



EcoSites implementation for industrial-urban symbiosis through social and technological solutions

Deliverable name:

Business Plans for the I-US based on the 4 EcoSites

Deliverable number	D6.9
Official date	
Submission date	May 05,2026
Responsible partner	AGRA
Authors	AGRA+ PRJ
Version	V03
Work package no.	WP6
Work package leader	OSM
Dissemination level	PU



List of Abbreviations:

Abbreviation	Meaning
AC	Adsorption Column
AnMBR	Anaerobic Membrane Bioreactor
BA	Benzoic Acid
BW	Biological Waste
COGS	Cost of Goods Sold
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
FORBI	Food Residue Biomass
FTO	Freedom to Operate
IP	Intellectual Property
IPR	Intellectual Property Rights
IRR	Internal Rate of Return
MaRREEF	Material Regional Recovery, Energy Efficient Facility
NRW	Non-Recyclable Waste
OIWW	Olive Oil Wastewater
PHA	Polyhydroxyalkanoates (Bioplastic)
POC	Proof of Concept
ROI	Return on Investment
WRRF	Water Resource Recovery Facility
WW	Wastewater
WWTP	Wastewater Treatment Plant

Abstract

This deliverable analyzes the potential for large-scale exploitation across EU Member States and beyond, and outlines a roadmap for implementation. It begins with a brief review of the regulatory environment relevant to SYMSITES, followed by an overview of industrial symbiosis and industrial-urban symbiosis, including key lessons learned, best practices, and the main technology and waste-stream areas involved. Part 2 presents SYMSITES' overall achievements, key exploitable results, and solutions, including the list of KERs, their owners, and their IP status. Part 3 introduces the developed business model, its main assumptions, and its detailed application to the four Eco-Sites, together with the main outcomes and parameters. Part 4 translates these findings into an implementation and business strategy, including a 10-year roadmap.

Executive summary

SYMSITES is a breakthrough project in the field of co-treatment of varied waste streams from different sources and co-production of multiple premium low-carbon bio-based materials. The project's results show potential to become a near-future high-end system for regional wastewater and organic waste treatment facilities.

In this business plan we overviewed the encouraging key results, while analyzing some possible scenarios of regional scale implementation, on the 4 EcoSites' regions (*Demo sites*). The scenarios were simulated for representation of optional business models.

Our model shows a promising route for commercialization of SYMSITES model as a transformative WWTP unit, at scales of 5,000-25,000 M³/Day, that can generate a competitive Return on Investment, while addressing some of the most urgent targets of WW, MSW, and low-carbon transition. The 4 EcoSites data and regional data, along with technical data and literature, were integrated to develop 4 regional scale up models. The average model calculation of 4 Ecosites showed a valuable product that on average treats a semi-urban town with approx. 40,000 population, with techno-economic solid figures and environmentally compliance on some of most- focused targets of the coming years, such as Energy balance, water quality, area efficiency and competitiveness of EU technologies. Yet, some factors need to be further improved, validated and progress to reach the various aspects and optimize the system.

To address the coming strategy, we have analyzed the many Projects' Key Exploitable Results and designed a strategy suggestion, to integrate the overall achievement ("mother ship"), while developing the Technology Readiness Level and the individual progress of each Achievement. Finally, a business plan was outlined to commercialize these achievements, including specific KERs and the holistic SYMSITES proposed entity interaction. The integration of the specific KERs development and the "mother ship" are oriented and can be used for further scale-up by potential adopters. A 10-year plan was outlined, with a revenue projection. This plan was designed with the support of Horizon Results Booster.

Objectives

The main objective is related and based on objective # O7 - Dissemination and exploitation activities for assimilating the I-US concept , Part iii - Develop business models for the flexible and robust management of exchange streams in dynamic production environments.

This document was integrated as an external public objective to analyze and preform the 4 Eco-Sites models for large scale implementation, and as well the internal objective for SYMSITES Consortium exploitation strategy, based on the Ecosites; labs; and theoretical research results, as well as discussions and consultation with Horizon Results Booster service.

Description of the work

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Part 1: Background

1.1 Waste and Wastewater sectors

1.1.1 The underutilized sector of wastewater

Wastewater (WW) streams comprise a promising source of water, energy and nutrients. The potential of recovering resources from municipal wastewater generated in sanitation systems is under-explored as large volumes of wastewater are not even collected. The astonishing fact is that 80% of the world's wastewater is not treated¹. By 2030, the world is expected to produce 470 billion M³ WW yearly², among it 68 billion M³ in Europe. The energy potential of WW is also enormous – whether by methane, Hydrogen or any other electricity and/or heat generation technology. The estimation for energy potential from WW can supply 474 million to 632 million people as well as decrease dramatically the CO₂ emission from current energy sources.

It should be mentioned that conventional WWTPs have a significant negative impact on the environment because of the use of electricity, so each KWH of produced electricity leads to the release of 0.9 kg CO₂³. The degradation of organics via aerobic and anaerobic processes and the production of energy used for plant operation are contributing factors to CO₂ emissions. CH₄ emission is associated with anoxic and anaerobic degradation of organic matter. Notably, wastewater treatment accounts for 5% of worldwide CH₄ emissions.⁴

Moreover, within the past couple of decades, WTPs have been designed without sufficient sustainability considerations. Consequently, they are highly energy intensive and classified as one of the most important energy consumers managed by municipalities. It was documented that water supply and wastewater treatment all over the world account for more than 2% of global electricity consumption⁵. Furthermore, a report by the International Energy Agency (IEA)⁶ indicated that the amount of energy used in the water sector will more than double in the next 25 years.

Moreover, each year, wastewater carries 22 million tons of nitrogen and 3 million tons of phosphorus, equal to a major share of global fertilizer demand. In Europe, recovery could meet up to 25–30% of phosphorus needs, with about 60% of WWTPs already designed for nutrient removal. While Europe advances, developing countries—where less than 8% of wastewater is treated—capture only a fraction of this potential.

¹ <https://www.worldbank.org/en/topic/water/publication/wastewater-initiative>

² Qadir, M.; Drechsel, P.; Jiménez Cisneros, B.; Kim, Y.; Pramanik, A.; Mehta, P.; Olaniyan, O. Global and Regional Potential of Wastewater as water, Nutrient, and Energy. *Natural Resources. Forum* 2020, 44, 40–51.

³ Gude, V.G. Wastewater Treatment in Microbial Fuel Cells—An Overview. *J. Clean. Prod.* 2016, 122, 287–307.

⁴ <https://www.sciencedirect.com/science/article/abs/pii/S0959652623037204>

⁵ <https://www.iea.org/commentaries/the-energy-sector-should-care-about-wastewater>

⁶ <https://www.iea.org/reports/water-energy-nexus/>

1.1.2 Biowaste promising era

Across the European Union, somewhere between 118 and 138 million tons of bio-waste arise annually, of which currently only about 40% (equivalent to 47,5 million tons per annum [Mt/year]) is effectively recycled into high-quality compost and digestate. As up to 50% of municipal solid waste is organic, the bio-waste fraction plays an important role in recycling and the nascent circular economy. Implementation of separate collections of bio-waste in all EU member states as laid down in the Waste Framework Directive is key for diverting organic waste from landfills and guarantees that high-quality secondary raw materials are produced.⁷ Biowaste opportunities in Europe are broad and driven by circular economic goals, energy security, and nutrient recovery. Key streams include household and municipal organic waste, agricultural residues, food processing by-products, and healthcare-associated waste. The primary pathways are anaerobic digestion (AD) with biogas/biomethane production, composting and soil amendments, and the extraction of value-added compounds (polyphenols, pectin, dietary fibers) from agricultural waste. Emerging trends include bio-based materials (bioplastics, enzymes), biochar for carbon sequestration and soil health, nutrient recovery (e.g., struvite, ammonium sulfate), and integration with power-to-X⁸ to couple renewable electricity with gas and liquid fuel.

1.1.3 Non-recyclable Waste (NRW)

Overall, among Europe municipal solid waste the current figures show quite close incineration and landfilling rates⁹, totals to about 51MT of landfilling and 58MT of incineration (2023). NRW is not a regulatory binding term, but the EU regulation does refer to "residual municipal waste" (RMW). This segment of waste shows great reuse potential. Here we can from the EU statistics the overall treatment of waste:

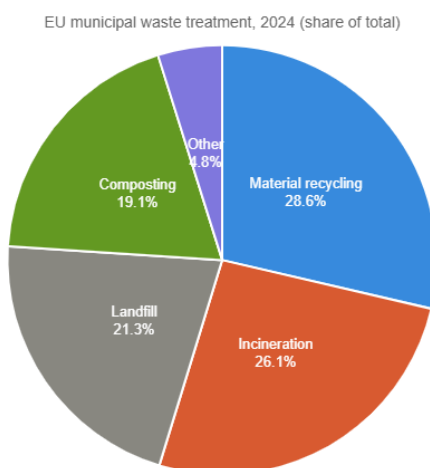


Figure 1: Waste treatment of waste in Europe, 2024 (kg per capita).

⁷ <https://www.compostnetwork.info/policy/biowaste-in-europe/>

⁸ Power-to-X (PtX) refers to technologies that convert renewable electricity into gaseous or liquid fuels, hydrogen, or chemical feedstocks, enabling sector coupling between the power system and gas, transport, and industrial value chains.

⁹ https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics

We see that landfills and incineration comprise approx. 47% (!) of the EU waste treatment and also composting is 19 %. Therefore, the options to utilize landfilled or incinerated waste should be explored, as done in SYMSITES.

1.2 EU targets and environmental directives

1.2.1 EU Policy Landscape - Regulatory Momentum

The SYMSITES project was developed in response to the growing development and awareness of EU environmental waste, water, and energy policies. These policies are shifting infrastructures from stand-alone systems to integrated ones that optimize energy, emissions, and resource recovery - driven by climate law, circular economy goals, and sector regulations. Municipalities and industries now operate in an environment that rewards systemic change: utilities must reduce energy use and improve discharge quality, and organic waste must be separated and treated as a resource. Early adopters benefit from funding, permitting, and strategic positioning.

1.2.2 Core EU Directives Influencing SYMSITES Development

1.2.2.1 Urban Wastewater Treatment Directive (UWWTD – Recast)

The revised UWWTD, published on 12 December 2024 and in force since 1 January 2025, sets stricter technical and financial requirements for municipal utilities. Member States must transpose it into national law by 31 July 2027. Key provisions include energy neutrality for large WWTPs ($\geq 10,000$ P.E.) by 2045, with interim targets: 20% by 2030, 40% by 2035, and 70% by 2040. Up to 35% of energy may come from non-fossil external sources. From 2035, the removal of micropollutants (e.g. PFAS, pharmaceuticals) becomes mandatory. The directive also introduces cost-sharing for treatment through Extended Producer Responsibility (EPR) and stricter nutrient discharge thresholds for nitrogen and phosphorus.

1.2.2.2 Waste Framework Directive and the 8th Environment Action Program (8EAP)

As of January 2024, all EU Member States are legally required to ensure separate collection of bio-waste at source, including from households, services, and the food industry. This obligation stems from Directive (EU) 2018/851, amending the Waste Framework Directive, and aims to improve compost and biogas quality, reduce landfilling, and support local treatment solutions. The measure aligns with the goals of the 8th Environment Action Program (8EAP), which prioritizes resource efficiency and circular economy practices across all waste streams.

1.2.2.3 Fit for 55 Package and the EU Climate Law

Fit for this law requires a 55% reduction in GHG emissions by 2030 compared to 1990 levels, under the binding European Climate Law. Wastewater and waste infrastructure are now expected to contribute through carbon reduction, energy efficiency, and LCA-based planning. This transition is enforced through regulatory tools like the Effort Sharing Regulation and reporting obligations, while supported by funding and incentives including the Innovation Fund, the LIFE Program, and the Recovery and Resilience Facility (RRF).

1.2.3 Policy Tools

EU policy combines regulatory pressure with enabling incentives, structuring the market for solutions like SYMSITES.

1.2.3.1 Enforcement Mechanisms

Compliance is driven by progressive deadlines: mandatory bio-waste separation by 2023, micropollutant removal requirements from 2035, and full energy-neutrality targets for WWTPs by 2045. At the same time, operating permits are tightening—non-compliance can mean not only higher treatment costs but also loss of license or restricted capacity. In parallel, Extended Producer Responsibility (EPR) schemes, such as mandatory textile recycling by 2025, expand the scope of obligations. Facilities that fail to align with the above regulations face escalating costs, stricter licensing conditions, and even exclusion from public funding and national planning strategies.

1.2.3.2 Support Mechanisms

To make adoption feasible, the EU combines financial incentives with procedural support that reduces risk and improves access to capital. Besides Horizon Europe, The Recovery and Resilience Facility (RRF) channels over €700B into green and digital transitions, including water infrastructure, circular economy projects, and low-carbon systems, with strict eligibility criteria on compliance and cost-effectiveness. At national level, subsidies and tax relief can cover 30–70% of capital expenditures, while projects aligned with EU climate and circular goals benefit from fast-track permitting and higher ranking in public tenders.

