging materials result in less EPR fees and product fees and introduction of waste reduction technologies can reduce waste management costs, thereby improving the company's financial efficiency.

Environmental Benefits

By using more sustainable production processes and raw materials, ecological footprint could be decreased on company level and adding up the effect on regional level, as well resulting in the protection of the environment and the preservation of natural resources.

Regulatory Compliance

The experience and technologies gained during the project can help to comply with current and future environmental regulations. Preparing for stricter sustainability standards can be a real competitive advantage in the market.

Social Responsibility and ESG (Environmental, Social, Governance) Aspects

Promoting sustainability and the circular economy can help companies achieve their ESG goals. Taking ESG aspects into account not only improves environmental protection performance, but also positively influences the company's social perception and corporate governance practices. Sustainability initiatives contribute to increasing the company's reputation and strengthen the confidence of consumers and investors.

On environmental side generally, the main benefits are the followings: the simplification of packaging (less packaging, monomaterial packaging instead of complex, multimaterial packaging that hinders recyclability) and the identification of alternative packaging materials could lead to more sustainable solutions: less amount of primary materials used, increased recyclability, waste reductions. By reducing the need for new fossil fuel-based plastics, it also reduces the greenhouse gas emissions associated with their production.

In addition, this approach promotes circular economy on company level, so DEMO9 is also relevant from awareness raising perspectives.

From an economic perspective, the eco-design of packaging can generate cost savings. This type of innovation increases the competitiveness of companies adopting sustainable practices and opens up new markets for innovative products (see above under company level advantages)

At the societal level, the sustainable company practices and increased awareness

has the potential to generate new jobs in research, development and manufacturing sectors. This contributes to improving the quality of life, as more sustainable and cost-effective products can be more accessible and environmentally responsible.

This approach has a direct connection with several Sustainable Development Goals (SDGs) and the European Green Deal.

With SDG 12: Responsible Consumption and Production, it aligns with helping businesses to find new solutions that enable sustainable production patterns. Our Demo helps to identify those packaging alternatives which could be a real sustainable solution for companies (avoiding green washing or seemingly greener solutions). Less packaging, alternative recyclable solutions promotes recycling and reuse of materials, ensuring sustainable consumption patterns, as well.

With SDG 9: Industry, Innovation and Infrastructure, it encourages innovation in the use of recycled materials and the development of sustainable infrastructure.

With SDG 13: Climate Action, it contributes to fighting climate change by reducing CO2 emissions and promoting sustainable practices.

With SDG 17: Partnership for the goals could be interpreted as local, regional or even national cooperations. In Demo 9 this partnership is amongst the food and packaging producer companies and the retail sector.

Finally, it aligns with the European Green Deal, which seeks to transform the EU into a modern, resource-efficient and competitive economy, ensuring no net greenhouse gas emissions by 2050 and decoupling economic growth from resource use. For this the business sector's awareness and sustainable production is indispensable.



2 Scope and Territory

2.1 The territorial context

Geographical Scope: What's the geographical scope of your solution. In which territory is it applied and where will it make a change? Does it have a local, regional, national scope? If possible, add a map.



Figure 16: Territorial Scope of Demo 9

In the first stage, the project will have a national Hungarian scope. Once the project is developed, the alternative solutions are tested, the know-how could be transferred to any of the EU countries.

Sectorial Scope: Which sectors are affected by your innovation? Is it related to waste management? Water? Industry?

Packaging sector – promoting industrial cooperation amongst food producer and packaging producer companies to identify commercially viable solutions that could be applied in the whole value chain (from production, through retail, till waste treatment)

2.2 The territorial policy framework

What are the main policy instruments for circular economy and the specific context of the CSS (e.g., waste regulations). Please list the main policy instruments, owner (e.g., a ministry), their objectives, the way they shape the system (e.g., funding vs. ban).

Aim to capture the most important policies and strategies in the context of the demonstrator regardless of its origin (EU/national/regional/local).

One of the most relevant policy instruments is the **Action Plan for the Circular Economy** of the European Union, which seeks to facilitate the transition to a circular economy in Europe. This plan, administered by the European Commission, promotes the efficient use of resources and the reduction of waste, establishing legal and financial measures that encourage innovation and the use of recycled materials.

The **European Green Deal**, managed by the European Commission, establishes a framework to transform the EU economy towards sustainability and climate neutrality by 2050, promoting the circular economy in all sectors and providing funds for technological innovations that reduce the environmental impact.

