RESOURCE

Regional project development assistance for the uptake of an Aragonese circular economy

D2.2 Circular bioeconomy readiness level

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Abstract	This document introduces a novel assessment model designed specifically for stakeholders in Aragon. The model evaluates the progress of circular economy initiatives within the region's key value chains. It presents a unique set of relevance criteria along with a clear ranking system using descriptive terms.
Keywords	TRL, criteria assessment, regional readiness, Industrial Symbiosis, Proactive public Behaviour, Supportive Legal

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EXECUTIVE SUMMARY

While the technology readiness level (TRL) scale is useful for gauging how close innovations are to market in traditional resource intensive economies, it falls short for circular economy projects especially if they include bio-based economic principles. In these projects, local consumption and short distance distribution are key, at least until transport sector is fully decarbonized. The RESOURCE pilot projects illustrate that TRL alone doesn't guarantee a project's success in boosting regional circularity. In this sense, entrepreneurs need a more well-rounded approach that considers regional factors beyond technology including aspects such as legal, governance, and infrastructure which all play an important role into a value chain. Academic frameworks for assessing economic, social, and organizational maturity exist, but they haven't been easily adapted to the specific realities of the RESOURCE pilot projects and their stakeholders. The TRL analysis for the RESOURCE pilot projects offers valuable insights and it focuses primarily on technological readiness. In order to gain a more comprehensive picture, a co-created regional circular economy maturity scale could be beneficial when it considers additional dimensions like the projects' impact and novelty within the circular economy, moving beyond individual stakeholder perspectives through a collaborative approach.

Five key areas were identified to gauge the region's readiness for a circular economy. These areas are:

- **PB - Proactive public Behaviour**: This area measures in what grade the society is informed about the benefits of the Circular Economy and if they are demanding Circular-based services and products.
- **SL - Supportive Legal framework**: The legal framework measures the local and regional regulations that have been included or adapted to enable circular strategies.
- **EE - Effective end-of-life Economy:** The end-of-life category consider the local and regional regulations that have been created or included in a specific environment to enable circular strategies.
- **EM - Efficient waste Management system:** EM is focus on the sorting, collection, reusing, and recycling system and how maximise the quantity and the quality of the circular building blocks.
- **PI - Prepared Industrial network:** PI quantify the level of connections among actors that have developed technologies to valorise the recycled building blocks and stablish a circular chain, it takes into a global vision of the hole value chain.

This was extracted from analysing RESOURCE pilot projects, and involving participating teams, conducting workshops, and exchanging ideas with stakeholders across Aragon region.

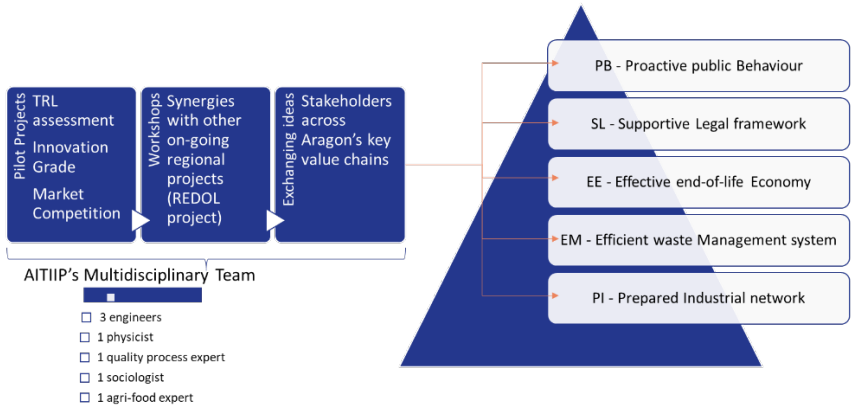

Figure 1 – Multifaced approach for involving key actors

Additionally, a five-point verbal scale was created for each area. This scale allows to assess the maturity of these aspects within different regional sectors.

CRL	Proactive public behaviour:	Supportive legal framework:	Effective end-of-life product management:	Efficient waste management system:	Prepared industrial network:
CRL_0	Society follows the classical behaviour of production-consumption-disposal approach	Local and regional regulations promote linear economy	There are not economic incentives to transform the linear economy	Waste management systems are limited to the disposal of the waste on landfills	Industry is far from any bio-based application
CRL_1	Society concerns the problematic of the linear economy	Local and regional regulations promote efficient waste management systems	There are some funding schemes that facilitate the creation of new entities related to the End of Life products	Waste management system includes some level of selective collection	A few innovative RTOs are starting to tackle some of the factors related to bio-based and circularity technologies
CRL_2	Society is committed with the utilisation of the waste management Systems for the reutilisation and recycling systems	Local and regional regulations promote the development of sustainable solutions	Public funds are available to improve the waste management systems	Some facilities for the recovering and recycling have been built	Technology transference between RTOs and companies is on-going
CRL_3	Society is modifying the behaviour to maximise the reduction of consuming single-use products	Local and regional regulations boost the responsible consumption	Public and private entities are collaborating to invest in valorisation facilities	The selective management system is quite improved, including water/bio-based waste fraction	Some value chains have been articulated but are still weak
CRL_4	Society is committed of the effective implementation of bio-based economy products and services	Local and regional regulation promote public and private green procurement	Economic framework is favourable to the implementation of circular bio-based strategies	Circular bio-refeneries are currently working producing low-quality bio-based products	Several value chains have been articulated and consolidated but without interrelation among them
CRL_5	Society is fully informed about the benefits of the Circular Bio-Economy and are demanding Circular Bio-based services and products	The local and regional regulations have been adapted to enable circular bio-based strategies	Economic instruments have been developed and implement to support circular bio-economy initiatives by an effective use of the end of life products	The sorting, collection, reusing and recycling system maximise the quantity and the quality of the bio-based building blocks	High level of relationships among actors with technologies to valorise the bio-based building blocks and stablish inter-sectorial circular bio-based value chains

Figure 2 – Five-point verbal scale

This innovative method for measuring a sector's readiness for a circular economy project is a valuable tool for regional actors, It also serves to define action plans based on good practices to evolve the maturity level of each criterion.

CBL	Pro-active Public Behaviour
PBL_0	Society follows the classical behavior of production-consumption-disposal approach
PBL_1	Society concerns the problematic of the linear economy. Our current "take-make-waste" system is raising alarms
PBL_2	Society is committed with the utilization of the waste management Systems for the reutilization and recycling systems
PBL_3	Society is modifying the behavior to maximize the reduction of consuming single-use products
PBL_4	Society is committed of the effective implementation of bio-based economy products and services
PBL_5	Society is fully informed about the benefits of the Circular Economy and are demanding Circular-based services and products

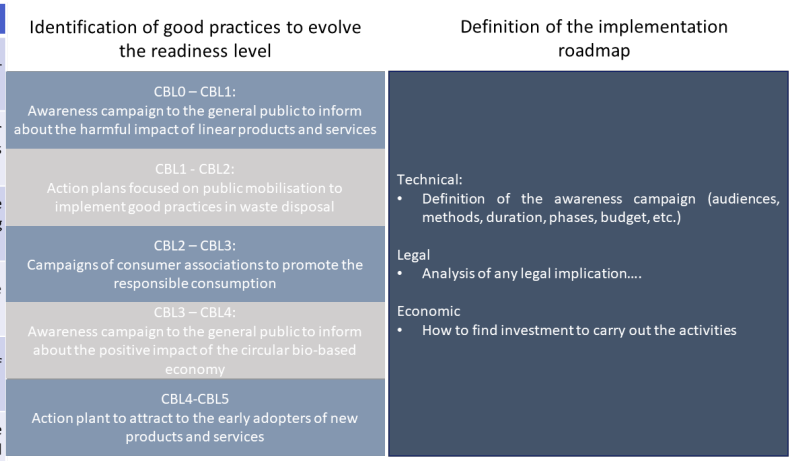

Figure 3 – Next steps for the CBL evolution by connecting with good practices, example for the Pro-active public behaviour criteria.