Here we can see several important mechanisms that are already active or will be in place gradually in the coming years, supporting SYMSITES market fit and competitiveness:

Table 1: Policy Overview

Policy Area	Requirement / Opportunity	Legal or Institutional Source
Separate bio-waste collection	Mandatory as of 2024 across households, services, and food industry	Directive (EU) 2018/851
Recast UWWTD – Entry into force	Effective 1 Jan 2025; national transposition by 31 July 2027	COM (2022) 541 final
Energy neutrality targets	20% by 2030, 40% by 2035, 70% by 2040, 100% by 2045	Aqua Publica Europea
Nutrient discharge limits	≤15 mg/L N, ≤2 mg/L P (2035); ≤6 mg/L N, ≤0.5 mg/L P (2040)	UWWTD Annex I
Micropollutants (4th stage treatment)	Required for large WWTPs; must be EPR-financed (80% by producers)	European Commission – UWWTD
EPR for pharmaceuticals/cosmetics	Producers must cover ≥80% of advanced treatment costs	environment.ec.europa.eu
Enforcement – Effort Sharing Regulation	National GHG reduction targets cover waste and water sectors	Regulation (EU) 2018/842

Policy Area	Requirement / Opportunity	Legal or Institutional Source
Permit and license tightening	Permit renewal tied to compliance with energy/discharge standards	EPA Ireland; Council of EU
Carbon pricing signals	ETS expansion creates financial pressure to decarbonize infrastructure	European Commission – Fit for 55
Public funding risks	Non-compliance may result in exclusion from EU/national funding	EIB Water Sector Orientation (2023)
Recovery and Resilience Facility (RRF)	€723.8B EU fund; ≥37% must go to green investments	European Commission – RRF
National subsidies	30–70% CAPEX support via grants or tax relief (varies by country)	EHPA; Andersen Italy (2023)
Streamlined permitting	Fast-track approvals for green-aligned projects (≤2 years)	REPowerEU; energy.ec.europa.eu
Green public procurement	Higher scores in tenders for projects supporting EU climate goals	European Commission procurement guidelines

In table 1 are mentioned numerous supportive mechanisms provided by the EC that show a great alignment with SYMSITES aim to build Industrial-Urban Symbiosis units, focused in the decarbonization and environmental added values of WWTPs. Among these it should be highly mentioned the recast of the **UWWTD**¹⁰ directive that will be focused later, that addressed some of the main factors that SYMSITES is introducing.

1.3 Industrial Symbiosis (IS) and Industrial-Urban Symbiosis (I-US)

1.3.1 Industrial Symbiosis & Industrial-Urban Symbiosis

Industrial Symbiosis is broadly defined as the use of one industry's byproducts or wastes for the purpose of advancing the targets of another industry. This mutually beneficial exchange reduces waste, lowers costs, and supports circular resource flows. When implemented on a scale, this approach generates measurable results, strengthens local economies, contributes to governmental sustainability targets, and increases ecosystem resilience. Since its inception, the concept has evolved across regions in response to variations in land availability, natural resources, technological capacity, and policy frameworks, offering valuable global insights into effective strategies and best practices for sustainable industrial development. A review of many industrial symbiosis cases has led to the development of symbiosis knowledge databases, covering both implemented and potential/planned symbiosis activities. Notably the SCALER project, which reviews 210 publications and analyses 25 case studies,

¹⁰ https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202403019

identifies four primary business models that characterize most IS systems¹¹. The first is direct by-product exchange, where companies enter bilateral contracts for materials or utilities. The second involves shared infrastructure, such as common wastewater-treatment facilities or district-heating systems, allowing firms to reduce capital and operating costs through collective investment. A third model is the facilitator-based hub, in which coordinating body maps resource flows, identifies synergies, and manages legal or logistical barriers. Finally, the service-based model such as energy-as-a-service outsources technical operation and maintenance to specialized providers, allowing smaller firms to participate without high upfront investment. It seems that SYMSITES can present a regional solution that answers these exact mechanisms.

Since the 1960s, IS has transitioned from informal material exchanges to data-driven regional networks collaborating between different institutions. The Kalundborg Symbiosis remains the global benchmark using a bottom-up network of seventeen partners exchanging steam, water, and waste¹². In contrast, South Korea's Ulsan Eco-Industrial Park illustrates a top-down, government-coordinated model where national R&D, funding and regulatory planning enabled resource-sharing among heavy industries¹². A hybrid approach appears in Israel's National Industrial Symbiosis Project (2019–2023), which divided the country into regional hubs operated by local facilitators. Over three years, it engaged more than 230 companies and demonstrated an eight-to-one economic return on public investment. This facilitator-driven model shows how governments can scale symbiosis by combining public policy with business-level coordination.

Together, these examples highlight how IS thrives when economic incentives, facilitation mechanisms, and supportive regulation align. Whether organically evolved or government-initiated, the essential enablers remain constant - collaboration, trust, and data accessibility, besides economic feasibility.

Industrial Urban Symbiosis (I-US) is established on the same strategy and extends it beyond industrial clusters to include municipal systems, utilities, and service sectors. This integration generates five key advantages. First, by linking industries with urban waste, energy, and water networks, I-US expands the available pool of recoverable resources, creating new pathways for efficiency and innovation that are often inaccessible within industrial-only networks. Second, collaboration with municipalities enhances infrastructure optimization including shared systems for water reclamation, waste treatment, and district heating reduces redundancy and improve economies of scale. Third, I-US strengthens policy alignment between industrial operations and urban sustainability goals, embedding circular practices into city planning and environmental regulation. Furthermore, the inclusion of cities as active stakeholders fosters social legitimacy and public support, which are crucial for long-term continuity. Finally, I-US provides broader economic resilience, as resource flows are diversified across multiple sectors, creating opportunities for green job creation and investment attraction.

Japan is an example of widespread government adoption of I-US, with a programmed launched in 1997 that designated 26 cities as national eco-towns to promote industrial recycling and urban waste reduction. One of the most successful examples is Kawasaki Eco-Town, where industries collaborate with recycling firms and municipal waste and wastewater facilities to reuse waste as raw materials or alternative fuels. In Kawasaki, the government subsidized the facility construction by an average of 48% of the total initial investment,

¹¹ [SCALER Project](#)

¹² [A sectoral eco-efficiency analysis on urban-industrial symbiosis](#)

demonstrating how financial support can accelerate implementation and long-term success¹³. The Kawasaki case also demonstrates the potential for realizing societal benefits through I-US, including enhanced public awareness and better public health by reducing solid and hazardous waste¹³.

In Portugal, the Relvão Project offers another significant example of developing I-US through combining top-down government support with bottom-up business initiatives. The project's main aspects included a collaborative effort involving the Portuguese government, the local municipality, the Technical University of Lisbon, and various private industries. Key to its success was leveraging existing large waste management facilities as core economic drivers to facilitate initial exchanges and attracting diverse industries like pulp and paper, agro-industries, and chemical companies. The initiative successfully navigated regulatory barriers through dialogue with national authorities and generated significant local impact, creating over 300 jobs and attracting crucial investment to an otherwise undeveloped region.

For cities, partnering with industry unlocks tangible benefits: reduced waste-management costs, enhanced energy efficiency, and job creation. For firms, collaboration with municipalities ensures regulatory stability, access to infrastructure, and social license to operate.

SYMSITES builds on these global lessons to operationalize regional Industrial-Urban Symbiosis ecosystems, combining digital resource mapping, stakeholder facilitation, and governance innovation to deliver resilient, low-carbon, and economically viable circular systems.

1.4 Core Technologies and their Challenges

1.4.1 Tech overview + challenges

SYMSITES leverages a combination of established and innovative technologies. Some of the main challenges of these technologies are addressed in the project's results.

AnMBR

Anaerobic Membrane Bioreactor (AnMBR) is considered a highly efficient and reliable technology for organic material removal from wastewater with no additional energy requirement for aeration or aeration basins. AnMBR is a combination of conventional anaerobic technology and a modern membrane system. AnMBR is a cost-effective alternative technology with pros of anaerobic microbial activity because methane-rich biogas can convert organic pollutant load of wastewater into renewable energy in the form of methane-rich biogas. This conversion is mainly done by the transformation of organic matter into energy by high chemical oxygen demand (COD), total suspended solids (TSS), and pathogens removal. Methane-rich biogas can be used as a storable source of supplemental energy for generating heat or power thus, AnMBR technology provides improved effluent quality, reliability, and efficiency over the other traditional technologies. AnMBR facilities were first introduced in the 1980s in South Africa and have been less investigated than aerobic MBRs. The first commercially available AnMBR plant was developed by Dorr-Oliver in the early 1980s for high-strength whey wastewater treatment and was known as the Membrane Anaerobic Reactor

¹³ Development of urban-industrial symbiosis to support sustainability: Bibliometric analysis and systematic literature review

System (MARS). Still today, the main problem associated with the use of membranes in AnMBR treatments is the fouling of the membranes. Although there are different configurations of AnMBR systems (side-stream, submerged and submerged side-stream), frequent physical and chemical cleaning operations are required, which reduce the useful life of the membranes and increase the operating costs of the purification process. Usually, membranes are frequently cleaned with physical methods like air sparging, backflushing, ultra-sonication, scouring, vibration or mechanical approaches like scrubbing or brushing. Another important aspect is the significant reduction of the energy demand linked to the treatment itself, indeed anaerobic technology transforms biodegradable organics into the gaseous energy carrier CH_4 , suitable for offsetting energy input from fossil sources. The goal is to allow, through the optimization of technologies that will be further studied-in-depth starting from the latest research carried out, to broaden the applicability of this treatment to different industrial and municipal contexts.

Adsorption columns

Adsorption columns are critical, high-efficiency separation units used widely in gas purification, carbon capture, and water treatment. While established, the industry is transitioning toward more sustainable, efficient materials and smarter, automated operations, with a 5.2% CAGR expected for the market from 2026-2035. One of the current limitations of adsorption techniques is that the adsorption capacity of most adsorbents is still relatively low compared to the high concentration and diversity of contaminants in wastewater¹⁴. A significant quantity of adsorbent is necessary to attain effective removal rates, leading to heightened expenses and intricacy in the treatment procedure. Moreover, the adsorption capacity of most adsorbents tends to decrease with increasing initial concentration of adsorbate, due to the saturation of available binding sites on the adsorbent surface. Therefore, there is a need to develop novel adsorbents with higher adsorption capacity and affinity for various contaminants in wastewater.

One of the current trends are hybrid Systems: Combining adsorption with other treatments, such as membrane bioreactors and advanced oxidation processes (AOPs), to enhance overall treatment efficiency.

Pyrolysis

Pyrolysis consists of heating the biomass or waste residues at typically between 300 and 700 °C in the absence of oxygen. Three different products are produced during pyrolysis: bio-oil (condensable liquid fraction), pyrolysis gas (non-condensable gases), and biochar (the solid fraction). Pyrolysis can be used to process a wide variety of waste materials, including biomass, municipal solid waste (MSW), sewage sludge, plastic waste, and waste cooking oils which makes it a versatile waste management technology. Pyrolysis Oil Market size was valued at USD 1.2 Billion in 2024 and is forecasted to grow at a CAGR of **12.5% from 2026 to 2033**, reaching **USD 3.5 Billion by 2033**.¹⁵

Pyrolysis can introduce a real innovation in the approach of alternatives to waste incineration, that is less preferred both from Environmental aspects, and from the economic point of view, since the utilization of materials yields much higher revenues.

¹⁴ Atyam S, Patra S. Innovations and challenges in adsorption-based wastewater remediation: A comprehensive review. Heliyon. 2024 Apr 20;10(9)

¹⁵ <https://www.verifiedmarketreports.com/product/pyrolysis-oil-market/>

Among the challenges of this technology should be noted the inconsistent standards, and less acceptance as a main-stream large scale utility. Also, the pyrolysis was focused mainly on the oil for energy, but now it's shifting to new low-carbon products and refinement of the raw outputs.¹⁶



Figure 2: Pyrolysis System Overview

¹⁶ Mong, G., Chong, C. T., Chong, W., Ng, J.-H., Ong, H. C., Veeramuthu, A., Tran, M.-V., Karmakar, S., Goh, B., & Mohd Yasin, M. F. (2022). Progress and challenges in sustainable pyrolysis technology: Reactors, feedstocks and products. *Fuel*, 324, 124777. <https://doi.org/10.1016/j.fuel.2022.124777>.

Part 2: Product specification – SYMSITES Regional I-US System

2.1 Brief Explanation:

SYMSITES proven model is transforming the local WWTP's to the next generation, using an Industrial-Urban Symbiosis structure of links to maximize the facilities' impact and revenue.

This future facility, anticipated to function fully in 5-10 years range, is treating Wastewater, Biowaste and Non-Recyclable Waste, both from Industrial and Urban sources. It will generate high quality (Tertiary) treated water, local energy (Biomethane) and several HVNR's (High Value New Resources) that are exceeding any other WWTP - Bioplastics, Hydrogen, Ammonium Sulphate, Activated Nano-Carbon Dots, and more. The core technologies are: AnMBR, AC, and Pyrolysis.

It is Beyond State-of-the-art combination of technologies, mostly focused on three pillars:

1. System Optimization: Anti Fouling systems, COD utilization maximizing, and more.
2. HVNRs production units
3. Digitized High-End Platform

Product vision: a “retrofit-for-55” turnkey solution for underutilized WWTPs.

Value Proposition: Decarbonization, Compliance, and Local Economic Value.

We introduce this term, **MaRREEF** – *Material Regional Recovery, Energy Efficient Facility*, to represent SYMSITES integrated product and its positioning as 3rd generation of Wastewater treatment technology.