The **European Packaging Directive** serves to ensure that packaging and packaging waste are of a uniform, environmentally friendly and health-friendly nature. In addition to the substances contained and their effects, the EU Packaging Directive 94/62/EC includes the objective and achievement of recycling. In March 2024, the Council of the European Union and European Parliament concluded negotiations on the EU's Packaging and Packaging Regulation. The current text is going through a legal review but is now de-facto final and is expected to be formally adopted in the coming months. The Regulation introduces waste reduction targets and requires that all packaging placed on the EU market is recyclable and carries recycling labeling. The Regulation also introduces new requirements for packaging minimization, minimum recycled content in plastic packaging, re-use targets for packaging, and bans certain packaging formats.

Directive on Single use plastics (Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment) aim to prevent and reduce the impact of certain plastic products on the environment, in particular the marine environment, and on human health. They also aim to promote the transition to a circular economy with innovative and sustainable business models, products and materials, therefore also contributing to the efficient functioning of the internal market.

EU Decision 97/129/CE - Commission Decision of 28 January 1997 establishes the identification system for packaging materials pursuant to European Parliament and Council Directive 94/62/EC on packaging and packaging waste

The **Waste Framework Directive** (2008/98/EC) is another key instrument that establishes a legal framework for waste treatment in the EU. Its objective is to promote the prevention, recycling and reuse of waste, as well as the reduction of landfilling. This directive, managed by the European Parliament and the Council of the EU, obliges Member States to implement waste management plans and promote the waste hierarchy, which favors the recycling of materials – highlighting the importance of packaging.

At the national level, in the **Fundamental Law of Hungary**, the National Avowal proclaims among others the following: “We commit ourselves to promoting and safeguarding our heritage (...), along with all man-made and natural assets of the Carpathian Basin. We bear responsibility for our descendants and therefore we shall



protect the living conditions of future generations by making prudent use of our material, intellectual and natural resources.”

Furthermore, according to Article P) (1): “Natural resources,(...); and cultural artefacts, shall form the common heritage of the nation, it shall be the obligation of the State and everyone to protect and maintain them, and to preserve them for future generations.”

As such, it is worth noting that the Fundamental Law of Hungary touches on sustainability and circularity. Certainly, it does so in very generic terms as it does with various other topics. Nevertheless, it is important to recognize the relevance of the fundamental law on this subject.

The process for preparing the National Circular Economy Strategy has started.

Towards a National Circular Economy Strategy for Hungary is a comprehensive and detailed OECD analysis, combined with a stakeholder dialogue and a multi-criteria assessment prepared in 2023. It identifies a set of priority areas and high-impact actions that are deemed critical to the Hungarian circular economy transition. These selected priority areas include biomass and food, construction, and plastics, as well as cross-cutting horizontal tools that can be put in place across product and material life cycles.

The 5th National Environmental Programme (NKP-5) 2021-2026 is a comprehensive framework for all environmental strategies, programmes and plans in Hungary renewed every 6 years since 1997. Its measures aim at strengthening the circular nature of the economy - the green transition - in addition to environmental benefits, they contribute to reducing resource dependence, increasing competitiveness and employment. Under the strategic directions of “Improving resource saving and efficiency, greening the economy and making it more circular” the Programme sets out the following strategic areas which are in line with the Hungarian Demo9 perspectives:

- Promoting environmentally friendly production
- Reducing the environmental impact of consumption
- Waste management
- Reducing greenhouse gas emissions, preparing for the climate change impacts
- Environmental aspects of the agricultural economy

The Széchenyi Plan Plus is the Partnership Agreement of Hungary for the programming period of 2021-2027. Through its operational programmes, the partnership agreement relies on the funds of ERDF, ESF+, the Cohesion Fund and the Just Transition Fund together with domestic co-financing, the cohesion funding amount is more than EUR 26 135.7 million. The partnership agreement (PA) deals with the transition to a circular economy and places its development to one its objectives. The PA states that “the economic, resource-saving and environmental potential of the circular economy is not sufficiently exploited.” Even though “waste generation and landfill rates are decreasing, but 50.6% of municipal waste is still



landfilled (EU target to reduce the rate to 10% by 2035, with derogation by 2040).” In terms of business, the PA claims that the uptake of environmental management and eco-certification schemes among business actors is currently low. Furthermore, the transition to a circular economy requires new business models to preserve the value of products, materials and resources for as long as possible and to minimise waste generation.

Under Thematic Objective No. 2. (A greener, low-carbon and resilient Europe) the PA commits to ensure a shift towards a life-cycle approach to the transition to a circular economy, while taking into account environmental and economic aspects. The PA intends to promote the feasibility of technologies that aim to process raw material resources and recycle them back into the economy, and reduce the production of primary raw materials.

It could be seen that Demo9 has many correlations with these objectives.