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ABBREVIATIONS

BIP	Biomethane Industrial Partnership
BRL	Business Readiness Level
CE	Circular Economy
DAC	Direct Air Capture
ERL	Environmental Readiness Level
LRL	Legal and Ethical Readiness Level
ORL	Organisational Readiness Level
PDA	Project Development Assistance
SoRL	Societal Readiness Level
TIRL	Technology and Integration Readiness Level
TRL	Technology Readiness Level

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1 Introduction

1.1 Context and background

Circularity is an essential aspect of the industry transformation towards resource-efficiency, climate neutrality and long-term competitiveness.

The RESOURCE project will study the private funding opportunities needed in circular projects and facilitate their development. RESOURCE's overarching objective is to develop new Project Development Assistance (PDA) services to fund regional circular economy investment projects. More precisely RESOURCE will:

- build an integrated expertise pool to support technically, economically, and legally the regional circular economy pilots SMEs,
- develop innovative financing schemes and business models.
- launch concrete investments.

The RESOURCE project is designed to ensure a high degree of replicability of the PDA and related services. Results will be disseminated to maximize their impact in Aragon and beyond.

Circular economy is a priority for the Region of Aragon. The Region has launched a manifestation of interest and identified a portfolio of circular projects in need of funding. Nine of these projects will serve as pilots in the RESOURCE project.

The methodology that will be developed for the RESOURCE project will ensure the financial sustainability of those circular economy projects by potentially completing their private funding with other sources of financing (European, national, and regional public funds).

The RESOURCE methodology consists of seven steps:

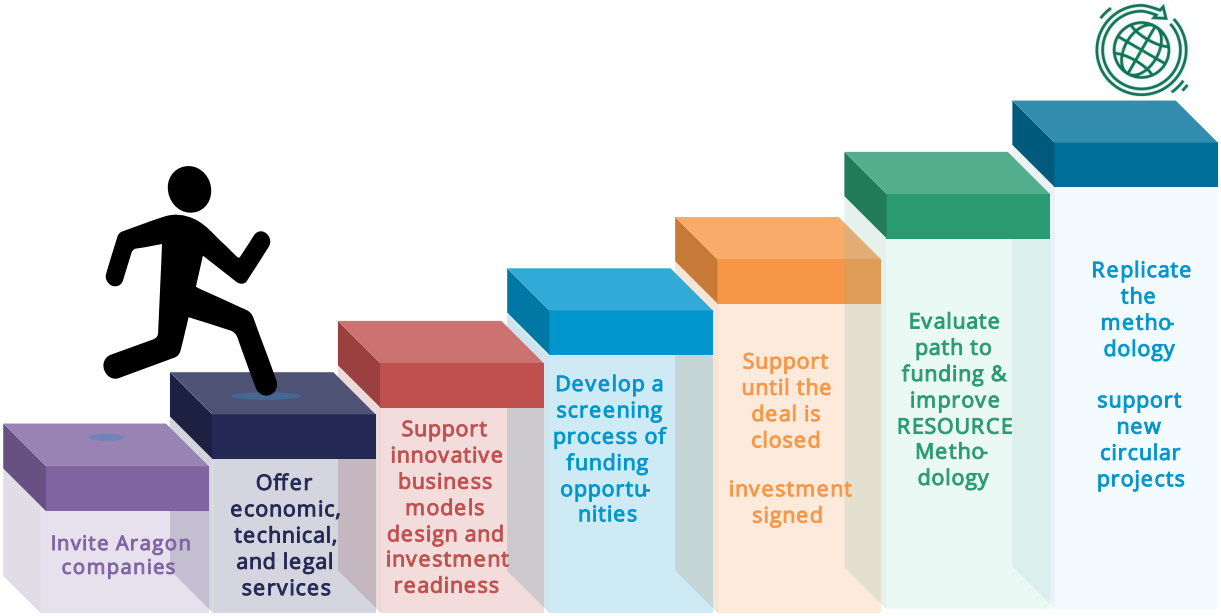

Figure 4 - The RESOURCE methodology in 7 steps

1.2 Purpose and scope of the report

Deliverable 2.2 of the RESOURCE project dives deep into assessing a territory's readiness for circular economy services and products. This analysis is crucial for the project's overall methodology, as it aims to equip key players with tools that diagnose the current situation and recommend concrete steps towards a more circular future.

The ideal toolset should strike a balance between scientific rigor and real-world applicability. A strong scientific foundation ensures the robustness of the assessment, while reflecting the territory's unique characteristics and the language used by its actors, which is a paramount for effective implementation. Deliverable 2.2 tackles this challenge by developing methods that not only measure a territory's preparedness but also speak the language of its stakeholders.

This involves going beyond a purely academic approach. The project will consider factors such as existing infrastructure, waste management practices, consumer behavior patterns, and the presence of companies already engaged in circular practices. By incorporating these territory-specific details, deliverable 2.2 aims to provide a practical roadmap for transitioning towards a circular economy. This roadmap will be tailored to the territory's context, using terminology and addressing challenges that resonate with local actors.

In essence, Deliverable 2.2 goes beyond simply measuring preparedness. It aspires to create a bridge between theory and practice, empowering key players in the territory to translate the principles of circular economy into concrete actions. This will significantly increase the project's impact and pave the way for a more sustainable future.

This report aims to assess the circular economy maturity of various industries within Aragon's main value chains. It will establish a standardized verbal rating system to evaluate each sector's progress. By identifying best practices associated with this maturity level, the report will guide the development of more impactful circular economy initiatives in the region

1.3 Methodology

In order to fulfil the scope outlined in the previous section, we have implemented a methodology that encompassed several key steps. This approach ensured an holistic understanding of the factors influencing the implementation of circular economy projects within identified environmental hotspots.

1. D2.1 Recommendations and TRL Analysis

Our initial step involved a thorough review of the recommendations presented in Deliverable 2.1[1] (D2.1). This document served as a valuable resource, providing insights into the environmental hotspots that warranted focused implementation efforts. These hotspots could be specific industrial sectors, resource consumption patterns, or waste generation points. By identifying these critical areas, we could effectively target our resources and efforts. Furthermore, we conducted a Technology Readiness Level (TRL)[2] analysis of existing pilot projects within the identified hotspots. TRL is a method for assessing the maturity of a particular technology[3]. This analysis allowed us to evaluate the feasibility and practical application of existing circular economy solutions within these environmental pain points.

2. Beyond Technology: Non-Technological Considerations

While technology plays a crucial role in enabling circularity, its successful implementation is contingent on a broader set of factors. To gain a deeper understanding of these influences, we embarked on a comprehensive literature review. This review focused on the readiness level of non-technological criteria that impact the feasibility and sustainability of circular projects. These criteria could encompass aspects such as:

- **Economic viability:** Will the project generate a return on investment, considering both short- and long-term costs and benefits?
- **Policy and regulations:** Do existing policies and regulations incentivize or hinder the implementation of circular initiatives?
- **Social acceptance:** Will the local community and stakeholders be receptive to the proposed circular project?
- **Market demand:** Is there a readily available market for the products or resources recovered through circular practices?

By delving into these non-technological factors, we aimed to develop a more comprehensive understanding of the prerequisites for successful circular economy implementation.

3. Identifying and Ranking Criteria

Building on the foundation of existing knowledge and the literature review, we ventured into collaborative efforts with stakeholders and key actors involved in the circular economy landscape. This interaction served two crucial purposes.

First, it facilitated the identification and classification of relevant criteria that impact the implementation of circular projects within the targeted environmental hotspots. Stakeholders' perspectives and experiences provided valuable insights into the practical challenges and considerations specific to the local context.

Second, we have used a verbal scale in collaboration with these stakeholders to establish a ranking system for the identified criteria. This ranking system allowed us to prioritize factors based on their relative importance in influencing the success of circular initiatives within the environmental hotspots.

4. Collaborative Application

The culmination of our methodology involved the application of the developed framework to real-world scenarios. We collaborated closely with the REDOL project[4], the designated Regional Hub for circularity in Aragon, Spain. This collaboration focused on the main value chains within Zaragoza's industrial and urban landscape.

Specifically, AITIIP, a key partner in the project, coordinated Work Package 2 (WP2) - "Development of a common symbiotic framework for Zaragoza's hub of circularity." This framework would leverage the insights gleaned from our methodology to facilitate the implementation of circular initiatives within the region.