Whereas 1st Generation of Wastewater treatment has focused in proper discharge of water into approved water bodies, and the 2nd generation has introduced higher level of re-use for irrigation and somehow for optional energy utilization ¹⁷ - SYMSITES has introduced and demonstrated POC of these 3rd generation models.



Figure 3: SYMSITES position as 3rd Generation product

¹⁷ In 2012, WEF officially started using the novel term of water resource recovery facility (WRRF), instead of WWTP.

2.2 Main Achievement Of SYMSITES

Integrated demonstration in Ecosites (TRL 6) at basic structure, and 5 low-carbon materials production at lab scale (TRL 4-5), Based on AnMBR technology core. Co-treatment of 3 major waste streams (and total of 6-7 sub-streams). Prediction and simulation of the regional models in IT platform with business model integrated to present estimated symbiotic links, yields and ROI.

2.2.1 Unique selling points:

1. Co-Treatment of 3 main waste streams
2. High compliance with updated UWWTD directive, and Fit for 55 strategies
3. Higher energy resilience (approx. weighted Balance 60%)
4. Lower area footprint per M³/ton
5. High ROI (approx. 11%)

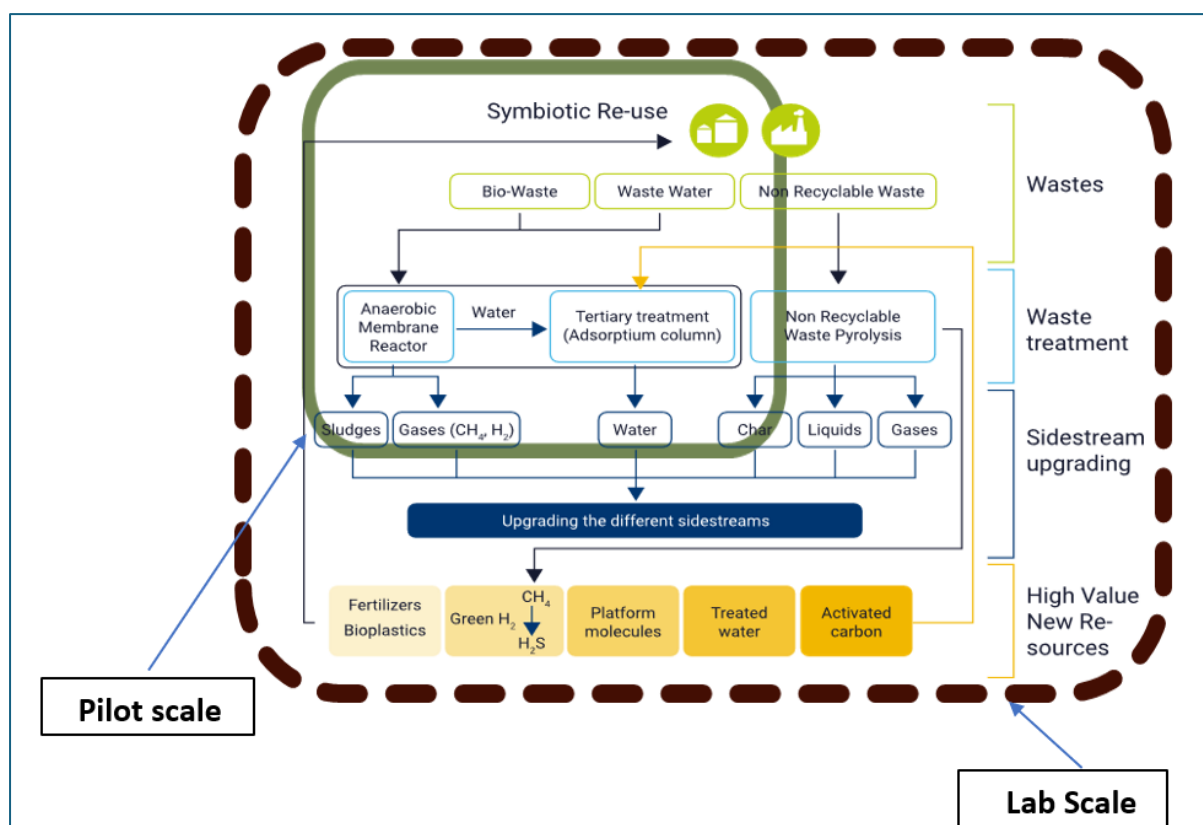


Figure 4: SYMSITES layout draft

The Above SYMSITES illustration - illustrates the integrated Industrial-Urban Symbiosis (I-US) Ecosystem, detailing the technological maturity of its components. *The green rectangles represent the core pilots that were proven at the 4 EcoSites. The Brown rectangle represents mostly lab experiments that were overtaken during the projects' years, with direct correlation to the EcoSites: Feedstock was tested from the EcoSites, or at the EcoSites, and some of the technologies were proven at lab-scale as POC for the implementation in the EcoSites.*

Overall, the integration of the lab scale and pilot scale creates the above illustration that was confirmed, at the POC level.

2.2.2 Layout/ Simulation of proposed structure

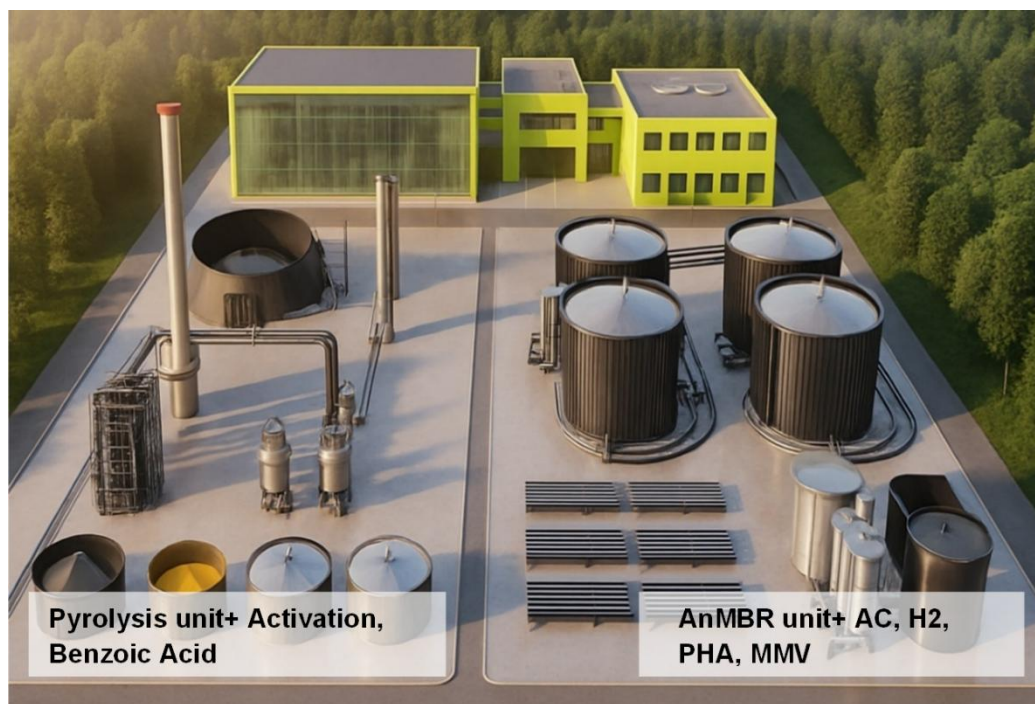


Figure 5: Conceptual SYMSITES Facility layout

Figure 5 shows our vision of scaling-up perspective for next phases of SYMSITES model. It shows two main units that interact and support each other. These units, in a dedicated area, usually proposed at the local WWTP's – are "retrofit for 55" models for the 3rd wastewater treatment generation.

The next tables show the relations between those units, and between the sectors.

Table 2: The symbiosis between the two units

AnMBR unit	Pyrolysis unit
Provides feedstock	Sludge treatment
Water for cooling/ emergency	Provides activated carbon
H ₂ for internal trucks	Provides heat for AnMBR

2.3 The Industrial-Urban Symbiosis added value by SYMSITES product

Table 3: Added value summary

	Urban sector	Industrial sector
Gives	High CAPEX investment	High COD water
	Land allocation	HVNRs procurement
	Biowaste & NRW secured feedstock	Specific, consistent feedstock for NRW and effluent.
		Optional engineering adjustments for System
Gets	Water for irrigation	Low-carbon HVNR's
	Integrated solution for main municipal "hard to abate" streams	Primum water for industry and energy
	Return on Investment	Central location for Wastewater and NRW

2.4 Overview of Specific KERs features:

These KERs are specific achievements that comprise the whole SYMSITES model but are partly licensed and protected also as individual achievements, to the consortium Partners.

See annex D for detailed structure and info of each KER.

The KERs were developed both on Lab scale and on Pilot scale (Ecosites), and have shown promising results, that are also detailed in the project's Deliverables where in public dissemination level ¹⁸ and in publications. ¹⁹The process of KERs analysis was updated periodically in the leading of Partner **PRJ**²⁰ by the EU methodology.

Ownership of KERs was discussed several times, online and in the GA.

The remaining KER to be updated is the overall achievement, which is detailed in this document. This can enable large-scale exploitation by sharing the contribution made to reach this significant structure, detailed design and implementation, along with a clear digital modeling and business case as defined in this document.

Below is the list of KERs:

¹⁸ <https://symsites.eu/deliverables/>

¹⁹ <https://symsites.eu/the-project/>

²⁰ <https://www.projecthub360.com/sustainability-and-innovation/>

Table 4: KER's overview

#	KER leader	Name/Short Description	Quantitative Result / beyond state of the art	TRL	IP of Partner
KER 1.1	NTUA	Lab scale optimization of the AnMBR plant to produce CH ₄ from WW and BW	Demonstrating the stable and efficient co-digestion of a challenging mixed industrial/municipal wastewater stream	6	Possible Overlap
KER 1.2	NTU	Lab-scale optimization of an advanced co-treatment system of WW and BW to produce H ₂ (ANAEROBIC Fermentation)	Demonstrating high-yield biological hydrogen production (1.2 mol H ₂ /mol sugar) from real, mixed food waste (fruit and vegetable waste) at pilot scale, without the need for chemical additives or substrate pre-treatment	5	FTO
KER 1.3	NTUA	Lab-scale optimization of an advanced co-treatment system of WW and BW to upgrade biogas	This setup leverages the synergistic potential of hydrogenotrophic methanogens enriched from WWTP sludge and the buffering capacity of AnMBR digestate to stabilize biogas upgrading.	5	FTO
KER 2.1	BIU	Lab Scale development of C-dots coated membrane with antifouling properties	Deposition of Cdots on membranes by ultrasound irradiation is novel and has not been found in the literature	5	FTO
KER 2.2	BIU	Lab Scale development of MeO-coated membrane with antifouling properties	Usage of CuO coated membranes for antifouling application	5	YES, RELATED
KER 2.3	KUL	Lab Scale development of Magnetic membrane vibration process to produce membranes with antifouling properties.	With MMV system the CF can go beyond 70 LMH and therefore the membranes can either be operated at high fluxes to treat more water or either keep the operational flux similar thereby significantly reducing the	6	YES

#	KER leader	Name/Short Description	Quantitative Result / beyond state of the art	TRL	IP of Partner
			cleaning frequency due to fouling		
KER 3	GREENE	New low costs char-based adsorption materials for tertiary treatments	10% increase in char yield compared to conventional pyrolysis.	5.5	TBD
KER 4	CSIC	Optimization of the PMR (Protonic membrane reactors) Technology	Production of planar protonic cells of 25cm ² to obtain PMR. This technology is only well known in tubular geometry. Planar geometry allows feasible modular integration without space or volume constraints.	5	FTO
KER 5	NTUA	Optimization of polyhydroxy alkenoates (PHAs) production	Demonstrating a robust and adaptable mixed microbial culture (MMC) capable of efficiently producing polyhydroxyalkanoates (PHAs) from real, variable effluents derived from dark fermentation processes. An efficient limitation was achieved since both N and C consumption was observed the microbial biomass expressed as TSS, reached 4.5 g/L approximately, corresponding to production of 1.25 g/L PHAs	5	FTO
KER 6	BOKU	Fertilizer production (NH ₄) ₂ SO ₄ ,) from nutrient recovery	Combine the desulphurization and stripping process with the AnMBR process.	5	Possible overlap
KER 7	UPC	Development of nano-enabled antimicrobial composite (CHAR) for water-absorbent columns	Introducing a combined system that integrates biochar derived from non-recyclable waste with	5.5	YES

#	KER leader	Name/Short Description	Quantitative Result / beyond state of the art	TRL	IP of Partner
			lignin-based nanoparticles, resulting in a dual-function material capable of both adsorption and antimicrobial action		
KER 8	GREENE	Upgrading of pyrolytic liquids to platform molecules	DME showed a 1.8× improvement in selectivity, while maintaining >90% solvent recovery. Solvent system developed: enables selective extraction efficiency up to 75 % of benzoic acid from the aqueous phase of pyrolysis oils	5.5	FTO
KER 9	KLINK	SDSS (Social Decision Support System)	A multi-stakeholder vision, facilitating process set up; HP product traceability, processes mapping, data driven models' integration, among others features	5	FTO
KER 10	ITG	Design and Development of the IIoT (Industrial internet of things) management platform (IIoTMP)		5	FTO
ER 11	ITG	Design and development of ITRMP (IT Regional Management Platform)		6	FTO
KER 12.1	NTUA	Greek Ecosite	Deploying a cutting-edge AnMBRs pilot system with different anti-fouling strategies for the on-site treatment of Biowaste and Wastewater, addressing both urban and industrial needs with advanced efficiency and lower environmental impact, to produce High value new resources.	6	FTO
KER 12.2	BOKU	Austrian Ecosite		6	Optional "soft" IP
KER 12.3	BEOF	Danish Ecosite		6	Optional "soft" IP
KER 12.4	FACSA	Spanish Ecosite		6	Optional "soft" IP
KER 13	PRJ	Life cycle cost assessment and life cycle assessment of the EcoSites	TBD	6	Optional "soft" IP

#	KER leader	Name/Short Description	Quantitative Result / beyond state of the art	TRL	IP of Partner
KER 14.1	BOFA	Social Spin off	TBD	6	FTO
KER 14.2	ICLEI BOFA	Training Materials	TBD	6	FTO
KER 14.3	ICLEI	Replication Package	TBD	6	FTO
KER 15	ITG KLINK	Virtual I-US game - trials and conclusions	TBD	6	FTO

2.5 KERs Groupings:

This grouping was made to simplify the various fields and vectors of achievements, and also to introduce the "mother ship" model as an overall KER.