One strand of the resource efficient priority of **the Hungarian National Smart Specialisation Strategy (S3) 2021-2027** covers a range of activities and sectors that can be classified as circular economy. That priority covers R&D activities related to the circular economy in both the business and research institute and university sectors, mainly in the fields of mechanical engineering, automotive, rubber and plastics, energy, engineering, metalworking, electrical equipment, food and agriculture. This priority may also include RDI activities on more efficient and safer management and reuse of secondary raw materials, or the application of solutions for their management. The priority will encourage the exploration of new materials with a lower environmental impact or new applications and production possibilities for previously known materials that are not yet competitive on the market due to production costs.

With the help of the National Waste Management Plan 2021-2027 (OHT) adopted in 2021 the Government's goal is to gradually move towards a circular economy and that the Hungarian waste management sector becomes a model for Europe. To this end, the Government intends to reform the Hungarian waste management sector and to introduce a system that treats waste as a raw material. Legislative changes included to shift to a circular economy, to eliminate illegal landfills, to impose stricter penalties on illegal waste disposal, to establish a take-back system and **extended producer responsibility**, and to rationalise waste management activities are expected to protect the natural environment and to clean up the country.

The OHT includes the National Prevention Programme (OMP), which sets out the waste prevention objectives and the measures to be taken to achieve them. The overall objective of the OMP is to introduce measures that promote the decoupling of resource use and needs-based, rational economic growth, reduce material use and waste generation, contribute to more efficient resource management and increase the life cycle of products, promote the use of solutions with the least possible environmental impact throughout their life cycle and create jobs. OHT presents and evaluates main waste streams **dedicating a separate chapter to**



packaging waste including paper, plastic, glass, metal, wood and composite packaging.

80/2023. (III. 14.) Government decree sets out the detailed rules for the operation of the extended producer responsibility system. The basic principle of extended producer responsibility is that the costs of waste management arising at the end-of-life cycle of a certain products should be borne by producers (also including in the case of products imported from abroad, the first supplier). The producer/obligor is responsible for the cost of the waste treatment of the waste generated by the product subject to the green tax. The new legislation imposes new fee payment and administrative obligations on almost all producers and traders in Hungary. As a consequence, from 1 July, most businesses will be affected by both the existing green tax obligation and the new EPR fee obligation mentioned above. The circular products covered by the EPR Decree are the following: packaging, certain single-use and other plastic products, electrical and electronic equipments, batteries, accumulators, motor vehicles, tyres, office papers, commercial printing papers, baking oils, baking greases, certain textile products and certain wooden furnitures.

2.3 Territorial Regulatory Framework

Provide a first approach of the main regulations that are relevant to your CSS in a local, regional, national, or European level.

Try to avoid including general regulation here. Just the regulation that is especially relevant for your case and makes it different from traditional practices

Table 15: Regulatory Framework for Demo 9

Level	Regulation	Requirements
EU	EU Circular Economy Action Plan (European Commission).	It promotes the transition to a circular economy. Promotes the reuse and recycling of materials, to increase the amount of secondary raw material.
EU	Waste Framework Directive (2008/98/EC) (European Parliament and Council of the EU).	It establishes the waste hierarchy, prioritising prevention and recycling. It is key to encouraging the simplification of packaging, increasing its recyclability and the identification of new materials. It emphasizes the extended producer's responsibility principle
EU	European Packaging Directive	The Regulation introduces waste reduction targets and requires that all



		packaging placed on the EU market is recyclable and carries recycling labeling. The Regulation also introduces new requirements for packaging minimization, minimum recycled content in plastic packaging, re-use targets for packaging, and bans certain packaging formats
EU	Directive on Single use plastics	Aims to prevent and reduce the impact of certain plastic products on the environment to promote the transition to a circular economy with innovative and sustainable business models, products and materials, therefore also contributing to the efficient functioning of the internal market.
National (Hungary)	“Towards a National Circular Economy Strategy for Hungary” OECD analysis 2023	It serves the base for the Hungarian circular economy strategy (not yet accepted). It identifies a set of priority areas and high-impact actions that are deemed critical to the Hungarian circular economy transition. These selected priority areas include biomass and food, construction, and plastics.
National (Hungary)	the Hungarian National Smart Specialisation Strategy (S3) 2021-2027	It covers R&D activities related to the circular economy in both the business and research institute and university sectors, mainly in the fields of mechanical engineering, automotive, rubber and plastics, energy, engineering, metalworking, electrical equipment, food and agriculture. This priority may also include RDI activities on more efficient and safer management and reuse of secondary raw materials, or the application of solutions for their management. The priority will encourage the exploration of new materials with a lower environmental impact or new applications and production possibilities for previously known materials that are not yet competitive on the market due to production costs.
National	National Waste	Legislative changes included to shift to a