By combining a thorough analysis of existing knowledge, stakeholder engagement, and real-world application through the REDOL project, our methodology provided a robust roadmap for fostering a more circular economy within the identified environmental hotspots. This multifaceted approach

holds the potential to create a significant impact by promoting sustainable resource management practices and fostering a more environmentally conscious future.

2 PILOTS PROJECT TRL INFORMATION

The work done with the pilot's projects, who are the different companies which are participating in the project could be resumed in two different stages, in terms of TRL assessment:

- **Self-evaluation of the TRL:** In this stage, AITIIP send to the pilots a tool to evaluate themselves into different criteria. The main goal of this was to obtain pilot's self-assessment and their thoughts of their position into the market related to their technology.

- **AITIIP's evaluation:** After the first stage, AITIIP using information required to the partners in previous stages of the project, the use of the state of art and experience of our technological centre, AITIIP did some comments and corrections of the self-evaluation.

At the end of this chapter, pilot's projects have been classified into their different sector and value chains.

2.1 Measures analysed

For this preliminary analysis, ATIIP used different measured to assess in the technical assessment:

- **TRL**: Technological Readiness Level are a type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest.
- **Innovation Grade**: The levels that AITIIP used was low, medium, and high based on two different points of view:
    - Novelty: This idea is based on the answer to the question "How new is the technology compared with the market or the existing ones?
    - Impact: This was used in terms of How big of a change does the innovation bring about. Does it solve a small problem or a major one? Does it affect a small group of people or a large one?
- **Market competition:** The aim of this measure is to know the number of companies in their market, the actual size of the market and the amount of money they can reach in order to classify their competitiveness level into low medium or high[5]. This measure is related to technology.

By establishing these 3 categories, AITIIP can tailor assessments, leading to a more effective and efficient evaluation process for each pilot, with the goal of giving a complete vision taking into account in terms of social, legal and other topics that could be interesting for the stakeholders.

2.2 TRL results

In this section, a brief introduction and the results of the abovementioned measures are presented for the 9+1 pilots.

BIOGAS DT - Founded in 2022, BioGas DT is headquartered in La Almunia de Doña Godina, Zaragoza, Spain. The pilot is a player into the bioenergy sector, regarding its activity, the pilot specializes in developing innovative solutions for organic waste treatment, transforming it into biogas and biomethane solutions. In terms of production process, BioGas DT leverages its technology to transform organic waste streams, such as municipal solid waste, agricultural waste, or industrial organic waste, into bioenergy. These BioSolutions can then be utilized in the transportation sector as a renewable fuel source or as an energy stream.

- **TRL:** Their technology, which comes from a third party, has a TRL 9. The pilot process consists of the transformation of organic waste from the farm (slurry, chicken manure, manure, etc.) through an anaerobic process inside a tubular Biodigester into two final products, Biogas and biofertilizer. The process is similar with all kinds of waste. TRL 9 is explained thanks to the capability of the technology to product the final outputs, adding that, it has been proven into a real environment because the final products have already been commercialized.
- **INNOVATION GRADE:** The pilot has a medium level of innovation because they are using an existing technology and transforming the input using an existing process. Their main innovation is in their approach to the market allowing companies to use their waste as another income source or as an energy stream.
- **MARKET COMPETITION:** In Europe, the company faces intense competition from technology competitors. There is an industrial partnership in Europe (BIP). There, also, are 1,322 operational biomethane plants in Europe, with only 7 in Spain.[6] The company has a gap to operate in Spain but the technological rivals around Europe is huge. For that reason, market competition is high.

BUGCLE - The pilot project Bugcle, based in Zaragoza, focuses on the production of raw materials for the agroindustry sector. The company is launching an intensive mealworm breeding program. In terms of technology, the pilot is creating a process that accelerates, controls, and automates worm care using an own bioreactor. The process is designed to be circular and efficient, resulting in sustainable and circular products.

- **TRL:** Pilot's technology is into a TRL 6, their process is based on a bioreactor that uses a bio digestion process through worms, they are using different wastes and as a result different alimentary products are obtained. The decision of classify Bugcle as TRL 6 is based on their results, that this process allows the company to obtained yields from the biodigester and calculating the necessary biomass in the evaluated waste. Confirmation of the required quality of the transformed raw materials at a preindustrial level.
- **INNOVATION GRADE:** The process is very innovative, presenting a high level of innovation. The pilot through its technology has developed new trays for their bioreactor that optimize the space and the production inside it, on a second hand, they have developed a new process that make the production very efficient. Thay also are using the chitin, a part of the worm that can be used to do bioplastics and it can be used into the pharmaceutical sector.
- **MARKET COMPETITION:** Market competition is low at national level, there are only 37 companies in Spain that work in a similar way, but there are only a couple that are focus on

the same target and sector as Buggle. A potential future concern that is not fully addressed is competition for the resources found in waste. While competitors might use different technologies to process this waste, they'll ultimately be vying for the same valuable materials.

CERFO - CERFO was founded in 2021 with a concern for the waste management of solar panels. In particular, they are focused on the recovery and valuing of the components of a solar panel, giving them a circular end-of-life[7]. In this sense, their mission is to develop a closed-loop system for the European solar energy industry. In terms of technological process, they are developing a thermal process that allows them to recover approximately 91% of the solar panel's components.

- **TRL:** The company develops innovative technology and has partnered with CIRCE, a local technology center, to test and validate their solutions in real-world settings. This collaboration demonstrates the technology's effectiveness in practical applications. The company's activity process includes pretreatment, thermal processing to break down the materials and separate them form each other, and finally, aftercare before reintroducing the components into the market. As a result, the company's oven technology has been classified as TRL 6 by Aitiip.
- **INNOVATION GRADE**: They have been researching mechanical, thermal, and chemical recycling technologies, and the results will allow CERFO to recover all kind of solar panels. They have demonstrated that through a photovoltaic module of 2W with suitable size for introduction into the muffle with the determinate characteristics of temperature and time, they can recover more than 91% of the materials. As a result, Aitiip can concluded that CERFO has a high innovation grade.
- **MARKET COMPETITION:** There are only a few companies in the world that specialize in this industry and possess these characteristics, like (PV CYCLE, Reiling, Sofies, Experia, Gedlec. In terms of market trends, the useful life (25- 30 years) of the first solar panels, installed in Spain at the very beginning of this century, is nearing its end, which may indicate that future market trends point to increased interest in this sector. That is why Cerfo's level of market competition is medium.
-

EWN SOLUTIONS - EcoHelp Waste Management (EWM) solves waste problems for public administrations, private businesses, individuals, and the environment. Their process is defined by the introduction of efficient technology and management systems, as well as the measurement, control, and participation of all actors (government, industry, service companies, and citizens) in order to shift the paradigm of linear waste management to a circular format, making residue valuable, transforming it into a resource.

- **TRL:** Due the company is using a patented technology, they have demonstrated that the technology is currently working in an operational environment, so this technology is in a TRL 9. The company is using a technology that converts food and organic waste by speeding up the decomposition process through direct oxidation with reactive oxygen. With a competitive advantage based on bacteria free process, meaning this that there is no generation of harmful or lixiviating gases. The result of this process is a conversion into a value resource of the approximately 70% of the initial waste.
- **INNOVATION GRADE:** The pilot's innovation grade is medium because they are using a modified existing technology that allows them to optimize the process and optimize the

recycling process. Through their process (full potential), they are estimating huge reduction of CO2 to the atmosphere.

- **MARKET COMPETITION:** Although they have a patented technology and a patented process, there are companies in Spain that offer similar solutions. Because of that the market competition for this pilot is high but is important to remark that EWM solutions present a big competitive advantage in their market approach.

FELTWOOD - Feltwood is based on Zaragoza, its activity is focus on developing and producing sustainable, biodegradable industrial materials from vegetable waste. The pilot's mission aims to provide a sustainable alternative to polluting, non-biodegradable materials such as plastic. FELTWOOD owns a patented technology that enables the production of industrial materials from plant waste that can replace plastic and wood. FELTWOOD materials are 100% vegetable fibres (no plastics, adhesives, or binders are used), biodegradable, recyclable, and compostable, closing the loop of the circular economy. Feltwood is operating into the bio-waste management sector and Agrifood industry.