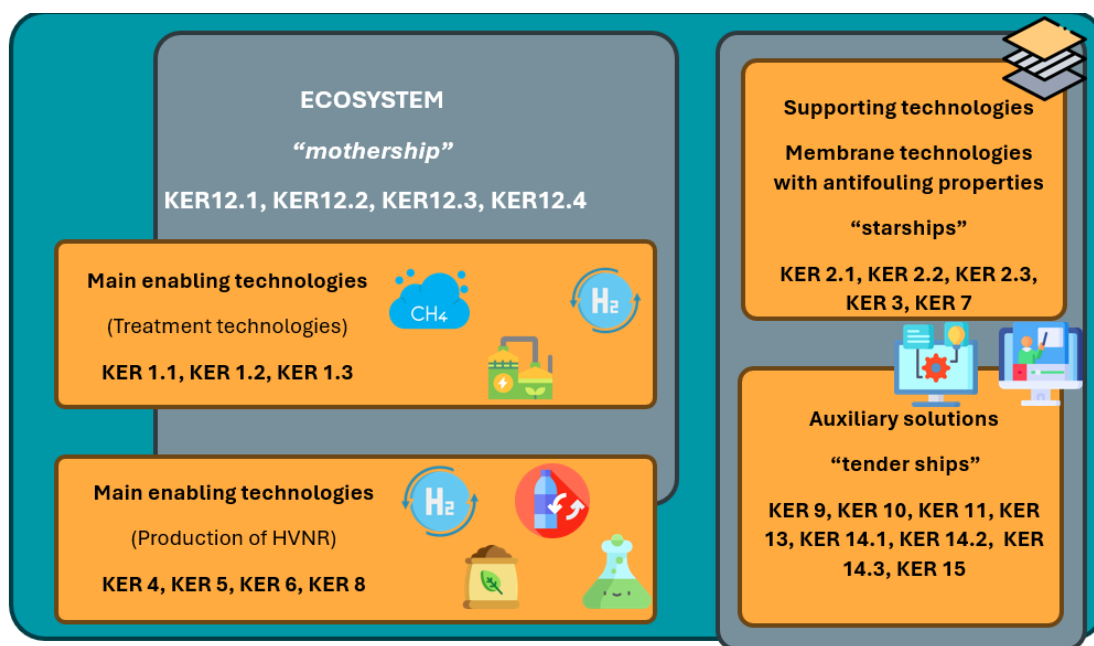


Figure 5: KER groupings

Figure 5, as analyzed by Partner PRJ, shows the grouping of the KERs into 4 groups, while all are connected to the "mother ship" KER which is KER 12, the demonstration in Ecosites. The 4 groups are: main enabling technologies (treatment); main enabling technologies (HVNRs), Supporting technologies – Membrane and Antifouling; enabling "auxiliary" – IT platforms, social and replication tools.

Part 3: Regional Business models for SYMSITES I-US Ecosystem

3.1 SYMSITES Business Model

Overall, the model contains the common main pillars of SYMSITES and adjustable configuration of High Value New Resources (HVNR) units. The model is an effective tool that can be used by various adopters to analyze the techno-economic aspects of new advanced wastewater and other wastes plants or upgrading of existing plants.

The numerical model includes assumptions that are based on various resources:

- The EcoSites demonstration technical data and lab scale achievements data – that is used to understand the mechanism of core-relations, and expected yields, correlations and observations.
- The EcoSites regional upscale data that is used for the 4 scenarios planning, both main relevant instreams, and the regions prioritized HVNR's. Local data such as treatment fees, tap water prices, salaries and more. Finally – general data on the region for scaling up: population, main industries, and local policies and goals.
- Literature survey on expected yields, membrane and reactors volume estimations, CAPEX benchmarks for industry of WW and AnMBR facilities, OPEX estimations for large scale facilities and more.
- The Partners' knowledge and experience.

Following is a list of some points and their sources:

Table 5: Sources for main topics

Data category	Source partner / reference	Used in
Municipal WW Qty & COD (4 regions)	BEOF, NTUA + West Achaia Municipality, BOKU, FACSA	Tables 8, 12, 16, 20
Biowaste streams & gate fees	Ecosite managers (BEOF, NTUA, BOKU, FACSA)	Section 3.2.1 (p. 27)
NRW rates	EU statistics + regional Ecosite data	Section 3.3 (p. 36)
Methane yield	Literature (Life Cycle Costing study of AnMBR) + Ecosite validation	Section 3.2.2 (p. 29)
PHA & H ₂ yields	NTUA – technical report, and literature.	Section 3.2.2 (p. 30)
NH ₃ SO ₄ yield	BOKU -scenario based on Bornholm Ecosite was calculated.	Section 3.2.2 (p. 30)

Data category	Source partner / reference	Used in
Benzoic / Acetic Acid yields	GREENE – by Email correspondence, backed by literature.	Section 3.2.2 (pp. 30–31)
AnMBR CAPEX / OPEX benchmarks	Literature (Robles et al. 2022) + partner estimates	Sections 3.2.7, 3.2.8 (pp. 33–35)
MMV energy reduction (KER 2.3)	KUL Article	Section 3.2.2 ,5.1 (p. 31)

Business Model excel sheet: This model was used to integrate all our calculations, has multiple tabs, to address the complex calculations. We have conducted over 14 versions to update, revise and modify the data and calculations.

MASTER SHEET			
No	name of tab / color	link to	Description
	DASHBOARD	link	
1	Assumptions	Link	
2	data input	Link	Input of stream types, quantities, population, country & region, by-products
3	pl	Link	Annual and monthly profit & loss statements changes automatically
4	prices	Link	selling prices of by-products and their relation to the sources
5	sales	Link	Sals value in Euro of all the products sold. Automatically changes
6	pyrolysis	Link	estimation on pyrolysis prices
7	CAPEX	Link	Estimate of the investment in the project with or without AnMBR
8	OPEX	Link	Estimates of the monthly expenses automatically adapts to the technology
9	loans & int	Link	Estimates on a monthly retutrn & intrest for the loans required for the projec
10	grits and screening	Link	Estimates of screening prices and monthly expenses
11	absorption columns	Link	Estimates on quantity of AC nedded and their prices
12	Membranes reactors	Link	Estimates on quantity of membranes and their prices + Reactors calculations
13	met pro & elec	Link	Estimates of the methane produced and its prices
14	electricity	Link	Estimates on electricity consumption
15	manpower	Link	Estimates on manpowe required
16	Hydrogen	Link	calculation of hydrogen production
17	BIOPLASTIC	Link	calculating the quantity of plastic
18	NH3SO4	Link	calculation of ammonium sulfate
19	Area calculations	Link	

Figure 6: Model excel master sheet

Model excel rationale:

Overall, most of the cells are fixed or have an "IF" phrase. The "Input data" tab is used to insert local EcoSite's data , such as : population, instream materials (WW,BW, NRW from all sources) , local electricity and water prices (of which irrigation water price was derived), local income tax, interest rate, and of course- the assumed weighted gate fee for WW & BW- whether by partners and/or statistics , and NRW gate fee. Also, adjustable 30/70 ratio for dark fermentation COD allocation can be set in this tab.

In the "DASHBOARD" tab, the HVNRs are selected, and the Governmental rate of funding. (default – 20%). A sensitivity adjustment is optional for rise/decrease of sales, cost of goods

or other expenses. In the "PRICES" tab, prices are set as fixed, but they can be adjusted to a specific value. These data cells provide us with the overall input needed for calculations. for each HVNR, a specific tab was created and edited continuously to reach our best assumptions ("Bioplastics", "Hydrogen", "NH₃SO₄", "Pyrolysis"). "CAPEX" and "OPEX" tabs are derived from various tabs, including the Input, HVNRs, "labor", "Membrane and reactors", "met (methane) and elec (electricity)", "Adsorption columns" and more. Electricity calculations are developed in the "electricity" tab, including the important Energy Balance factor we have investigated deeply, to design configurations that comply to the EU targets.

Variable factors worth mentioning are:

- Membrane modules (were calculated per M³/day, with 10% redundancy), based on hollow fiber technology benchmarks.
- Hydrogen production was calculated both as HVNR and as electricity source, and the best outcome can be selected automatically unless configured otherwise.
- NRW was calculated depending on the country, by EU statistics.
- Activated Carbon and Carbon dots were calculated in two methodologies, and the best yield was set to be selected.
- Olive BW in Greece was calculated from the only source we got, which was the number of olive trees in the region.
- Reactor size was influenced by the HRT time.
- Area factor varies between larger facilities and smaller facilities.
- CAPEX factor varies where 20,000 M³/day was calculated as 100% norm.
- Electricity consumption was calculated as 90% (10% more efficient) above 25,000 M³/day (such as in Alcoi case).

Here you can see a glance to some of the model excel tabs and calculations:

3.2 Technical assumptions

3.2.1 Infeed streams

Municipal WW Quantity

This data was calculated directly from the 4 Ecosites information. The Qty that we analyzed in the 4 Ecosites varies from Approx. 4,500 M³/day up to 28,000 M³/day which reflects the range of the proposed facility capacity unit's types: 1500, 5000 and 25000 M³/day. This data was provided by the Ecosites leaders (BEOF, BOKU, NTUA, FACSA). In one case (West Achaia) only half of the current WW stream was decided to be integrated into SYMSITES system.

Municipal WW COD

The literature shows a range of 200-700 mg/L COD²¹ for domestic wastewater, due to various factors. However, we have relied on the EcoSites data, given by the EcoSites' managers, ranging from 250mg/l to 1,250 mg/l (!) – due to integration of industrial WW in Spain.

Concerning the Qty of urban WW they have large impact on the model from various reasons: firstly, the qty of annual or even daily usage has large significance on the capital investment, area footprint, maintenance, manpower and more. Also, the qty has a major impact on the gate fees revenues, since it is by far the largest in stream of this system. (sometimes in ratios of 1:100), and last, it has a crucial factor on the weighted COD, therefore, implying on the overall system configuration and yields. Also, this factor was calculated directly from the 4 Ecosites data. The Qty that we analyzed in the 4 Ecosites varies from Approx. 1,700,000 yearly (4,500 M³/day) up to 10,000,000 M³ yearly (28,000 M³ daily) which reflects the range of the proposed units / "products" (1,500 ,5,000, and 25,000 M³/day) that can evolve gradually with the product maturity.

The gate fee

The gate fee was assumed to be the current fees. It is assumed that the retrofit of existing WWTPs will maintain the current level of gate fees, while increasing the overall revenues from NRW and from HVNR sales. In some scenarios we have even lowered the gate fees, to be competitive and increase the municipality and other stakeholders' motivation to participate in the project development. Gate fee for biowaste was calculated as "industrial wastewater" and then weighed in the overall gate fee, with minor effect on the overall calculated fee.

Biowaste

The sources, Qty, and COD parameters were delivered by SYMSITES Partners, both liquid and solid. On some cases with no concrete data - the household biowaste was analyzed as 30-40% from the total municipal stream, according to the local statistics. A slight variance on COD levels reported from different EcoSites – varying between 30,000 and 100,000 mg/L.

²¹ Life Cycle Assessment and Cost Analysis of Water and Wastewater Treatment Options for Sustainability: Influence of Scale on Membrane Bioreactor Systems

²¹ Energies 2022, 15, 4981 23 of 40 Table 5. The characteristics of real domestic wastewaters treated in AnMBRs.

NRW

"Non-recyclable waste" can be interpreted in various ways. The EU has defined an official term - "residuals". We used the statistics on recycling rates, incineration and landfill²². Based on this data, we have assumed a factored proportion of NRW and suggested relatively competitive gate fees.