(Hungary)	Management Plan 2021-2027 (OHT)	circular economy, to eliminate illegal landfills, to impose stricter penalties on illegal waste disposal, to establish a take-back system and extended producer responsibility, and to rationalise waste management activities. The OHT includes the National Prevention Programme (OMP), which sets out the waste prevention objectives and the measures to be taken to achieve them. OHT presents and evaluates main waste streams dedicating a separate chapter to packaging waste including paper, plastic, glass, metal, wood and composite packaging.
National (Hungary)	80/2023. (III. 14.) Government decree on the detailed rules for the operation of the extended producer responsibility system	The basic principle of extended producer responsibility is that the costs of waste management arising at the end-of-life cycle of a certain products – including packaging as well - should be borne by producers in a form of an EPR fee paid as a tax.

2.4 The territorial metabolism

What material flow is the demo concerned with. Origin, flows, and destinations as well as main actors along the value chain. Quantified as much as possible.

Packaging is needed to maintain the quality and safety of food products to ensure their protection during transport/logistics, to extend shelf life and to reduce (food) waste. This is the key point to keep in mind. However, due to the amount of packaging (thus the amount of waste) used, it is a must to look for sustainable, eco-friendly solutions. More producers have realized this fostering eco-innovation in the packaging industry.

The key customers of Ugrinpack and their products are the sample out of which 15 food products could be chosen to test during DEMO9 offering alternatives to plastic food contact packaging materials.

The selection criteria:

- quantities of packaging materials
- replicability to reach a wider range of products in the long-run



Mainly FMCG products are targeted at, however keeping in mind the farm to fork strategy - farmers' markets are also involved in the demo - offering sustainable solutions for farmers to transport their goods directly to the customers.

Regions dealt with include Budapest - where packaging sector is concentrated-, and mainly East- and Central Hungary where the agro-food industry flourishes.

The Demo9 - relying on previous experiences from European and domestic R&D projects - will promote symbiosis between packaging and food companies to identify viable and sustainable solutions. These solutions (that must address key pre-chosen products) will be analyzed through an LCA, without neglecting the technical (quality aspects) and economical aspects that a material intended for packaging must fulfil. The key aspect is simplification to promote mono-material solutions instead of multi-layer plastics – ensuring material recycling and decreasing the quantities of materials used and lightening their weight.

Materials envisaged:

- PE,
- PP,
- multilayer plastic packaging to mono-material plastics,
- biodegradable mycelium packaging,
- paper packaging,
- biodegradable biopolymers (e.g. polylactide-acid (PLA), polyhydroxyalkanoates (PHAs))
- general 4 - PE, paper, PE, ALU-, and 2-layer-composite packaging materials substituted by biodegradable biopolymers: Combining paper/PHA could create a bio-based and fully biodegradable material. It is worth testing oxygen and water vapor permeability, which can be measured if necessary. The Paper/PHA material can be compared with Paper/PE - in the long run, PE could be eliminated this way.

Regarding the quantities and the main KPIs of the DEMO:

Decrease of Plastics in food contact packaging in a way that the primary function of packaging – protection – is maximally kept: At least 20 %, around 150 kgs

The amount of plastics used in the predefined 15 product categories– 750 kg.

2.5 The territorial stakeholders

Who are the stakeholders with the interest and influence on the CSS? Consider all quadruple helix actors (Public administration; industry and business; civil society; academia, RTOs and NGOs).

Public administration.

Since the transition to circular economy is one of the most relevant challenges what companies have to face, public administration will play a crucial role in regulating



and promoting sustainable practices in the packaging sector.

The need of the companies should be deeply analysed to understand them and to identify the policy development opportunities to promote green economy.

Also, a design of a grant, finance call could be the result if a financing gap is identified within the value chain hindering the transition to ensure the long-term positive effect of the DEMO.

Industry and Companies.

The industry and companies are fundamental partner in Demo9. Within the industrial sector, food producer companies will be the fundamental actors in the supply chain. These companies are interested in reducing their operating costs and improving their innovative capacities and competitiveness whilst increasing their environmental sustainability, which will encourage them to collaborate in initiatives like CircSyst project. Additionally, recycling companies are also crucial, since the offered packaging solutions should be able to get recycled to decrease the amount of waste for landfilling and incineration.

Civil society.