- **TRL:** Feltwood technology is already on a pilot scale, producing and commercializing products such as packaging and insulation panels. Their technology has been proven and functionally implemented in a real-world environment, so Feltwood technology is at TRL 9. Feltwood's technology is based on its ability to transform abundant agricultural waste into a valuable and sustainable material with promising applications. Their emphasis on biodegradability, versatility, durability, and environmental impact demonstrates their commitment to creating environmentally friendly solutions.
- **INNOVATION GRADE:** Both technology and the outputs are very innovative, meaning that the innovation grade is high. The main innovation resides in the outputs are 100% vegetal composition, with biodegradability and recyclability qualities. That grade of vegetal composition is no frequent inside this market.
- **MARKET COMPETITION**: Due the fact that the company operates in two markets using similar technology, we have separated the market competition. One hand is used to package products. Most of them are at the research level (R&D projects), with similar products/technology, so competition is low (Smileat, Two Farmers). On the other hand, in the insulation products, competition is high (trademarks, geopannel).

GREEN FOUNDRY - Green Foundry Castillonroy is based on a small village in Huesca. The pilot project aims to develop an industrial activity necessary to supply foundation pieces for key equipment in other industries, as well as the ability to provide machined pieces using sand moulds. Their process has a very low environmental impact of around 80% less in terms of CO2 emission because of the use of green energy, coming from the sun, and a circular end of life approach of all their products.

- **TRL:** Green foundry technology comes from a third party, and it is completely functional, so in terms of technology they are in a TRL 9. The technology that they are planning to use have some advantages like cost reduction, the capability to give a circular end of live, efficiency and personalization.
- **INNOVATION GRADE:** The pilot project approach has a high level of innovation. Their innovation resides in the business plan, specifically in their energy stream, the pilot will use solar energy instead of the fossil fuels. Also, they have developed sand moulds that will allow a high level of personalization and a more efficient process in terms of small pieces.

- **MARKET COMPETITION:** Green Foundry has detected a huge gap in the market. They are the only company in Sapin with these characteristics and only a couple at an international level, but they have different process. For that, pilot's project competition is low.

RECICLA - The Pilot project activity focuses on the digital processing of citizen recycling, for the sale of compensation certificates carbon footprint. Their specific technology is based on a software that verifies a photo that the users have taken to their recycling garbage giving them in exchange money for their contribution to recycling.

- **TRL:** RECICLA's technology is on a TRL level 9. AITIIP arrives to this conclusion because the app is already available on the market. You can find this app on Google Play and Apple Store, and it already has more than 10.000 users. The App is complete, and it has some updates frequently, so AITIIP has concluded that their technology is already in an actual system proven in operational environments.
- **INNOVATION GRADE:** AITIIP has classified the innovation grade on medium. The innovation in terms of novelty is quite innovative in terms of big data and software innovations, on the other hand in terms of impact the idea has high impact due the fact that the app is helping the society to recycle and reducing the emissions to the CO2 to the atmosphere.
- **MARKET COMPETITION:** Market competition is high. The recycling booster sector is very competitive in Spain, in this sense, you can find different companies that have the same technology and the same final use. Examples of this kind of companies are RECICLOS, CLIMATE TRADE, RECICLA Y GANA.

SMART MOSS - The pilot project based in Teruel, Aragon, focus its activity on Incorporating live moss into technological solutions to improve indoor air quality and foster a connection with nature. Their technology call Moss Box is a smart frame that contains live moss. It has sensors that monitor the environment and an app that allows for communication and customization of the moss experience. The circularity resides in when the life of the moss arrives to an end, the pilot uses it to do compos and introduce it into another sector.

- **TRL:** Pilot's TRL is on a level 7. This level is explained because of they have tested their technology into a real environment. Moss box was introduced in Naturgy facilities with the main goal of test the functionality into a real environment with a positive result in the gas exchange. The TRL 7 is also demonstrated because of two devices were taken to the CITA (Agri-food research and technology centre of Aragon) to check the success of the plant in its reproduction and in the conversion of CO2 to O2 within the specific environment.
- **INNOVATION GRADE:** Smart Moss present a high level of innovation due their capability to have life moss that has a very low impact in the production process, and they can monitor the gas exchange, as well as the useful life of the moss in real time.
- **MARKET COMPETITION:** Although there are different companies in the market with similar characteristics than Smart Moss, but only their product has the following advantages: live moss, high efficiency, low production footprint, circular end of live and real time information. For that reasons we can concluded that market competition is medium because there is a risk of process imitation.

THERMOWASTE - Thermowaste, based in Zaragoza, has developed a new concept for waste treatment plants that will replace landfills with emission-free material recovery plants. Their process aims to solve the problem related to the landfills, reducing the effects and impacts in terms of methane emissions to the atmosphere. The solution that Thermowaste is proposing is a circular because they are converting the waste into valuable resources again, for that the company is involved into the waste management sector.

- **TRL:** Thermowaste has developed a modular and prefabricated plant concept that allows equipment to be quickly and easily transported and installed anywhere in the world. This technology can work as a modular unit or as a production line, it can also be transported easily. The technology is in TRL 9, and it works using steam to sterilizes and transforms waste morphologically, facilitating its subsequent classification, and in fact, its recyclability characteristics in only 30 minutes. Another reason for the TRL valorisation is that the company is already working into a real environment with results of 80.000 tons of material recovered.
- **INNOVATION GRADE:** The pilot project has a high level of innovation. They have developed a patent limpulation process that allows all the materials that make up urban solid waste to return to society in the form of raw materials, embracing the principles of the circular economy.
- **MARKET COMPETITION:** Market competition is low, there are a limited number of companies with similar technological conditions at an international level, but different process. As far as Thermowaste has a patent process they have huge advantage from other competitors or companies.

CADIUCO - CADIUCO project aims to produce and sell CO2 from Direct Air Capture (DAC) plants using GT-DAC technology to produce goods and services. The pilot project will convert an environmental liability into marketable assets, accelerating the transition to a renewable energy economy. Their vision is to contribute to Aragón's endogenous technological development by developing new CO2-based production technologies for goods and services.

- **TRL**: CADIUCO technology is on a TRL 9 as they are using a technology obtained from a third party. The process is based, as said before, on a patented solids adsorption process, which uses highly efficient fans to blow air through patented contactors that bind to CO2, which is then separated with low-temperature heat.
- **INNOVATION GRADE**: Pilot's project grade of innovation is high. Their process allows to produce final product with 0 CO2 emissions in the production process or even reducing the CO2 of the atmosphere. The process will allow capture CO2 and its conversion into a plethora of goods or services with market value like cryogenic cleaning, concrete injection, extraction with supercritical fluids among others.
- **MARKET COMPETITION**: Market competition is low, but there are a couple of companies that have international presence and are the main dominant companies into the gas production sector. These companies are focus on the production and distribution of different gases, that is why CADIUCO, who is specialize in the CO2 has a technology advantage.