Table 6: Estimation of NRW per capita/ year

EcoSite	Kg per Capita/year	Gate fee (€)
Spain	220	40 €
Denmark	300	64 €
Austria	380	30 €
Greece	200	40 €

²² Denmark: (<https://www.eea.europa.eu/en/topics/in-depth/waste-and-recycling/municipal-and-packaging-waste-management-country-profiles-2025/dk-municipal-waste-factsheet.pdf/@download/file>), (https://en.wikipedia.org/wiki/Recycling_rates_by_country), (<https://symsites.eu/denmark-waste-management/>), (<https://www.cewep.eu/wp-content/uploads/2021/10/Landfill-taxes-and-restrictions-overview.pdf>), (<https://bofa.dk/en/faq/waste-prices-for-businesses/>)[2]

Greece: (<https://www.eea.europa.eu/en/topics/in-depth/waste-and-recycling/municipal-and-packaging-waste-management-country-profiles-2025/gr-municipal-waste-factsheet.pdf/@download/file>), (<https://www.eea.europa.eu/publications/many-eu-member-states/greece>), (<https://news.trust.org/item/20220721155610-hvcf4/>), (<https://ieep.eu/wp-content/uploads/2022/12/EL-Landfill-Tax-final.pdf>)[9]

Spain: (<https://www.reportlinker.com/dataset/9395d361c7c954235bff9d64198c24514c0d0b11>), (<https://www.ine.es/dynqs/Prensa/en/CR2022.htm>), (https://www.cewep.eu/wp-content/uploads/2024/05/4.-Amalia-Cerda-Lacaci_AEVERSU.pdf), (https://www.garrigues.com/en_GB/new/spain-new-tax-measures-law-waste-and-contaminated-land-circular-economy), (<https://www.magaldi.com/en/spains-waste-challenge-time-turn-tide-waste-energy>), (<https://assets.kpmg.com/content/dam/kpmg/es/pdf/2022/05/tax-alert-impuesto-deposito-residuos-eng.pdf>), (<https://www.cuatrecasas.com/resources/lf-esg-waste-tax-62666fa58041c906015605.pdf?v1.44.2.1.20230223>)[10]

Austria: (<https://europe-data.com/what-eu-country-generates-the-most-municipal-waste-per-person/>), (<https://www.theinternational.at/austria-ranks-5th-in-global-waste-index-2025-despite-803-kg-per-capita/>), (https://en.wikipedia.org/wiki/Recycling_rates_by_country), (<https://www.eea.europa.eu/en/topics/in-depth/waste-and-recycling/municipal-and-packaging-waste-management-country-profiles-2025/at-municipal-waste-factsheet.pdf/@download/file>), (<https://ieep.eu/wp-content/uploads/2022/12/AT-Landfill-Tax-final.pdf>)[17]

3.2.2 System Units

Main units

The operational structure proposed consists of 2 main units:

- Wastewater unit (AnMBR, AC, DF, MMV and more)
- NRW unit (Pyrolysis, Extraction unit/s, activation unit, CD's)

Between these units there are at the moment a few but promising relations: (as presented in table 4)

- Usage of activated char and/or CD's and/or NPs – in the absorption columns.
- Sludge treatment - Pyrolysis or in the future Hydro-thermal carbonization.
- Optional – heat and electricity balance and surplus exchange - between the units.

3.2.3 HVNRs

The model structure allows designing the system with 1/0 selection of the HVNRs produced:

Table 7 HVNRs selection

Unit	Selection
Green hydrogen	0/1
PHBV Bio plastics	0/1
Ammonium sulphate	0/1
Activated carbon	0/1
CD's/ Nano particles	0/1
Benzoic acid	0/1
*Carbon credits	0/1
** Water	
** Methane	

*Carbon credit is considered as extra revenue stream.

**Water for irrigation is set by default for sale, and methane is set by default for self-consumption.

3.2.4. Overall flow

COD allocation in the WW unit

- Sludge is expected to receive 10% of the source organic load.
- Methane production is set by default to receive 70% of the main COD load.
- PHA production (if chosen) is set for 15% of the main COD load. (13.5% of total)
- H₂ production – the same allocation (13.5% of total)
- This configuration is optional to set differently.

3.2.5 Yields rates:

- **Tertiary Water:** water is assumed to yield 90% of the overall qty received (due to biowaste and other solid components) of which, we aim to reach grade A or B by the 2020/741 Directive The units assumed are of UF or NF type.
- **Methane:** We assumed that at 35°C production will be 0.27 M³ CH₄/kg, by literature (see below) and the Ecosites data, to our advisor comments, and the professional literature. For each scenario. It should be noted that lower temperatures, especially in winter, have created large fall in the CH₄ capacity in the Ecosites, therefore we consider, as a key point, the residual heat "symbiosis" with the pyrolysis unit.

Table 8 summary of literature on AnMBR parameters

Source	Influent COD Strength (mg/L)	COD Removal (%)	Reactor Temperature (°C)	HRT (day)	Reactor Volume (m ³)	Biogas production (m ³ CH ₄ /kg COD)
Baek et al., 2010	-	64	-	0.5-2	0.01	-
Berube et al., 2006	-	70-90	11-32	-	-	-
Chang, 2014	342-600	90	20-30	1-25	0.06-0.35	0.25-0.35
Chu et al., 2005	383-849	-	-	6.04	-	-
Gao et al., 2010	500	-	-	2.08	-	-
Giménez et al., 2011	445 ± 95	86.9 ± 3.4	33.3±0.2	0.25-0.875	1.3	0.294 ± 0.04
Ho & Sung et al., 2009	500	90	25	0.25-0.5	0.004	0.21-0.22
Ho & Sung et al., 2010	500	85->95	15-25	3.75-15	0.004	-
Hu & Stuckey, 2006	460±20	>90	35	2.0	0.003	0.22-0.33
Huang et al., 2011	550	>97	25-30	1.25-2.5	0.006	0.138-0.25
Kim et al., 2011	513	99	35	0.175-0.246	0.003	-
Lew et al., 2009	540	88	25	0.25	0.18	-
Lin et al., 2011	425	90	30	0.42	0.08	0.24
Martin et al., 2011	400-500	-	35	0.33-.58	-	0.29-0.33
Martinez-Sosa et al., 2011	402±73	84-94	20-35	1.5-0.67	0.35	0.24-0.27
Saddoud et al., 2007	685	88	37	0.625-2.5	-	-
Salazar-Pelaez et al., 2011	350	80	-	0.16-0.50	-	-
Smith et al., 2011	440	92	15	0.67	-	-
Smith et al., 2014	430	85-90	15-25	0.33	-	0.35
Wen et al., 1999	100-2600	97	12-25	0.16-0.25	-	-

Notes: COD = Chemical Oxygen Demand; HRT = Hydraulic Retention Time; SRT = Solids Retention Time

- **HRT:** was assumed at 24 hours. This affects the tanks area and the capital investment needed.
- **Electricity production** – is assumed at 2.87 kWh/M³ Biogas²³, and it is supported by the Ecosites results.
- **NH₃SO₄:** Based on analysis by Partner BOKU the expected yield is assumed to be approx. 0.022 Kg/M³ Biogas.
- **Hydrogen + PHA:** We addressed H₂ + PHA as one unit, according to NTUA methodology of Dark Fermentation. As described above, we estimate roughly that 30% of the remaining 90% will be allocated to PHA+H₂ process. PHA yield was calculated as 55% from theoretical yield, by the best result of NTUA- This was calculated to approx. 247 gr/ KG COD. Concerning H₂ - According to Our technical report by NTUA, the estimated conservative yield was assumed 0.6 Mol H₂/ Mol Sugar. This, with the above allocation of approx.13.5 % net COD for H₂, was translated to 12g / Kg COD.
- **Benzoic Acid:** Based on discussion with partner GREENE, the yield of benzoic Acid from Pyrolysis is estimated at 1% of the NRW mass, depending on the mixture of textile and MSW.
- **Acetic Acid:** The extraction of Acetic Acid was found to be more difficult, so for this model it was omitted. However, the estimation is approx. 0.8% yield out of the NRW stream, by our estimations and Partner GREENE.²⁴
- **Char and Activated Carbon:** After some analysis, the best method proposed is to produce activate carbon, at yield of 30% from the feedstock (mixed of NRW and sludge – and 10% were allocated to Cd's.
- **Carbon Dots:** Carbon dots were assumed to be 10% of the Activated Carbon. (Eg approx. 0.03 of feedstock).

3.2.6 Promising KERs on lower TRL and implications on the model

Will be suggested for further exploration in coming steps.

MMV (KER 2.3): Magnetically induced membrane vibration is assumed to potentially reduce the energy consumption of Membranes AnMBR. The reduction in energy usage is still on research; therefore, we have conducted a sensitivity analysis assuming varying energy reduction of 10-50% as reflected in Figure 18.²⁵

²³

https://www.researchgate.net/publication/369392542_Life_Cycle_Costing_of_Anmbrr_for_Urban_Wastewater_Treatment_A_Case_Study_Based_on_a_Demo-Scale_Anmbrr_System

²⁴ It should be noted that the Partners look for promising opportunity to increase the PHA yield using the pyrolysis oil, therefore it might be optional to divert these resources to the PHA yield calculations.

²⁵ Ilyas, A., M. Davenport, D., Dysserinc, B., Rombaut, K., & Vankelecom, I. F. J. (2025). Patterned Vibrating Membranes at Pilot-Scale: Membrane Preparation and Setup Design. *Separation and Purification Technology*, 369, 133143. <https://doi.org/https://doi.org/10.1016/j.seppur.2025.133143>

TBR Trickle bed reactor (KER 1.3): TBR can utilize hydrogen to achieve 100% conversion of biogas to methane, but it will be favorable mostly when allocated in a complex of renewable energy as solar, with low-price available hydrogen, as an optional conversion tool. This route can be further explored in the coming steps of SYMSITES exploitation.

PMR protonic membrane reactor (KER 4): the promising results were presented near the project end, and it is still to be further explored with partner CSIC.

3.2.7 Prices- sales

Table 9: Prices assumptions

Material/ Service	Projected price (€ per Ton/M ³)	Reference
WW gate fee	1-3	Ecosites regions data
NRW gate fees	20-40	According to incineration prices -slightly lower
Treated water	0.2-0.8	By Ecosite manager and/or Eurostat, An estimation of 15% lower than tap water.
Bio Methane	--	Assumed for internal use to achieve the best energy balance. ²⁶
Electricity	0.14-0.35	Local Electricity prices were provided by the Ecosite managers (NTUA, FACSA, BEOF, BOKU).
PHA (PHBV)	3,000	Conservative assumption, lower than current market prices. ²⁷
Bio- Hydrogen	5,000	Conservative assumption according to market trends. ²⁸
NH ₃ SO ₄ - Fertilizer	250	Slightly Higer that current. ²⁹
Sludge	0	Sludge if allowed to be used is referred to as 0 pricing.
Char	100	Conservative assumption. ³⁰
Activated Char	2,000	Medium grade activated carbon market. ³¹
Carbon dots	6,000	Highly dependent on quality and scale.

²⁶ .If used externally (only if balance exceeds 100%) - to be calculated by biomethane / electricity prices.)

²⁷ It was verified with a PHA startup COO at 10.3.26, Stating that current prices for large scale are Approx 5 Euro/kg.

²⁸ Curcio, E. (2025). Techno-economic analysis of hydrogen production: Costs, policies, and scalability in the transition to net-zero. *International Journal of Hydrogen Energy*, 128, 473–487.

²⁹ <https://businessanalytiq.com/procurementanalytics/index/ammonium-sulfate-index/>

³⁰ Soka, O., & Oyekola, O. (2020). A feasibility assessment of the production of char using the slow pyrolysis process. *Heliyon*, 6(7), e04346. <https://doi.org/https://doi.org/10.1016/j.heliyon.2020.e04346>

³¹ <https://businessanalytiq.com/procurementanalytics/index/activated-carbon-prices/>

Material/ Service	Projected price (€ per Ton/M ³)	Reference
Benzoic Acid	1,600	Conservative assumption relating to 2025 prices. ³²
Acetic Acid	650	Conservative assumption relating to 2026 prices. ³³
CO ₂ credits	70	Conservative according to ETS rates and forecasts.

3.2.8. Operational costs: OPEX

Electricity consumption

Electricity was found to be the main operational cost, and environmental factor (see LCA). We have estimated the energy consumption of the 3 main units – AnMBR, AC and Pyrolysis (with activation). By far, AnMBR and Pyrolysis have higher energy costs. Here are the main aspects of this estimation, based on literature^{34 3536} and technical data:

Table 10: AnMBR Energy consumption assumptions

Grit & Screening	0.05–0.15 kWh/M ³	Mechanical rakes, grit classifiers. Lower for passive systems.
Odor Control	0.1–0.3 kWh/M ³	Biofilter blowers, chemical scrubbers, or activated carbon systems.
Membrane Filtration	0.5–1.5 kWh/M ³	Permeate pumps, backwashing, fouling control (major energy consumer).
Pumps & Misc.	0.25–0.7 kWh/M ³	Feed pumps, recirculation pumps, instrumentation, controls.
Reactors & Other	0.1–0.3 kWh/M ³	Mixing energy; heating (if required) adds 0.3–0.8 kWh/M ³ (temperature-dependent).

A size factor was calculated to adjust size and optimization, and 8% of unexpected was added.

³² <https://www.imarcgroup.com/benzoic-acid-pricing-report>

³³ <https://www.imarcgroup.com/acetic-acid-pricing-report>

³⁴ Zhang, S., Tchalala, M., Cheng, H., Medina, J., Xiong, Y., & Hong, P. (2023). Anaerobic membrane bioreactor as the core technology for future decentralized wastewater treatment plants. *Current Opinion in Chemical Engineering*, 42, 100975.