Civil society, including consumers and community groups, will influence the SSC of eco-designed packaging through demand for more sustainable and environmentally responsible products. Consumers are increasingly interested in purchasing products that reduce environmental impact, motivating companies to adopt sustainable practices and the public acceptance of the alternative packaging solutions are indispensable. Civil society organizations and environmental NGOs also play an important role in advocating for sustainable production, consumption, responsible separate waste collection, stricter waste management policies and raising awareness on the benefits of the circular economy and sustainability.

Academia, RTOs and NGOs.

Academic institutions and research and technology organizations (RTO) will also play a key role in the testing phase of possible alternative packaging materials (like PLA, PHA, mycelium packaging) carrying out the test processes and examining the effects.

NGOs, both locally and internationally, act as mediators and facilitators of collaborative projects between the different actors of the quadruple helix, promoting sustainable practices and participating in the implementation of circular economy projects. They will be invited to the regional meetings to showcase the results.

The interaction between these actors (public administration, industry, civil society and academia) will be essential to develop an integrated approach that maximizes the economic, social and environmental benefits of eco-designed, alternative packaging solutions.



3 The Circular Systemic Solution

3.1 The intervention in a value chain

Please describe the existing value chain and the material flows. Where do you intervene in this system?

Based on the current value chain model food producer companies use packaging to maintain the quality and safety of their products to ensure protection throughout the whole value chain. Keeping in mind this objective, less emphasis is put on sustainable, eco-friendly and circular solutions.

Currently, packaging technology primarily uses materials produced from polyolefin derivatives. In addition, the packaging materials and tools used today are usually produced with environmentally harmful solutions. An example of this is the sealing of multi-layered materials, which is done with isocyanate glue or diluting it with ethyl acetate.

In Hungary, the use of plastic plays a significant role in the packaging industry, plastic packaging waste is more than 30 % (47.5 kg per capita) of all packaging waste. The recycling rate of plastic packaging was only 24.9 % (2020) compared to the 50 % to be reached by 2025 and 55 % by 2030.

In addition to that, due to the challenges we face globally (increasing amount of packaging waste, overuse of primary resources, loss of biodiversity, climate change etc.) and due to the strict regulations, directives affecting the companies' directly (extended producers' responsibility, new packaging and eco-design directive, ESG related obligations) it is already a must to look for sustainable, eco-friendly solutions. More producers have realized this fostering eco-innovation in the packaging industry.

During our DEMO 9 activities, the design phase of packaging will be in the centre of attention. 10 food producer companies are currently involved as stakeholders in co-designing, simplifying, and greening their food packaging. During the project the working groups will focus on a minimum of 15 selected products whose package will be eco-designed based on the following aspects:

- simplification of packaging in order to create monomaterial, recyclable solutions and to decrease the amount of plastics used in them
- testing alternative materials

Then the final eco-design will be validated in real environments by the food producing companies and other stakeholders.

Identify where your CSS is situated and how can it change the various stages. Does it make the value chain more circular?

With our Circular System Solution, those types of packaging will be worked out together with the food producer and packaging producer companies which could be sustainably (from all the 3 aspects) applied by the producer companies fulfilling all the criteria needed to protect their product throughout the whole value chain (from transport/storage through retail till waste management).

The whole eco-design process will definitely intervene in the production of packaging phase, however it will also affect the raw material production phase since less materials will be used for properly eco-designed packaging solutions and with the utilization of alternative materials even some of the primary raw materials (like plastics) could be completely substituted.

The end of life phase is also taken into account, since sustainable packaging solution should fulfil the recyclability/compostability criteria aiming to close the loop feeding secondary material sources.

Our CSS significantly enhances the circularity of the packaging value chain of the participating producer companies.

3.2 Value Chain Overview and Stakeholders' Identification

Identify the stakeholders involved that will be affected by the CSS shift.

UGRINPACK Ltd. is responsible for DEMO9 activities and for the involvement of at least 10 food producer companies. This company - founded in 1923 - has been dealing with flexographic printing of packaging materials since 1980, and has become an increasingly successful family business on the domestic market. Since 2011, Ugrinpack could produce environmentally friendly and, if required, 100% compostable packaging materials promoting ethyl acetate-free or isocyanate-containing glue - free solutions. Their main concept is the application and promotion of the 3R (Reduce-Reuse-Recycle) approach towards their clients. Their products are currently unique in Hungary.

MGFÜ – Hungarian Economic Development Agency owned by the Ministry of National Economy is the Hungarian central agency for SME development with the objective to support their growth and their business. Since the transition to circular economy is one of the most relevant challenges what companies have to face, MGFÜ should also provide assistance in this field understanding the companies' needs and identifying the policy development opportunities to promote green economy.

Utilizing this function, MGFÜ performs the DEMO9 coordination, furthermore it will also assess and validate the results under public policy perspective.