After giving an overview of all pilots analyzed during the activity 2.2 technical assessment a summary table of the contents presented above is presented:

Pilot	TRL		INNOVATION GRADE	MARKET COMPETITION
BIOgásDT	9	Actual system proven in operational environment → Technology licence (3rd party tech) for industrial plants for biogas production. Pilot biogas refinery (La Almunia)	**MEDIUM** – Provides the necessary infrastructure and technology for industrial biogas plants developed by its Partners	**HIGH** - There is an industrial partnership in Europe (BIP), There are 1,322 operational biomethane plants in Europe and only 7 in Spain (Data April 2023).
bugcle	6	Technology demonstrated in a relevant environment → Test in the company's bioreactor and its transformation for analysis of properties in flours, oils, chitin and chitosan.	**HIGH** – development of new trays for their modules, new production processes, development of new products based in chitin for bio-plastics and pharmaceutical sector	**LOW** – couple of companies in Spain with similar processes but no with the same outcome (TEBRIO, GALINSECT, IBERINSECT)
cerfo	6	Technology demonstrated in a relevant environment → Termical treatments were carried out in a controlled environment to a small part of a solar panel	**HIGH** – research in mechanical, thermal and chemical recycling technologies for the complete recovery of solar panels. It will be the first plant in Europe that allows more than 90% of the materials to be recovered	**MEDIUM** – companies across Europe and rest of the world (PV CYCLE, Reiling, Sofies, Experia, Gedlec) have similar characteristics
ewm Soluciones Energy & Waste Management	9	Actual system proven in operational environment → technology licence (3rd party tech) for oxidation processes.	**MEDIUM** – existing technology, implementing modifications that allow filtering processes, optimize the process and recycle.	**HIGH** – significant number of companies with similar technology (Sacyr, Valoriza, Urbaser) competitive advantage in business model
FELTWOOD Engineering Nature	9	Actual system proven in operational environment → Feltwood is currently working into a pilot scale, their technology is in the phase to escalate to a high scale production.	**HIGH** - 100% vegetal composition, biodegradable, recyclability.	**LOW** in packaging products. Most of them at research level (R&D projects), companies with similar products/technology (Smileat, Two Farmers) **HIGH** in insulating and protection products (Trademarks: Geopannel)
GREEN FOUNDRY CASTILLONROY	9	Actual system proven in operational environment → technology licence (3rd party tech) their innovation resides in the business plan (green energy) → new process developed and proven in a pilot scale	**HIGH** – innovation process developed (sandless Molds), CO2 and energy reduction	**LOW** – Green Foundry is the only one using this process in Spain. There are couple around the word (ExOne, Voxeljet, Desktop Metal)
RECICLA	9	Actual system proven in operational environment → The App is currently working and available for user in Google play and Apple Store (+10.000 users)	**MEDIUM** – Development of software (Big data system)	**HIGH –** There are similar options in the market (RECICLOS, RECICLA YA, CLIMATE TRADE, RECICLA Y GANA)
SMARTMOSS	7	System prototype demonstration in operational environment → Technology were tested into ITA laboratories with positive results.	**HIGH** – Life moss, monitoring (real time) tool, very low footprint and circular end life	**MEDIUM** – Substitutive products are available in the market. Smart Moss has a lot of competitive advantages
THERMOWASTE technology for circular economy	9	Actual system proven in operational environment → Technology licence (3rd party tech) → Two previous pilot plants	**HIGH** – Limpulation, process patented by Thermowaste, transforms municipal solid waste into clean materials which allows the elimination of smells and pathogens.	**LOW -** Companies at international level (TOMRA, COPARM, BESTONGROUP), but they use different processes.
CADIUCO	9	Actual system proven in operational environment → technology licence (3rd party tech) → Global - thermostat	**HIGH** – their process allow to produce with 0 CO2 impact or with negative impact (< 0)	**LOW** – Companies at international level (Carbon Clean, Climeworks, Carbon Engineering)

Figure 5 - Pilot's TRL summary

2.3 Pilots project sectors

The primary aim of this statement is to provide a brief overview of all technologies used by pilot projects, as well as the sectors in which they operate or intend to operate. The results presented in the table below will show which sectors are more representative, as well as which sectors are relevant in Aragón.

PILOT NAME	SECTOR OF APPLICATION	SUBSECTOR
BIOGAS DT	Bioenergy	Biogas production
BUGCLE	Agrifood sector	Insect farming
CERFO	Recycling sector	Solar photovoltaic
EWN SOLUTIONS	Biowaste management	-
FELTWOOD	Biowaste management	Agrifood industry
GREEN FOUNDRY	Recycling sector	Steel making
RECICLA	Recycling sector	Recycling booster
SMART MOSS	Air treatment / Pollution	Air filtering
THERMOWASTE	Biowaste management	-
CADIUCO	Air treatment / Pollution	CO2 capture

Figure 6 - Pilots project sector of activity

As shown in the table, there are five major areas of interest for the RESOURCE project. The sector most represented among the pilots is biowaste management, but in subsequent sections of this report, more metrics of interest will be analysed for all sectors detected with the goal of providing the pilots with a comprehensive view of their value chain, including information on various aspects such as public behaviour and industrial networks, among others.

3 Criteria Identification for Circular Readiness Level

Academic frameworks for assessing economic[8], social[9], and organizational[10] maturity exist, but they haven't been easily adapted to the specific realities of the RESOURCE pilot projects and their stakeholders. For example:

- **Technology and Integration Readiness Level (TIRL)[11]:** TIRL evaluates the level of technological maturity as well as the system integration into a society or environment, based on the technological readiness level. This measure goes further than one technology, instead of focusing only on a particular technology, this dimension considers the integration of the entire system within the entire hub and incorporates the assessment of the level of interaction in the economic environment. Furthermore, the evaluation of the achieved level of digitalization, the development of infrastructure and equipment, and material flows and circularity are included.

- **Business Readiness Level (BRL):** The goal of the BRL is to oversee and facilitate the establishment of a sustainable business model for the Industrial symbiosis (IS) network. In this dimension the global competitiveness of the value chains is the key aspect to evaluate.

- **Organisational Readiness Level (ORL)[12]:** In order to include more aspects beyond the managerial concept, the organisational readiness level evaluates more aspects like a broader range of organisational factors that are pertinent to the establishment of an Industrial Symbiosis network. This dimension contemplates the existence of management platforms and an adequate governance structure to direct project activities.

- **Environmental Readiness Level (ERL):** It is important to consider the environmental and ecologically aspects in order to assess the sustainability of the value chain. The ERL is used to evaluate the circular economy ability to produce the same (or a higher) level of benefits, generating lower environmental impact, compared to "stand-alone" facilities with current state-of-the-art technologies and systems".

- **Legal and Ethical Readiness Level (LRL):** This dimension stands that "no new technology, product, process, or intervention can survive if proven to go against the existing set of binding rules that govern the selected domain". In the case of Circular Economy projects, it is relevant to evaluate the authorizations, regulations and permits that must be complied with when carrying out Circular Economy activities.

- **Societal Readiness Level (SoRL)[13]:** This dimension is focused on assessing the level of maturity of society when the time comes to adopt the solutions proposed by the activities developed under the Circular Economy project. This dimension also covers the evaluation of socio-economic aspects produced from the establishment of Circular Economy activities, such as: job creation and upskilling, knowledge creation and circular cities.

Therefore, while the TRL analysis for the RESOURCE pilot projects offers valuable insights, it focuses primarily on technological readiness. To gain a more comprehensive picture, a co-created regional circular economy maturity scale could be beneficial. This scale would consider additional dimensions like the projects' impact and novelty within the circular economy, moving beyond individual stakeholder perspectives through a collaborative approach[14]. Five key areas were identified to gauge the region's readiness for Aragon circular economy. This resulted from analysing RESOURCE pilot projects, involving participating teams, conducting workshops, and exchanging ideas with stakeholders across Aragon.

3.1 . Proactive Public Behaviour (PB)

Background - The nature of circular systems needs a collective effort of all the actors in an environment, that means that businesses, consumers, and governments should be align. While, in one hand, the techno-economic sides of the circular economy have attracted large attention in recent years, on the other hand, the role of consumer behaviour, which is a critical factor in defining the long-term success of 'sustainable production and consumption' initiatives[15], remains less explored.

Nowadays consumers have a great impact and are the driving force behind a sustainable future. Every choice consumers make, from selecting eco-friendly products to reducing waste, could change the strategic plans of companies due the message that consumers are sending to businesses through their actions[16]. This consumer behaviour creates a demand for sustainability, incentivizing businesses to adopt greener practices[17].

Stakeholders Perception in Aragon - Consumers play a key role in getting the most out of products throughout their lifespan. The choices and attitudes that consumers make at each stage affect the environment and how well a circular economy works for these products. Proactive public behaviours reduce waste, saves resources and open market opportunities.

However, as a general conclusion, the Aragonian stakeholders do not perceive the power of consumers and citizens to influence value chains from the input to the output.