³⁵ Martin, I., Pidou, M., Soares, A., Judd, S., Jefferson, B. 2011. Modeling the energy demands of aerobic and anaerobic membrane bioreactors for wastewater treatment. *Environmental Technology*, 32(9): 921-932

³⁶ Feickert, C.A., Guy, K., and Page, M. 2012. Energy Balance Calculations on an Anaerobic Membrane Bioreactor. Construction Engineering Research Laboratory (CERL). U.S. Army Engineer Research and Development Center. ERDC/CERL SR-12-15

Adsorption columns:

Without exact data, we assumed 10% from the AnMBR, according to the literature.³⁷

Pyrolysis

After research, we assumed the cumulative demand of the Pyrolysis, Activation and the HVNRs such as BA, CD's – as total of 1.5 kWh/kg³⁸ of which, most of the pyrolysis unit usually goes for self-sufficient process from the Syn-gas contribution. However, with the activation unit, and the heating of the AnMBR to 35 degrees, we have estimated a factor of 60% self-sufficiency.

3.2.9 Others: labor, maintenance:

- Labor is assumed at 24 workers for 20,000 M³/day (100%) capacity.
- Maintenance, renewals, depreciation – 4% annually of capex
- Raw materials – coagulants, acids, activated carbon (will be sold internally optionally), solvents for extraction – were assumed at 2% of total qty, in 500 euros/ton.

3.2.10 Capital investment

Capital investment was calculated by size factor, referring to 20,000 M³/day as a 100% baseline for general assumptions. For the main factors, such as Membranes, Reactors, Pyrolysis, HVNR's etc. – in each Tab a similar factor sheet was created. At 120% Capacity, as in Bornholm scenario, the overall Capital investment was estimated at 103,000,000 Euros, In the following main pillars:

Table 11: Example of CAPEX for Bornholm case

(i)AnMBR + AC+DF unit	Estimated cost (€)
Reactors	18,000,000
Membranes	3,040,000
Methane storage	300,000
Instrumental and control systems, pipes, blowers	14,252,000
H ₂ + PHA	8,390,000
(ii)Adsorption columns	1,800,000

³⁷ Robles, Á., Jiménez-Benítez, A., Giménez, J. B., Durán, F., Ribes, J., Serralta, J., Ferrer, J., Rogalla, F., & Seco, A. (2022). A semi-industrial scale AnMBR for municipal wastewater treatment at ambient temperature: performance of the biological process. *Water Research*, 215, 118249.

³⁸ Miteva, K. (2019). "Production of sustainable energy from solid waste by pyrolysis: A review." *Recycling and Sustainable Development*.

(iii) Pyrolysis unit	
Pyrolysis Reactor	1,674,000
Activation unit	800,000
Drying System	558,000
Benzoic Acid unit	533,250
Distillation	350,000
Solvent Extraction	275,000
Instrumentation and Control Systems	6,478,218
Pumps and Blowers	3,886,931
site civil engineering	11,846,000
Installation & construction	19,922,000
Permits and Regulation	3,171,000
Unexpected 10%	9,527,670
Total cost estimation of Capital investments	104,804,000

As mentioned, a CAPEX factor was added to estimate the efficiency for scale, which is not linear:

Table 12 Scale factor for capital expenditure

M ³ /day	Percentage factor
<5,000	50%
5,000	70%
10,000	80%
15,000	92%
20,000	100%
25,000	128%

3.2.11 Financing

We assume that these high CAPEX investments will need a blended mechanism of financing, aligned with the EU targets, and European development banks channels. One methodology for this mechanism is called: HAM (Hybrid Annuity Model)³⁹ that a share of the capital needed

³⁹

<https://www.pas.org.in/Portal/document/UrbanSanitation/uploads/Hybrid%20Annuity%20Model%20for%20Sanitation%20April%2023%202018.pdf>

will be allocated by government, mostly at around 40% shares. This amount is provided every year according to target-based results. Our main assumptions regarding the financing are:

- 20-40% Governmental funding (adjustable) and can be even larger.
- The rest in 20 years loans, with 6% annual interest rates.

3.2.12 Area footprint

We have created a table of estimated areas for the plant units, and multiplied by 2 to allow logistics, roads and unexpected. It reveals a highly efficient area footprint, especially in comparison with the alternative of 3 plants: WWTP, Biogas and Pyrolysis plant.

Table 13: SYMSITES facility area per component

Component	Typical Area Requirement (m ² /(m ³ /day))	Value	Area (m ²)
Screening & Grit Removal	0.02–0.1	0.09	1,002
Inlet/Equalization Tank(s)	0.05–0.1	0.09	1,002
Anmbr Bioreactor Tank (HRT tank)	0.15–0.4	0.38	4,229
SRT/Sludge Storage	0.02–0.05	0.05	556
Membrane System (UF/MF)	0.08–0.2	0.20	2,226
Pipes & Pumps	0.01	0.01	111
Disinfection/Absorption Columns	0.03–0.08	0.08	890
Treated Water Tank	0.04–0.1	0.10	1,113
Methane (Biogas) Tanks	0.04–0.06	0.06	668
Electricity Generation Area	0.03–0.07	0.07	779
Hydrogen Production (if included)	0.04–0.07	0.07	779
Hydrogen Storage Tanks	0.02–0.04	0.03	334
Material Absorption Area	0.01–0.03	0.03	334
NRW Crusher (for solid reduction)	0.01–0.03	0.03	334
Pyrolysis Unit	0.03–0.08	0.07	779
Offices	0.01–0.02	0.02	223
Control Center	0.01–0.02	0.02	223
Warehouse/Workshop	0.02–0.06	0.04	445
Miscellaneous (corridors, utility)	0.03–0.1	0.10	1,113
Unexpected/Buffer	0.03–0.05	0.05	556
Total estimated range	0.5–2	1.59	17,695

3.3. Conclusions

Feedstock

Water and Biowaste: we assumed typical COD's and liter per capita. However, when more updated data was received from Ecosites, we have used Ecosite data. e.g. Qty of Urban WW was found to be much higher than in the literature, perhaps due to drainage water. Some of more intensified streams like animal manure, were factored as 90% liquids in the water supply calculations.

NRW rates were calculated by EU data, and mostly by the actual data in the 4 regions. Incineration streams were treated as NRW.

Gate fees – gate fees of WW were taken from the Ecosites data. We have considered slightly higher costs of gate fees due to the high COD streams that will be involved. However, some cleaner streams of BW in Europe might have 0 cost or even negative, therefore we assumed a fix-price for gate fee that is slightly higher than existing WWTP. More complex models can reflect COD in the gate fee payments; however, we see that trend is changing due to future demand for COD for HVNR's production.

Weighted COD: from the preliminary calculation, we see that 1,000-10,000 mg/L are the expected range of COD in the mixture of Urban WW, industrial WW, and Bio waste. It can be affected both from the available regional sources, the current agreements, and from the system design – meaning that we can design a SYMSITES unit for partial QTY of the urban WW, thus creating more condensed stream with lower CAPEX / project cost. This can be crucial for the first steps of the upscaling process.

Cascading operational rationale – COD utilization

According to the attached diagram, we assume that COD as the main factor (but not only) will be allocated by system preferences, in the following structure:

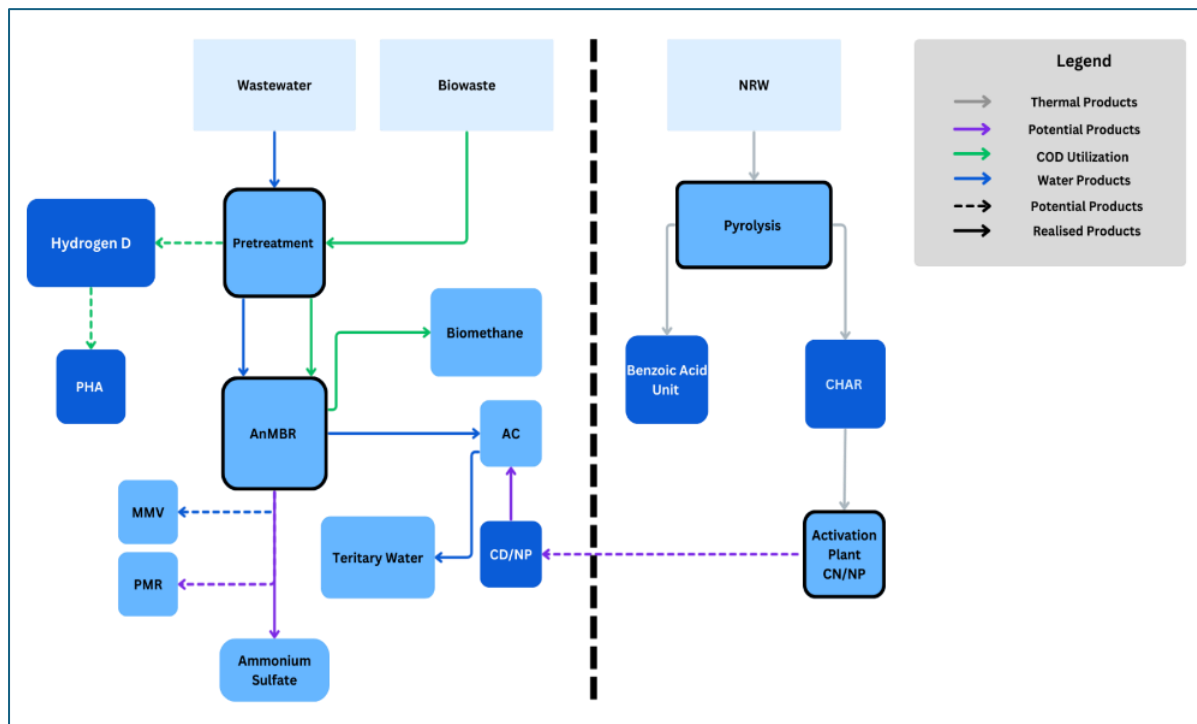


Figure 8 : COD flow and utilization in SYMSITES

Our main assumptions regarding the COD allocation are:

1. 30% is allocated to Dark Fermentation unit (H_2 +PHA)
2. 70% is allocated to Biomethane production

We refer to COD as a main "resource", however it is treated mostly as a burden to WWTP's. COD is utilized in both units to maximize and diversify the yield. A 30/70 ratio between the "Dark fermentation" and the standard AnMBR was implemented where applicable, and this ratio is adjustable.

1. NRW is a separate stream to produce benzoic acid and Activated carbon (CD's / NP)
2. Sludge utilization –is preferred to hydro-thermal carbonization process (HTC) – which hasn't been described yet in the project design, therefore in this analysis was calculated as default in the pyrolysis system.

To summarize, here are a few fixed variables that were assumed in our calculations:

Table 14 Key factors variables

Factor	Value	Behavior / source
CAPEX baseline capacity	20,000 M ³ /day	Scales linearly; 100% reference point (p. 34)
Maintenance / renewals / depreciation	4% of CAPEX/yr	Fixed ratio (p. 33)
Raw materials (coagulants, solvents, AC)	2% of COD × €500/ton	Scales with throughput (p. 34)
Unexpected / contingency	+8% OPEX; +10% CAPEX	Fixed add-on (pp. 33, 35)
Labor	24 FTE at 100% capacity	Scales sub-linearly (p. 33)
Energy scale efficiency	×0.90 at large scale	Applied in Alcoi scenario (p. 52)
Governmental / HAM share	20% of CAPEX can be adjusted.	<i>Variable input</i> ; (p. 35)
Loan terms on remaining CAPEX	20 yrs, 6%	Fixed financing assumption (p. 35)

3.4 Scenarios

3.4.1 Scenario 1: The Island of Bornholm, Denmark



This Analysis was made with the support of the Ecosite leader, partner BEOF.

The Island of Bornholm is a municipal unit in Denmark. It has targeted a 0-waste goal in 2032⁴⁰. The HVNRs produced can be very valuable in turning this goal into a reality. Therefore, in our model for Bornholm, we assumed all possible high-COD streams to be integrated with the WWTP system. This model represents a “all-in-one” turn-around of existing WWTP. Concerning HVNRs sales, it is noted that the Island is remoted from mainland, therefore some products are suggested for self-consumption, local use, or local delivery with minimal payment - while more “commodified” HVNRs can be transported to mainland and be sold. An updated input by the Ecosite manager in GA42 has informed us that water is not yet allowed to be sold for agriculture. Therefore, only 10% of the water was calculated for sale to industry.

Table 15: In streams- Bornholm

	Qty	COD
Municipality WW	7,000,000	250
Brewery WW M ³	6,000	7,500
Dairy wastewater M ³	130,000	5,000
Household, restaurants (ton)	3,000	90,000
Farming (manure) (ton)	495,000	40,000
Dairy wastewater Whey (ton)	73,000	60,000
Total in streams	7,707,000	
Weighted COD		3,490

⁴⁰ <https://bornholm.info/en/bornholm-shows-the-way/>

Table 16: HVNRs selected for the model Bornholm

Parameter	Choice
Hydrogen	1
Bioplastics	1
Sludge	0
NH ₃ SO ₄	1
Activated Char from Pyrolysis	1
Benzoic Acid	1
Acetic Acid	0
CO ₂ reduction	1
Carbon dots	0

As mentioned in the introduction for this analysis, all possible HVNRs were selected in this scenario, deriving from the large amount of urban WW, and high COD, as well as the Island motivation for 0 waste.