1. Plastic Saving Packaging workshops organized to screen the plastic packaging usage in case of the food producer companies – mainly SMEs with the involvement of plastic packaging experts to identify the general promoting and hindering factors
2. Design of a grant, finance call if a financing gap is identified within the value chain hindering the transition to ensure the long-term positive effect of the pilot.

Through the involvement of MGFÜ also the Ministry of National Economy will monitor the DEMO's progress, so the policymakers could also get an insight of the defined processes.

During the Demo 9 activities 10 food producer companies will be involved in the common thinking and testing process. Based on the criteria defined by the food producers – the alternative packaging material is demonstrated, then comes the complex testing and validation process (like economic analysis, test rolls durability test (length depending on the shelf life of the products, test production, production optimization, communication towards customers & retail). These companies could be nominated in September, when their participation will be formally settled in Demo 9.

The Omnipack First Hungarian Packaging Technology Cluster is a strategic partner for the CircSyst project. It will be also involved in the DEMO9 process as a relevant stakeholder. This Cluster is an alliance of producers of the packaging technology sector as well as of those companies serving it and peripherally linked to it. They are active and acknowledged players in the development of environmentally friendly packaging materials and state-of-the-art packaging technology solutions functioning also as a knowledge center of market players engaged in environmentally friendly packaging material.

Furthermore, other key NGOs will be identified and involved who are relevant for this reform of the packaging sector targeted by the Hungarian DEMO.

In summary, the demonstrator project brings together those stakeholders who are relevant players on the market including representatives from the packaging sector, from the food producers using the packaging, from the policy makers and economic development side, as well ensuring the long-term impact of the project.

3.3 The solution in the value chain

Please describe the solution in its context – what is the new practice? What is the new technology (if it is a technology)? How does it change the interaction among actors? How does it affect the material flows?

The solution introduced is a Circular Sustainability System (CSS) that makes



producer rethink their current packaging solutions together with packaging and sustainability experts in order to identify new, more sustainable and circular solutions for them.

This process changes interactions among stakeholders by creating a collaborative framework contributing to deeper, long term cooperation with the food producers and the packaging company resulting in more circular and sustainable operations. This new approach significantly impacts material flows creating alternative packaging solutions for various applications. These new alternatives reduce primary resource need, waste disposal and incineration need and promote the use of alternative materials substituting or decreasing plastic usage, aligning with circular economy principles.

This integration not only provides economic benefits but also advances environmental sustainability by minimizing waste and enhancing resource efficiency.

3.4 The Value of your solution

Briefly compare your CSS to the current existing solutions and explain how your CSS can improve the results of the current solutions.

Based on the current value chain model food producer companies use packaging to maintain the quality and safety of their products to ensure protection throughout the whole value chain. Keeping in mind this objective, less emphasis is put on sustainable, eco-friendly and circular solutions. In Hungary, the use of plastics plays a significant role in the packaging industry, plastic packaging waste is more than 30 % (47.5 kg per capita) of all packaging waste. The recycling rate of plastic packaging was only 24.9 % (2020) compared to the 50 % to be reached by 2025 and 55 % by 2030.

Moreover, due to the challenges we face globally (increasing amount of packaging waste, overuse of primary resources, loss of biodiversity, climate change etc.) and due to the strict regulations, directives affecting the companies' directly (extended producers' responsibility, new packaging and eco-design directive, ESG related obligations) it is already a must to look for sustainable, eco-friendly solutions. More producers have realized this fostering eco-innovation in the packaging industry, but they need sustainable and applicable solutions.

During our DEMO9 activities, the design phase of packaging will be in the centre of attention:

1. simplification of packaging in order to create mono-material, recyclable solutions and to decrease the amount of plastics used in them

2. testing alternative materials: biodegradable mycelium packaging, biodegradable biopolymers (e.g. polylactide-acid (PLA), polyhydroxyalkanoates (PHAs))

Since in Demo 9 Hungarian partners will work together with the business sector (namely food producer companies), the societal, economic and environmental perspectives should be identified on company level, as well.

There are many benefits for food production companies to participate in the Demo relevant from both sustainability and economic perspectives.

In the framework of the project, by testing sustainable raw materials, innovative products can be developed that can provide a competitive advantage and can meet the ever-increasing sustainability related demands and contribute to the company's innovation potential.

The use of recycled raw materials and alternative packaging solutions can reduce raw material procurement costs and EPR fees. In addition, the introduction of waste reduction technologies can reduce waste management costs, thereby improving the company's financial efficiency.

By using more sustainable production processes and raw materials, ecological footprint could be decreased on company level and adding up the effect on regional level, as well resulting in the protection of the environment and the preservation of natural resources.