Proposed verbal scale to quantify maturity level -

- **PBL_0 - Society follows the classical behaviour of production-consumption-disposal approach.** This level reflect that the society is currently operating into a linear cycle. In PBL_0, the economic environment is using a traditional market approach. These models are mainly based on the extraction of resources, manufacture of goods, and at the end, them are discarded as waste. This "take-make-dispose" model is unsustainable and have a huge impact on the environment.
- **PBL_1 – Society concerns the problematic of the linear economy. Our current "take-make-waste" system is raising alarms**. Society is aware of the linear economy problems that comes from the use of depletes resources, which produce environmental problems like pollution or generation of massive amounts of trash. This level is also unsustainable, and society is aware of need of a new way to manage limited resources.
- **PBL_2 – Society is committed with the utilisation of the waste management Systems for the reutilisation and recycling systems**. A growing commitment to waste management prioritizes reuse and recycling systems appears in the society, this behaviour aims to create a closed loop where materials stay in use, not landfills.
- **PBL_3 – Society is modifying the behaviour to maximise the reduction of consuming single-use products**. A shift is happening, at this level people are changing habits to ditch disposables. Reusable alternatives are becoming the norm, and the economy is reducing single-use waste. This cultural movement is minimizing environmental footprint and other effect related to a single use economy.
- **PBL_4 – Society is committed of the effective implementation of bio-based economy products and services**. Society's behaviours are focus into a transition to a circular economy, inhabitants of a region are actively working to replace traditional products and services with sustainable

alternatives derived from renewable biological resources. At PBL_4, the main goal is to reduce dependence on fossil fuels, minimize environmental impact, and create a more circular economic system.

- **PBL_5 - Society is fully informed about the benefits of the Circular Economy and are demanding Circular-based services and products**. Society prefers the circular economy, with its eco-friendly and no harmful solutions. At this point, consumers are actively seeking out circular products and services, prioritizing sustainability in every purchase.

Activities to evolve the criteria's level – The success of a circular economy hinges on public engagement. To escalate this criteria society needs to develop of the convenient and accessible consumer-centric systems. Furthermore, public education initiatives are crucial to foster a culture of reuse and responsible disposal practices. As a conclusion, challenges exist but principal changes required are related to infrastructure development and the implementation of effective incentive programs. Finally, the biggest change to do is consumer mentality and perception, it is essential to the success of circular products design into a tangible market. Here are how consumers can help:

- **Buy products built to last[18]:**
  - **Invest in quality over quantity:** Commercialize a well-made item has a bigger opportunity cost, in terms of manufacturing cost, but brings money in the long run and more advantages like good reputation. For this is important to avoid fast selling or one-use selling trends.
  - **Prioritize repairability:** Promoting the selection and commercialization of products designed to have an easy fixing, recycling or sell products with longer lifespan.
  - **Research brand reputation:** Companies should potentiate the green image and market positioning. In addition, consumers should have the need of looking for companies known for crafting durable goods and the ones that have designed an appropriate CSR (Company Social Responsibility) align with circular economy.

Finally, as commented before, there are activities that should be implemented to promote this proactive behaviour in the citizens:

1. **Education and Awareness:** Public awareness campaigns could inform and bring closer the environmental and economic benefits of a transition to a circular business model economy. This could be included through the use of educational programs, informative labelling on products, and community workshops on 3r's.
2. **Incentivize Sustainable Choices:** Designing programs or action that can support circularity through reward systems could be the best option. These programs could involve deposit schemes for refillable containers, discounts for buying second-hand goods, or points programs for responsible waste sorting, among other activities.
3. **Make Reuse and Repair Accessible:** Support the creation of repair cafes, community composting programs, and easily accessible drop-off points for various recyclable items. This infrastructure makes circular practices convenient and encourages participation.
4. **Promote the Sharing Economy:** Encourage platforms for sharing underutilized resources like carpooling, tool libraries, or clothing rental services. This reduces reliance on individual ownership and promotes a more efficient use of existing products.

3.2 . Supportive Legal Framework (SL)

Background: The authorities should design a coherent legal framework that could serve as dynamic corpus juris. It should be designed to facilitate the pursuit of implementing circular economy models.[19] This architecture emphasizes transparency, predictability, and enforceability, creating an enabling ecosystem[20] in which stakeholders can engage strategically with foresight and agility. The legal framework should be aligned with the circular requirements to create and smooth transition to new and innovative business strategies.

Stakeholders Perception in Aragon - Local and regional regulations play a crucial role in the development and adoption of sustainable solutions. Governments should set standards, create incentives, and allow the local innovation, facilitating and paving the way for a more sustainable future. In addition, the actual framework highlights the different regulations that are distributed into the European and national legal framework that are generating inequalities within the regions of Spain and countries of Europe.

Proposed verbal to quantify maturity level -

- **SLL_0 – Local and regional regulations promote linear economy**. Local regulations are supporting a linear economy making difficult an optimal end of life. Examples of this are focusing on waste disposal rather than encouraging reuse and recycling, making repairs difficult through restrictions on spare parts or repair businesses, favouring short-lived products with lax durability standards, disincentivizing product take-back programs by businesses and/or limiting investment in circular infrastructure like composting facilities or repair workshops.
- **SLL_1 – Local and regional regulations promote efficient waste management systems.** The actual legal framework is promoting recycling programs and potentially implementing waste disposal fees. They, also, encourage residents and businesses to reduce waste and participate in responsible disposal practices, with the main objective of fostering a more sustainable and cost-effective process for everyone.
- **SLL_2 – Local and regional regulations promote the development of sustainable solutions.** In SLL_2 local and regional regulations act as a springboard for sustainable solutions. Here a set of clear standards for energy use, waste disposal, and resource management, have been defined, and in this way, regulatory authorities are creating a framework that encourages innovation. At this level, businesses and communities are motivated to develop new technologies and practices that this framework allow, and, in this regard, accelerating the shift towards a more sustainable economy.
- **SLL_3 – Local and regional regulations boost the responsible consumption.** The actual legal framework protects the environment and keeps informed consumers about the new framework and next steps for the future making easier to choose eco-friendly options, and stablishing a clearer future, in terms of legislation for companies. This legal regulatory framework allows regions empower individuals to make sustainable choices.
- **SLL_4 – Local and regional regulation promote public and private green procurement**. This level is characterized by the creation of a “green criterion” for government purchases pushing public entities towards eco-friendly options. This effect ripples outward, as businesses see the demand for sustainable products and services rise, incentivizing them to adopt greener practices as well. It's a win-win for the environment and the economy.

- **SLL_5 - The local and regional regulations have been adapted to enable circular based strategies**. This level shows that regulations now encourage practices like product redesign for reusability, extended producer responsibility (where companies take back products), and creation of repair and recycling infrastructure. It's a shift from a throw-away model to one that keeps resources in use.

Activities to evolve the criteria's level: Local and regional regulations can act as catalysts for sustainable solutions[21] by:

- **Establishing clear and concise laws and regulations[22]:** These define all inhabitants' rights, responsibilities, and limitations, reducing ambiguity and conflict**.**
- **Incorporating mechanisms for ongoing review and adaptation:** The framework must be adaptable enough to changing circumstances and emerging needs through regular reviews and updates.
- **Promoting best practices and international standards:** Effective frameworks frequently incorporate successful approaches used by other jurisdictions to achieve similar goals.

3.3 . Effective end-of-life Economy (EE)

Background: Effective end-of life economy focuses on developing a system that maximizes the value of products and materials throughout their lifecycles while reducing waste and increasing resource efficiency. It seeks to shift away from the traditional "take-make-dispose" linear economy and toward a more circular model. In addition, The EEL framework provides a roadmap for achieving this vision[23], demonstrating that transitioning to an Effective End-of-Life Economy requires not just technological advancements but also a shift in economic incentives and consumer behaviour that may be supported by economic incentives and instruments[24].

Stakeholders Perception in Aragon - Stakeholder perceptions on funding for the circular economy are very different among each other. Businesses see it as a valuable tool to offset initial investment risks in new technologies and infrastructure for reuse, repair, and recycling. They might also find grant programs attractive for research and development of circular products and business models. However, they can find fear and complex application processes or competition for limited funds. Environmental groups see funding as an accelerator for broader circular economy adoption but may worry about schemes prioritizing profit over true sustainability. Overall, stakeholders generally welcome funding, but emphasize the need for accessible programs with clear environmental goals.