Table 17: Revenue streams Bornholm

Annual	Annual qty	Unit	Price per unit	Annual sales (€)
Treatment fee (gate fee)	6,242,670	M ³	3.6	22,479,111
Gate fee NRW	8,888	ton	64	568,800
Treated water sold	6,936,300	M ³	0.7	512,939
Hydrogen	48,411	kg	5.0	242,055
Bioplastics	1,414,509	kg	3.0	4,243,526
Activated carbon	1,867,643	kg	2.0	3,735,285
Benzoic acid	133,313	kg	1.6	213,300
CO ₂ reduction	2,653	ton	0.07	185,719
Total revenues				32,261,000
Methane yield	4,574,840	M ³		-

This calculation is made by multiplying the expected yield as was described in sub chapter 3.

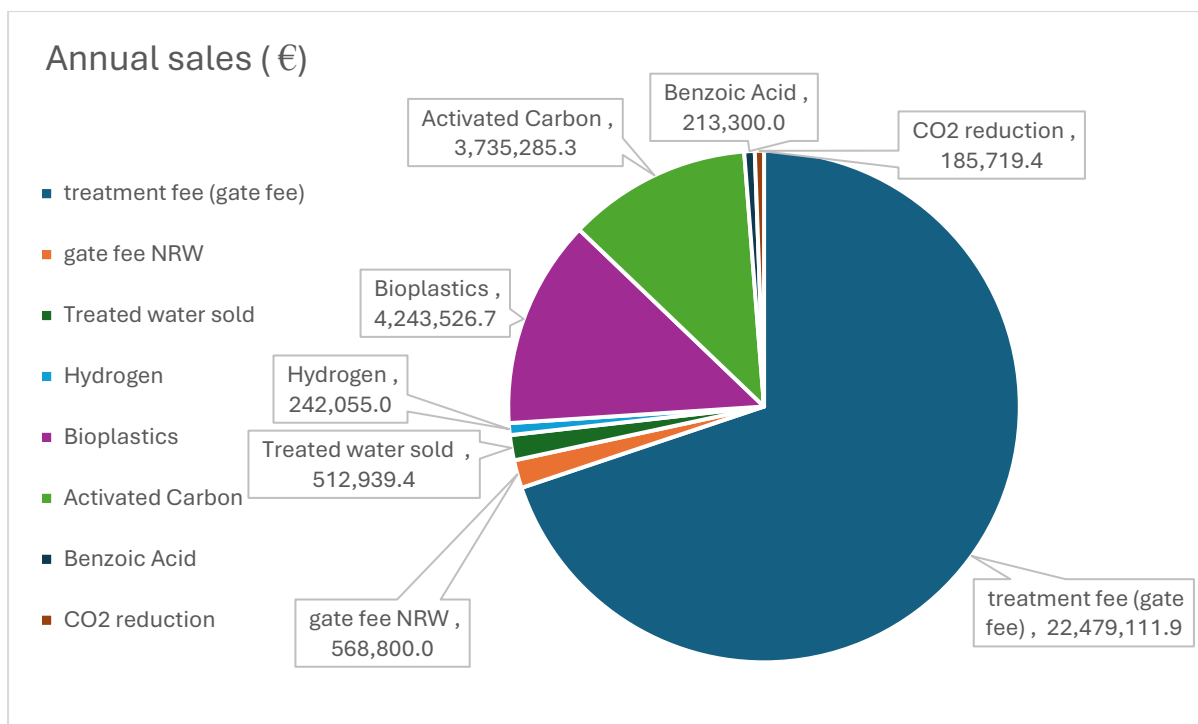


Figure 9: Annual sales Bornholm

Table 18 HVNRs and Energy Balance - Bornholm

HVNR %	26%
Energy Balance (WW unit)	91%

Table 19: Profit/loss Bornholm (€)

Total sales	32,261,609
Cost of goods sold	8,257,895
Gross profit	24,003,714
Gross profit %	74%
Management	1,309,641
Operations	5,205,589
Operational P/L	17,488,483
Operational profit	54%
Income before tax	17,488,483
Income tax	3,497,697
Net profit (loss)	13,990,787
Roi	14%

$ROI = \text{Net Profit (Year 1)} \div \text{CAPEX, pre-financing.}$

Table 20: Accumulated cash flow Assuming 20% Governmental / Other grants (€)

Year 0	-82,470,235
Year 1	-69,235,426
Year 2	-54,265,284
Year 3	-38,247,232
Year 4	-21,107,917
Year 5	-2,768,849
Year 6	16,853,953
Year 7	37,850,351
Year 8	60,316,498
Year 9	84,355,274
Year 10	110,076,765
Year 11	137,598,760

Insights from Bornholm model results:

We see a clear, firm business model that presents a positive vision for implementation on the Island scale and aligning with the Island ambitious targets. Two main HVNRs that were developed are PHA and activated Carbon. The Carbon dots, if not active from local forestry residues (needs more research), can be imported, theoretically from a SYMSITES EcoSite in Greece, creating a network. Hydrogen is recommended to be used for local energy use, without complicated transport. The overall CAPEX is relatively high, but with 20% grant and following these assumptions it is a firm model.

Sensitivity analysis shows that the Gate fee is still a major factor, therefore, to stay on 10-20% IRR, the gate should stay on 3.4-4.2 €/ton.

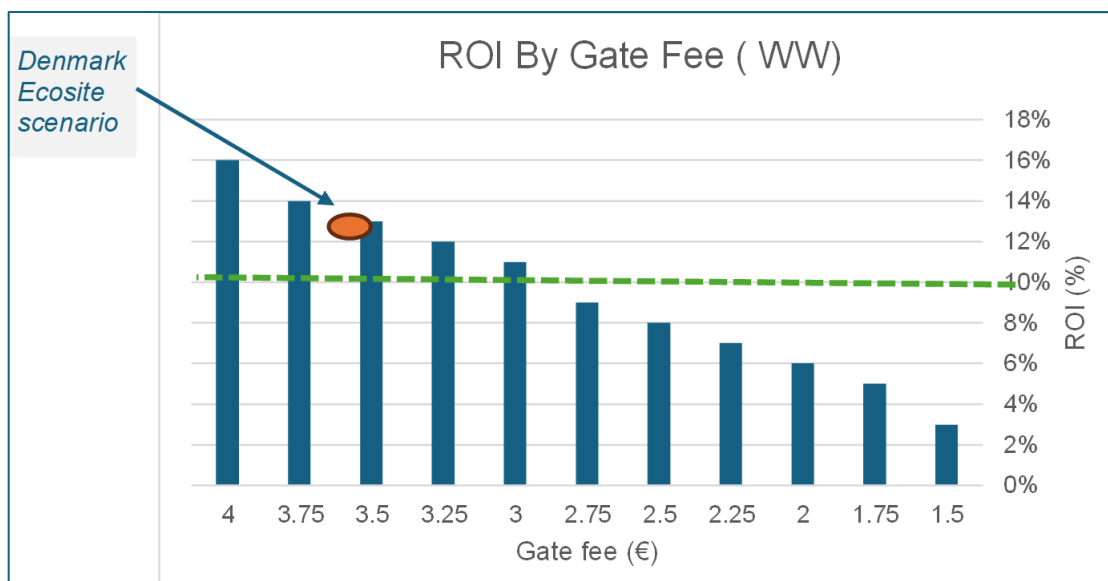


Figure 10: ROI by gate fee Denmark

We see that the preferred gate fee is about 3 €/M³. In our model and calculations, the Gate fee for all WW streams was calculated as 3.6 Euros/M³ that reflects 14% ROI.

Animal Manure and Energy Ratios

It should be well taken, that in order to achieve these good results of energy balance, a large qty of Animal manure was provided by the Ecosite Manager. We see that the contribution of animal manure is vital to the model to reach the highest yields of energy ratios:

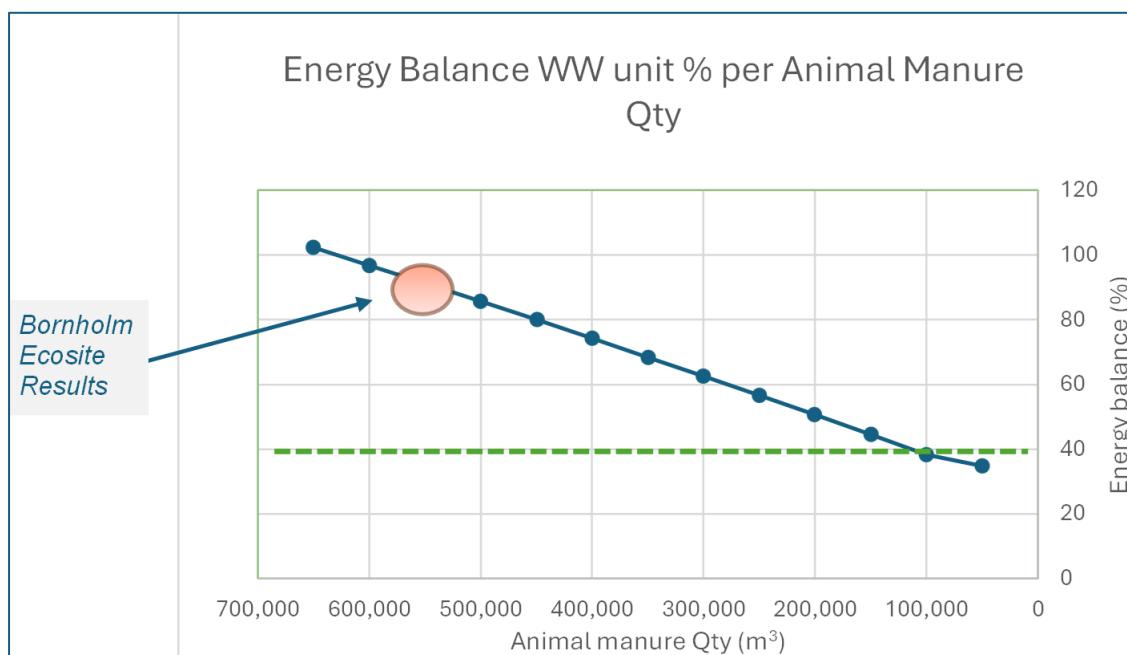


Figure 11: Energy balance WW unit, Denmark

3.4.2 Scenario 2: Greece – West Achaia



This Analysis was made with the support of the Greek Ecosite: and mostly – NTUA (Ecosite leader), SIRMET, MWA.

This scenario represents a dominant olive industry as a COD "contributor". Also, the region has a large tourist effect in the summer months. In this scenario we have received only an estimation of the olive trees in the region, from which an estimation of the overall OIWW quantity was derived. Still, it should be noted that on an overall scale, the weighted COD that was analyzed is comparatively low. Therefore, as suggested by Partner SIRMET the strategy here was to divide the site into 2 parts, and use SYMSITES product only for half of the municipal WW, 2,000,000 M³/Year. This of course increases the weighted COD, but less revenues are gained from WW treatment and treated water sales. on the HVNR section, it is focused on producing olive Carbon Dots to achieve maximum economic yields, while PHA and H₂ will be less feasible since the daily COD weight is low (however these HVNRs know-how will be "exported" and licensed as our main strategy of integrated consortium).

In streams

Table 21: In streams West Achaia

Waste Streams	Qty M3	COD mg/l
Municipality WW M ³	2,000,000	250
Brewery WW M ³	0	7,500
Dairy wastewater M ³	0	5,000
Meat or bones Biowaste M ³	0	80,000
Olive bio waste M ³	7,087	140,000
Household, restaurants ton	2,000	90,000
Farming (manure) ton	0	10,000
Dairy wastewater Whey ton	0	60,000
Weighted COD		832
Non-recyclable waste (NRW)		3,845

Table 22: HVNRs selected West Achaia

Hydrogen	0
Bioplastics	0
NH ₃ SO ₄	0
Activated Char	1
Benzoic Acid	1
Acetic Acid	0
CO ₂ reduction	1
Carbon dots	1

As Mentioned, the AnMBR unit is focused here on water treatment, and possibly on optimization of membrane with the Carbon dots. However, the PHA+ H₂ are not produced due to less COD.