The experience and technologies gained during the project can help to comply with future environmental regulations. Preparing for stricter sustainability standards is an advantage in the market.

Finally, promoting sustainability and the circular economy can help companies achieve its ESG goals. Taking ESG aspects into account not only improves environmental protection performance, but also positively influences the company's social perception and corporate governance practices. Sustainability initiatives contribute to increasing the company's reputation and strengthen the confidence of consumers and investors.

On environmental side generally, the main benefits are the followings: the simplification of packaging (less packaging, monomaterial packaging instead of complex, multimaterial packaging that hinders recyclability) and the identification of alternative packaging materials could lead to more sustainable solutions: less amount of primary materials used, increased recyclability, waste reductions. By reducing the need for new fossil fuel-based plastics, it also reduces the greenhouse gas emissions associated with their production.

In addition, this approach promotes circular economy on company level, so DEMO9 is also relevant from awareness raising perspectives.

From an economic perspective, the eco-design of packaging can generate cost savings. This type of innovation increases the competitiveness of companies

adopting sustainable practices and opens up new markets for innovative products (see above under company level advantages)

At the societal level, the sustainable company practices and increased awareness has the potential to generate new jobs in research, development and manufacturing sectors. This contributes to improving the quality of life, as more sustainable and cost-effective products can be more accessible and environmentally responsible.

Why Is Your Solution Fit for the Challenge Targeted and Why Is It Better than Existing Solutions?

During our Circular Sustainability System (CSS) all the relevant players are involved in the process and we start the common thinking process from the direct needs of the food producer companies. Starting from these framework conditions the circular economy and packaging experts could find those solutions that can fulfil the criteria defined by the demand side in away to offer more circular and sustainable solutions.

The advantages to participate in this Demo for the producer companies are very diverse (see above) and the timing of this common work could not be better: parallel to the new eco-design and packaging directive and thanks to the recently initiated ESG related obligations more and more producers are looking for more sustainable alternatives in their operation and for their packaging.

They need assistance in identifying the most proper solutions for them which are really more sustainable (from all perspectives of sustainability). In DEMO 9 this expertise will be provided to them.

3.4 The envisioned impact

What are the targets and how can they be monitored? Please identify social, ecological, and economic impacts the demo might have.

What are the main KPIs for the Demo considering also those three key aspects (environment, society, economy).

Expected Scientific Results and Knowledge creation:

As a result of the pilot directly:

Decrease of Plastics in food contact packaging in a way that the primary function of packaging – protection – is maximally kept: At least 20 %, around 150 kgs (The amount of plastics used in the predefined 15 products – 750 kg)

The gained scientific knowledge is internationally (within the EU) promoted, the validation process is also strengthened with cross-sectoral cooperation in CircSyst project.

With the extension of the pilot to more producers within the whole country:



- the decrease of Plastics in food contact packaging - 1600 t/ year

Based on regional extension:

- East-Hungary: 455 t
 - Mid -Hungary: 725 t
 - West - Hungary- 420 t
- The increase of the recyclable packaging amount: 4200 t recyclable/com-
postable packaging materials

In Hungary each year more than 5800 t of composite packaging waste is generated which now could not be recycled due to the complexity of the materials

Extension of the pilot to more producers outside Hungary within the EU

- the decrease of Plastic in food contact packaging - could achieve 54 000 t/ year within the EU

Expected Economic Impacts:

Short term impact:

Cost benefits for the food producer companies taking part in the pilot:

Since July 2023 the obligated companies must pay an extended producer responsibility fee - deductible from the environmental product fee - on quarterly basis. The heavier the weight of packaging, the higher the fee to be paid.

Therefore, each producer using packaging for their products seeks now new alternatives for sustainable packaging solutions to decrease the payable amount of fee in this respect.

The Hungarian pilot action offers solutions for them: due to the less composite recyclable materials with less plastic content EPR & environmental product fee could be decreased significantly (since within packaging plastic packaging has the highest rate - decreasing the weight of packaging results in less fees immediately)

Mid-term impact:

In the long run - due to the increasing cost, taxes and fees for the producer companies - new models should be looked for in order to be more competitive on the Hungarian market. So, cost benefits for the food producer companies involved in the extension phase could mean cheaper sales prices offering a competitive advantage for them.

Sustainable packaging materials also attract new, environmental conscious customers increasing the amount of sales.

Increased profitability: due to less costs, increased sales thanks to the newly attracted customers, as well.

Wider long-term effects

In the long run - due to the increasing costs, taxes and fees for the producer companies - new models should be looked for in order to be more competitive on the European market, as well.