Proposed verbal to quantify maturity level -

- **EEL_0 – Current economic incentives support the linear economy**. The actual economic system rewards constant production and consumption, for example: subsidies often favour raw material extraction over recycled materials, tax breaks incentivize businesses to manufacture new products, not repair old ones, low prices for virgin resources make it cheaper to create something new than extend the life of something existing. This cycle of take-make-dispose, fuelled by economic incentives is what keeps the linear economy going.
- **EEL_1 – There are some funding schemes that facilitate the creation of new entities related to recycled products.** The actual framework proposes grants and programs to allow the jumpstart businesses built around recycled materials. These initiatives provide financial aid to

launch companies that collect, process, or manufacture products from recyclables. This fosters innovation and helps close the loop on resource use, becoming into a more circular economy.

- **EEL_2 – Public funds are available to improve the waste management systems.** Different public programs put public grants available to upgrade waste management systems, invest into better recollection systems or into recycling facilities. This will create a cleaner environment, reduce pollution, and benefit everyone in the community.
- **EEL_3 – Public and private entities are collaborating to invest in valorisation facilities.** At this level governments and businesses are working together to fund facilities that turn waste into valuable products. This "valorisation" effort aims to reduce landfill dependence and create new resources. In this framework public funding helps build the plants, while private expertise ensures efficient operations, creating a win-win for the environment and the economy.
- **EEL_4 – Economic framework is favourable to the implementation of circular bio-based strategies.** EEL_4 is a supportive economic framework that can fuel circular bio-based strategies. In this framework policies are incentivizing the use of renewable biomass and designing products for reuse or composting. It also includes penalties or deduction to traditional/circular economy model through the use of tax exemptions for bio-based businesses or penalties for landfill waste create a market shift. As a result, consumers empowered by eco-labels can choose sustainable options, shifting towards a circular bioeconomy and reducing dependence on virgin materials and creating new green jobs.
- **EEL_5 - Economic instruments have been developed and implement to support circular bio-economy initiatives by an effective use of recycled products**. Economic tools are driving the circular bioeconomy by making recycled materials more attractive. Taxes on virgin resources and subsidies for recycling companies are creating a financial incentive to prioritize reused materials, as a result of the reduction of waste and also fostering a bio-based economy where products are designed for multiple lifecycles, creating a more sustainable system.

Activities to evolve the criteria's level: Activities to improve the economic incentives for implementing circular economy in Aragon region.

1. **Targeted Tax Breaks[25]:** Reduce taxes for businesses that design durable, repairable products and implement take-back programs. Conversely, consider tax increases on virgin materials and products with short lifespans.
2. **Subsidies and Grants:** Offer financial assistance for businesses to adopt circular practices. This can include funding for infrastructure development in repair, reuse, and recycling facilities.
3. **Green Public Procurement[26]:** Public institutions in the region should prioritize purchasing products made with recycled materials, designed for longevity, and with take-back options.
4. **Circular Economy Business Awards:** Recognize and celebrate businesses excelling in circular practices. This incentivizes innovation and raises public awareness of successful circular models.

3.4 . Efficient waste Management system (EM)

Background: Waste management is an essential component for achieving an Effective End-of-Life Economy[27] (Connexion to 3.3). Economy can change the paradigm from a linear economy to a more sustainable and resource-efficient economy by focusing on resource recovery, product lifespan

extension, and waste minimization. In order to create a circular economy; governments, businesses, and consumers must work together to view waste as a resource with the potential for a second life.

Stakeholders Perception in Aragon - Industry perception about efficient waste management as a game-changer for a circular economy. It provides a steady stream of valuable resources like recycled materials, reducing reliance on virgin resources and lowering production costs. Efficient systems can also create new revenue streams through waste-to-product ventures. However, upfront investments and potential changes in production processes might be seen as challenges. Overall, industry recognizes the long-term benefits of efficient waste management for a more sustainable and cost-effective circular economy.

Proposed verbal scale to quantify maturity level -

- **EML_0 –Waste management systems are limited to the disposal of the waste on landfills**. In this level landfills are overflowing because a large portion of the trash is not recycled or composted. This clogs up valuable space, creates pollution, and buries materials that could be reused.
- **EML_1 – Waste management system only includes some level of selective collection.** The community's recycling program only sorts some recyclables, leaving a lot of resources in landfill and increasing landfill waste and missing the chance to reuse resources.
- **EML_2 – Some facilities for the recovering and recycling have been built.** EML_2 is a significant step towards a more sustainable future, the region has built several new resource recovery facilities. These centres will play a vital role in processing recyclables and transforming them back into usable materials, minimizing waste and promoting environmental responsibility.
- **EML_3 – The selective management system is quite improved, including water/bio-based waste fraction.** The Selective Management System has undergone significant enhancements, incorporating a focus on specific resources like water and bio-based waste fractions ensuring a more comprehensive and sustainable waste management strategy and promoting resource recovery and environmental responsibility.
- **EML_4 – Circular factories are currently working producing medium-quality circular products**. The market trends have made that new of circular factories emerged, them are focused on designing and manufacturing products with a closed-loop lifecycle. These facilities prioritize using recycled materials and implementing processes that minimize waste and the efficiency. At EML_4 the current focus lies on achieving medium-quality production, advancements in technology and material science will be necessaries to enable the creation of high-quality circular goods soon.
- **EML_5 - The sorting, collection, reusing and recycling system maximise the quantity and the quality of the intermediate building blocks.** A robust closed-loop system for sorting, collection, reuse, and recycling optimizes the recovery and quality of valuable intermediate materials. This new system maximizes the quantity of these building blocks available for production, and ensures their suitability for new applications, being completely align with the circular principles.

Activities to evolve the criteria's level:

1. **Embrace the Waste Hierarchy:** This means designing products for durability and repairability, and implementing practices that minimize waste generation during production.

2. **Invest in Smart Sorting:** Implement a multi-stream waste collection system with clear signage and education campaigns. This allows efficient separation of recyclables, organics, and general waste, maximizing the potential for diversion from landfills.
3. **Foster Innovation:** Encourage and support the development of new technologies for waste processing. Innovative technologies could include advanced recycling facilities that handle complex materials or composting infrastructure for organic waste. In addition, creating new pathways for waste to become valuable resources, will make that the system become more efficient and sustainable.

3.5 . Prepared Industrial network (PI)

Background: Industrial symbiosis, whereby different actors derive mutual benefit from sharing utilities and waste materials, requires large-scale systemic innovation with the aim of turning waste from one industry into useful feedstock for another one[28]. The management of waste material flows coming from different sectors calls for reliable and harmonised data for the estimation of composition, patterns of supply and quantity of wastes generated over the year(s), in order to achieve reliable and predictable feedstocks of secondary raw materials for industrial plants[29]. Industrial symbiosis needs ample coordination between a variety of stakeholders[30], such as industry, research, civil society organisations, public authorities and policy makers[31], and an increased awareness of producer responsibility[32] for waste production, which is essential in consideration of the central role of businesses in the economic and societal transformation.

Stakeholders Perception in Aragon - The perception of industry's preparedness for the circular economy is mixed. There is growing recognition of the environmental and economic benefits, but many industries continue to face challenges. Upfront costs for redesigning products and infrastructure can be prohibitive. Furthermore, the absence of standardized recycling processes and long-term government support can cause uncertainty. Overall, the industry is seen as moving in the right direction, but significant progress will require overcoming these obstacles and fostering collaboration throughout the supply chain.

Proposed verbal scale to quantify maturity level -

- **PIL_0 – Industry is far from any circular application**. The current industrial model is largely linear, where the resources are extracted, processed into products, and ultimately discarded as waste. At this point, transitioning to a circular model requires significant changes in product design, manufacturing processes, and consumer behaviours.
- **PIL_1 – A few innovative RTOs are starting to tackle some of the factors related to bio-based and circularity technologies.** The organizations at this level are actively addressing key challenges to achieve advancements and adoption of sustainable technologies. Their efforts pave the way for a future circular model where bio-based products and circularity are at the forefront of innovation.
- **PIL_2 – Technology transference between RTOs and companies is on-going.** PIL_2 is based on a continuous exchange of knowledge and advancements between Research and Technology Organizations (RTOs) and the private sector. This technology transfer initiative ensures findings in the practical applications of the solutions.