The more eco-conscious consumers could be attracted only with eco-friendly

products.

This will result in increased sales and market shares for the producer and packaging companies using the alternative, more circular packaging alternatives.

Social and Environmental Results

Short term effect:

The multilayer plastic packaging generally cannot be recycled, so there is no focus on separate waste collection and awareness raising of these materials. However, food packaging – due to their amount generating waste in the households - are crucial “players” in the transition to a circular economy.

Focusing on the minimization of packaging, using up less plastic and offering recyclable solutions, accelerates the process. The result is less landfilled and incinerated materials.

Mid-term impact:

Generally, the Hungarian population is less environmental conscious compared to the European average. Still 50 % of the municipal solid waste is landfilled, the recycling rate of municipal solid waste was only 34.9 %, the recycling rate of plastic packaging was only 24.9 % (2020). Separate waste collection should be promoted and more materials should be recycled.

Packaging waste could be a key in the awareness raising – due to its amount, frequency and visibility of its generation in every household in Hungary. So more sustainable packaging could be a great tool for awareness raising.

Less landfilled and incinerated materials directly contribute to the targets defined in the European Green Deal and in the Circular Economy Action Plan for Hungary.

More people could work in green jobs leading to a wider spread of environmental consciousness, so the share of green jobs will increase.

Long-term impact:

Thanks to the good examples, the packaging industry of the European Union will focus more on circular, alternative solutions, eco-conscious producers and consumers will be the mainstream effecting the policy making process, as well. In the latter case, more concrete eco-design packaging practices could be identified and the applicability of bioplastics could be clarified, which are currently missing due to the lack of concrete practical examples and applications.

The share of green jobs within the EU will increase and the packaging industry will be more circular.



4 Potential Barriers and Risks

Technological barriers

Are there technical/technological issues hindering the application of your CSS. Do you need further research?

Knowledge barriers

Are you facing knowledge barriers to implement your CSS? Do you need more training? Do you need access to knowledge protected under IPR?

Policy barriers

What challenges do you foresee from a policy perspective? Does your CSS need more policy support to be implemented?

Regulatory Barriers

Are there regulations that are hindering or that will stop the adoption of your CSS?

Business barriers

Is your CSS too risky to mobilize investments? Are there no business models that would fit for exploring your innovation? Do you need to make your CSS more profitable or less costly so it can reach a market exploitation stage?

At this stage it is hard to define the barriers below since in this initial phase of the project our focus is on understanding the needs of the food producer companies. The biggest barrier and risk at this stage is the willingness for cooperation of the food producer companies. To properly analyse their need, detailed data is needed which could be time consuming to be provided to the packaging company. The success at this stage depends on how well the partners could emphasise and how well the given companies understand the advantages of their participation. After analysing their criteria towards the packaging solutions, we could identify further potential barriers and risks according to the classification below.



5 Aims and Goals

What are the future steps to be taken to bring your CSS to a higher level of acceptance and application. Do you need further technology research? Is your CSS ready to penetrate the market?

After the alternative packaging solutions and materials are validated, the results should be demonstrated to the Hungarian packaging sector's and food producers' representatives.

There is an openness of the producers towards these new packaging alternatives, but real tested applications are needed to offer sustainable solutions. Once the DEMO has them the long-term aim is to raise the awareness of more and more producer companies to use these solutions.

Thanks to the involvement of MGFÜ in the coordination process, the country wide replicability is also backed with the provided assistance from the agency in understanding the companies' needs and identifying the policy development and financing opportunities to promote green economy to ensure the long-term positive effect of the pilot.



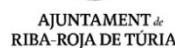
6 Synergies among Demos: Identifying potential for systemic cross-sector symbiosis

As far as you know, are there any potential synergies that your Demo can establish with other CircSyst Demos? How do you plan to test and develop those synergies?

Table 16: Demo 9 Identified Synergies

Demo Number	Synergy envisaged
DEMO 1	
DEMO 2	
DEMO 3	
DEMO 4	
DEMO 5	testing of the PHA material and plastic with organic fibers, as alternative packaging materials.
DEMO 6	
DEMO 7	The m-PET fraction could be transferred to Demonstrator 7 to be mechanically recycled /Spanish granulates could be also tested here in Hungary As a first phase, 5-10 kgs of waste materials will be sent to AIJU by Ugrinpack to be tested - specifications of the waste have been already agreed
DEMO 8	testing how biodegradable materials/packaging decompose (Greek alternatives in Hungary) prototype – packaging material could be tested in the supermarket of MASOUTIS just initial ideas, need to be worked out in a more detailed way
DEMO 9	

Project partners:



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