- **PIL_3 – Some value chains have been articulated but are still weak.** This level 3 presents a lack of robustness in terms of effectiveness. Further development is needed to strengthen these chains and ensure optimal flow of goods, services, and information.
- **PIL_4 – Several value chains have been articulated and consolidated but without interrelation among them.** In this case individual value chains have been meticulously defined and optimized arriving to the requirements of circular model, but in a general context there is a concerning lack of integration. This siloed approach fails to capitalize on potential synergies and may lead to inefficiencies across the broader ecosystem. To unlock the full potential of our operations, fostering collaboration and identifying interdependencies between these value chains is crucial.
- **PIL_5 - High level of relationships among actors with technologies to valorise the circular building blocks and stablish inter-sectorial circular bio-based value chains.** This top level shows a circular economy hinges on strong collaboration. This requires a network of actors, from researchers to industry leaders, who leverage innovative technologies to unlock the full potential of bio-based materials. The inter-sectorial relationships can establish a robust circular value chain, which will optimize resource utilization.

Activities to evolve the criteria's level: Industrial symbiosis (IS) presents a powerful tool for creating a more sustainable and resource-efficient industrial landscape[33]. By encouraging collaboration between companies to exchange by-products and waste streams as valuable resources, IS can minimize environmental impact while boosting economic opportunities. However, fostering successful IS implementation requires a multi-faceted approach:

1. **Public Grants and Incentives**: Government grants and tax breaks can significantly reduce the upfront costs of implementing IS projects. Programs that target specific industries, geographical regions, or innovative approaches can incentivize companies to explore collaborative opportunities.
2. **Private Investments:** Impact investors and venture capital firms seeking sustainable projects can be a valuable source of funding. Highlighting the economic and environmental benefits of IS can attract these investors.
3. **Peer-to-Peer Lending**[34]: Facilitate platforms where companies with surplus resources can connect with potential buyers, creating a system of internal resource exchange within the industrial ecosystem. Establish online or physical platforms that connect companies across different sectors. These platforms can foster communication, share information on waste streams and resource needs, and facilitate matchmaking between potential partners.
4. **Workshops and Events**: Organize workshops, seminars, and conferences to educate companies about IS principles, share best practices, and showcase successful case studies. These events can spark collaboration by bringing together industry leaders, policymakers, and potential partners.
5. **Industry Associations**: Leverage existing industry associations to promote IS. Associations can act as information hubs, organize collaborative projects, and create sector-specific guidelines for safe and efficient resource exchange.

4 Conclusions and next steps

4.1 . CONCLUSIONS

Circular economy models seek to reduce waste by modelling closed-loop systems by emphasizing reuse and repair, closing the material loop, shifting focus to products as a service, embracing renewable resources, and designing for disassembly. In addition, the circular economy seeks to reuse and recycle resources, whereas the bioeconomy focuses on renewable biological materials, where connecting the two aspects is critical for sustainability. We can reduce waste and our reliance on virgin resources by designing longer-lasting bio-based products and recycling them efficiently. This powerful combination contributes to pollution reduction, resource conservation, and climate change mitigation, all of which are critical for a healthier planet. A circular economy seeks to decouple economic growth from resource depletion, resulting in a system that benefits both the environment and businesses. However, circular economy models, unlike the linear "take-make-dispose" model, resemble a complex ecosystem. Transitioning to these models is far more intricate than simply streamlining a one-way flow. Some of these factors are:

- **Multiplicity of Players**: Circularity involves a web of actors such as product designers, manufacturers, repairers, recyclers, consumers. Each of them has distinct needs, challenges and goals. So, in this sense, finding ways to incentivize collaboration and ensure everyone benefits are crucial.
- **Balancing Individual and Collective Needs:** Connecting collective benefits with individual goals should be the final objective of every circular business model. For example, a clothing company might design durable garments for multiple wearers (collective benefit) but ensuring fair compensation for those who "rent" or resell them might require creative solutions (individual needs).
- **Resource Constraints:** The success of circular models hinges on the availability of resources within a region. A city with limited recycling infrastructure might struggle with product-as-a-service models that rely on efficient material recovery.
- **Consumption Behavior:** The effectiveness of circularity is heavily influenced by consumer habits. If people are unwilling to buy used or refurbished products, efforts to create these loops will be hindered. Regional culture and existing waste management systems play a significant role here.

These factors interweave to create a complex web that necessitates a **regional approach.** A successful model in one city with a strong repair infrastructure and high consumer acceptance of second-hand goods might fail miserably in another with limited resources and different consumption patterns. Therefore, implementing circularity effectively requires a deep understanding of the regional context. It's not a one-size-fits-all solution, but rather a tailored approach that considers the unique strengths, limitations, and stakeholder landscape of a specific area:

- **Firstly,** businesses face challenges revamping products for disassembly and reuse. Supply chains often lack the infrastructure to handle returned goods efficiently. Financing these changes can be a hurdle, too. Consumers, used to the "buy and toss" mentality, might need convincing that pre-owned or refurbished options are just as good.
- **Regionally,** success hinges on collaboration. Effective recycling plants and collection systems are crucial. Regulations that incentivize circular practices and discourage waste are essential.

Universities and research centers can play a role by developing innovative recycling technologies. Ultimately, a successful circular economy requires a collective effort from businesses, consumers, and governments working together within a supportive regional framework.

Tailored Measurement: Assessing Regional Circular Economy Readiness: The successful transition towards a circular economy necessitates the development of region-specific preparedness assessment models. These models should leverage established scientific frameworks but require adaptation to capture the unique realities of individual regions. This adaptation entails a two-pronged approach. Firstly, the very conception of the criteria used to gauge circular economy readiness must be adjusted to reflect regional specificities. This could involve considering factors such as dominant industries, infrastructure availability, or waste management practices. Secondly, the maturity scales associated with each criterion need to be tailored to the regional context. A region with limited existing recycling infrastructure might define "advanced" on this criterion differently compared to a region with established systems. By adopting such a nuanced approach, these models can provide a more accurate picture of a region's preparedness for implementing circular economy practices, thereby enabling targeted interventions and fostering a smoother transition.

4.2 . NEXT STEPS

The development of a robust tool to gauge a region's circular economy (CE) maturity level is a crucial first step. However, this assessment becomes even more powerful when strategically linked to a curated set of success stories. By analysing successful CE initiatives implemented in other regions, we can glean valuable insights and adapt them to the specific context of the Aragon region. This approach offers several key advantages:

- **Enhanced Project Definition:** Maturity assessments provide a clear picture of the region's current state within the CE landscape. Success stories from regions at a similar maturity level showcase practical implementations that have demonstrably yielded positive results. By analysing these successful projects, stakeholders in Aragon can identify gaps in their own approach and pinpoint areas for improvement. This comprehensive understanding allows for the development of more targeted and impactful CE projects tailored to the region's specific strengths and weaknesses.
- **Comprehensive Stakeholder Identification:** Often, successful CE initiatives involve collaboration between various players, including businesses, government agencies, research institutions, and citizens. By examining how these actors have interacted and synergized within successful projects from comparable regions, we can identify the necessary stakeholders in Aragon who would be crucial for successful implementation. This proactive stakeholder identification streamlines project planning and ensures the inclusion of all essential voices from the outset.
- **Contextualization and Transposition:** While directly replicating success stories from other regions might not be feasible due to differing socioeconomic contexts, these stories serve as valuable blueprints. Through a process of careful analysis and adaptation, key elements such as innovative business models, policy instruments, or community engagement strategies can be transposed to the unique circumstances of the Aragon region. This process ensures that CE

projects implemented in Aragon are not only well-defined but also grounded in real-world examples that have demonstrably achieved positive outcomes.

In conclusion, the strategic pairing of regional CE maturity assessments with a curated set of success stories is a powerful tool for fostering impactful circular economy implementation in the Aragon region. By leveraging these insights, stakeholders can define more comprehensive projects, identify key actors for collaboration, and adapt successful strategies to the specific context of the region, ultimately accelerating the transition towards a more sustainable circular economy.

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