Table 23: Revenue streams West Achai

Annual	Annual qty	Unit	Price per unit (€)	Annual sales (€)
Treatment fee (gate fee)	1,627,360	M ³	1.5	2,485,719
Gate fee NRW	3,845	ton	40	153,798
Treated water sold	1,808,178	M ³	1	1,859,711
NH ₃ SO ₄	20	ton	250	5,028
Activated carbon	1,203,650	Kg	2	2,407,301
Carbon dots	120,365	Kg	6	722,190
Benzoic acid	57,674	Kg	1.6	92,279
CO ₂ reduction	850,000	Kg	0.07	59,500
Total				7,785,526
Methane yield	406,340	M ³		

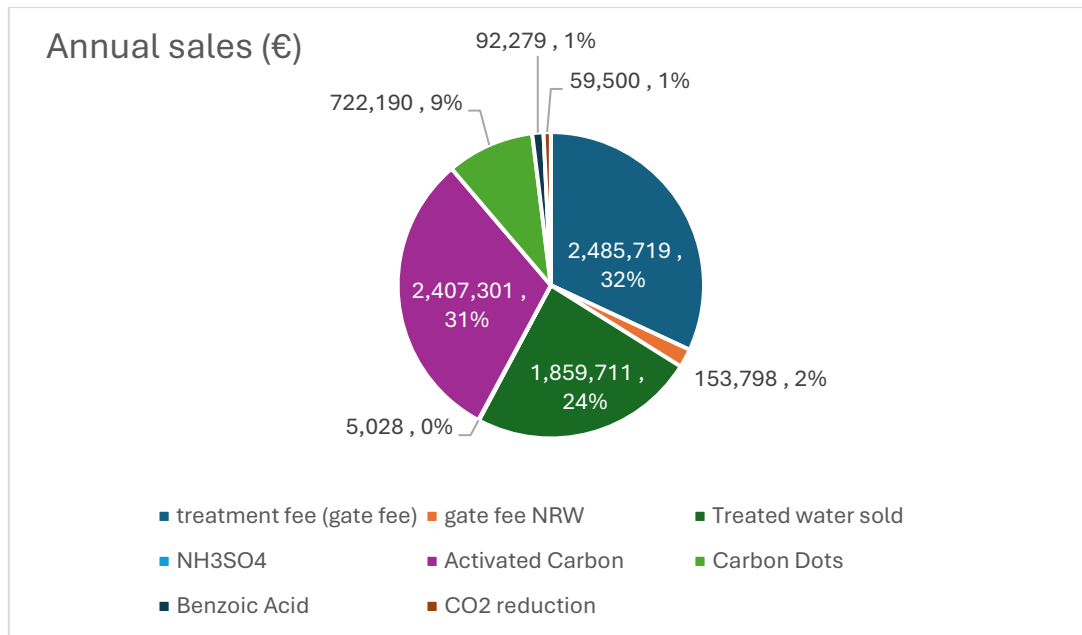


Figure 12: Annual sales West Achaia

Table 24: HVNRs and Energy balance – West Achaia

Energy Balance WW unit	40.50%
HVNRs%	41%

Table 25: Profit/loss West Achaia (€)

Sales	7,785,526
Cost of goods sold	1,959,293
Gross profit	5,826,233
Gross profit %	75%
Management	395,621
Operations	1,967,999
Operational P/L	3,462,613
Operational profit %	44%
Income before tax	3,462,613
Income tax	692,523
Net profit (loss)	2,770,091
ROI	9%

Table 26: Accumulated cash flow (assumption of 20% Government/ other grant, in Euros)

Year 0	-19,493,450
Year 1	-16,902,049
Year 2	-13,938,052
Year 3	-10,766,575
Year 4	-7,373,095
Year 5	-3,742,071
Year 6	143,124
Year 7	4,300,283
Year 8	8,748,443
Year 9	13,507,974
Year 10	18,600,673
Year 11	24,049,861

Sensitivity analysis of Wastewater qty

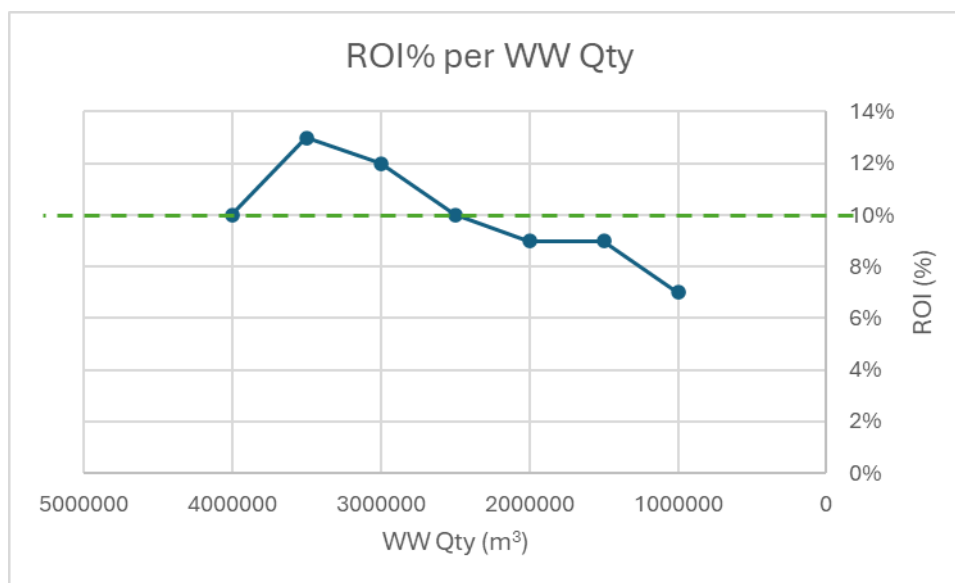


Figure 13: ROI per WW Qty West Achai

We see the mechanism that increasing the annual WW Qty will increase revenues, therefore also the ROI, however as the CAPEX will increase as well, there is a sensitivity that is optimized at 3,500,000 M³.

Energy Balance Per WW qty

In our strategy Scenario, we decided (with the Partners' advice) to divide the WW in 2. Here is analysis of different scenarios of WW instreams. (NRW and Biowaste are the same)

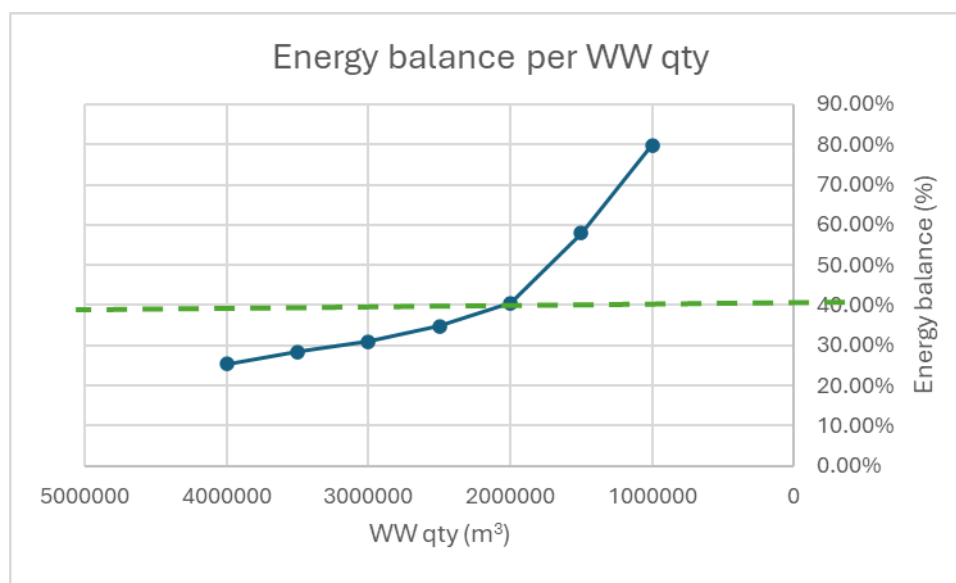
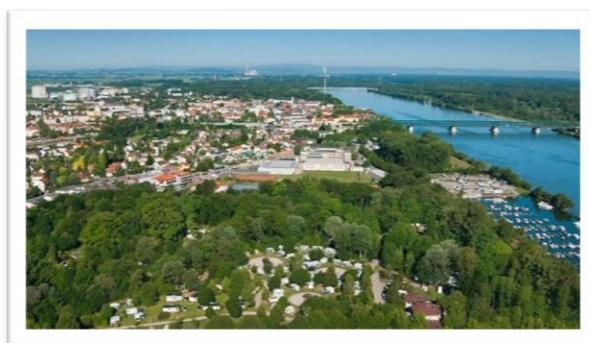


Figure 14: Energy balance per WW Qty

We see that while the Energy Balance is directly going up when we decrease the qty of Municipal WW, the ROI has more complex mechanism (due to capital investment, operational costs, and sales dispersion) and is optimal at 3,000,000 M³. However, at this WW Qty we are below the 40% threshold energy balance by UWWTD directive. Therefore, it seems that our scenario for 2,000,000 M³ municipal reflects a good balance and compliance.

3.4.3 Scenario 3: Austria (Tulln)



Tulln is a town and municipality in lower Austria state, about 30 km from Vienna. The Ecosite was placed in a large meat processing factory (Berger Schinken), aiming to treat in a symbiotic

way the plant's WW, while giving back the water for the cooling tower, and utilizing energy and fertilizers to the plant and the agricultural surroundings. Also, it should be noted that a large sugar industry exists in the area. The input given by the Ecosite managers highlight large industrial WW stream. Also, we have considered that the regulation in Austria for Irrigation with water are still not set. Also, a large qty of organic waste from the meat industry and some from local pig farm have been integrated. Our strategy, due to low COD, was to emit the Dark Fermentation unit, and focus on reaching nearby the EU regulation UWWTD for energy balance. Also, only 10% of the water was currently calculated for sale (for cooling tower and urban landscaping – not agriculture).

Table 27: In streams Tulln

In-streams	Qty	COD mg/l
Municipality WW	1,870,000 M ³	500 mg/l
Meat or bones Biowaste	1,373 ton	80,000 mg/l
Biowaste household, restaurants	850 ton	100,000 mg/l
Farming ton (manure)	1800 M ³	10,000 mg/l
Meat WW	156,000 M ³	2,800 mg/l
Weighted COD (mg/l)		780 mg/l
Total	2,030,023	-
Non-Recyclable Waste (NRW)	4,545 ton	

Table 28: HVNRs selected Tulln

Hydrogen	0
Bioplastics	0
NH ₃ SO ₄	1
Char from Pyrolysis	1
Benzoic Acid	1
CO ₂ reduction	1
Carbon dots	0

Table 29: Revenue streams Tulln

Revenues	Qty	Unit	Price per unit	Sales (€)
Treatment fee (gate fee)	1,870,000	M ³	2.9	5,422,362
Gate fee NRW	4,545	ton	30	136,347
Treated water sold	182,702	M ³	1.7	310,594
NH ₃ SO ₄	19	ton	250	4,750
Activated carbon	1,411,008	Kg	2	2,822,015
Benzoic acid	68,173	Kg	1.6	109,077
CO ₂ reduction	794	ton	70	55,633
Total				8,854,064
Methane yield	385,067	M ³		

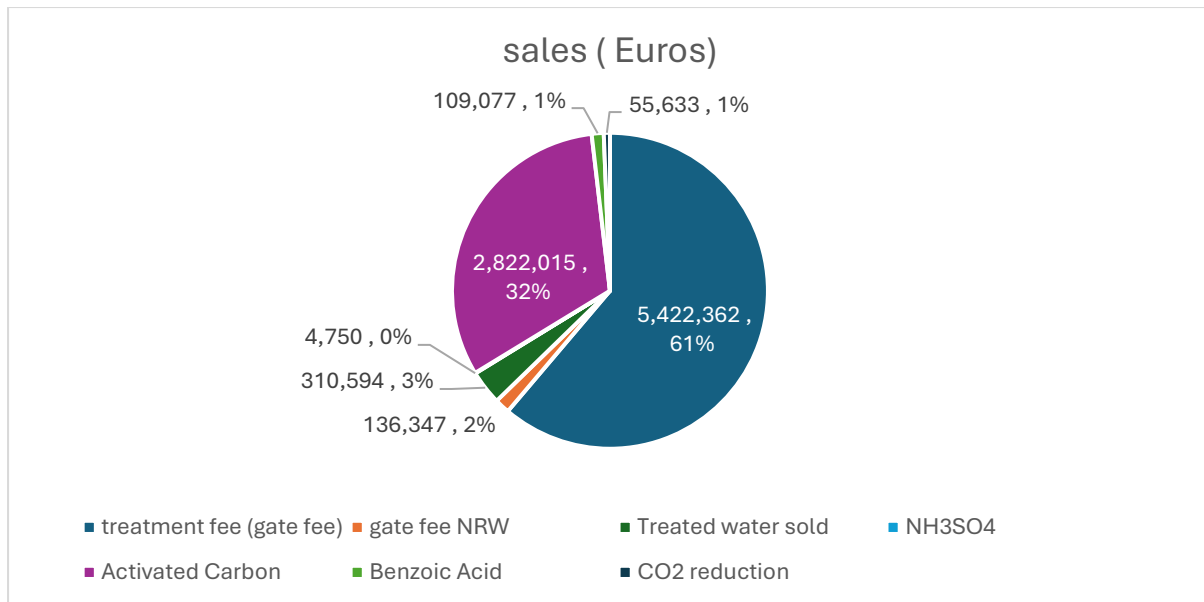


Figure 15: Sales Tulln

We see that due to low water sale, the revenues in Tulln will be focused on the gate fees and the activated carbon sales.

Table 30 HVNRSs and Energy Balance in Tulln model

HVNRs	33%
Energy Balance	38%

Table 31: Profit / loss analysis Tulln

Sales	8,860,793
Cost of goods sold	2,304,975
Gross profit	6,555,818
Gross profit %	74.0%
Management	433,079
Operations	1,882,925
Operational P/L	4,239,814
Operational profit %	47.8%
Income before tax	4,239,814
Income tax	847,963
Net profit (loss)	3,391,852
Roi	10%

Table 32: Accumulated cash flow (with 20% EU/ Government / other fund)

Year 0	-19,890,102
Year 1	-17,209,467
Year 2	-14,146,098
Year 3	-10,868,294
Year 4	-7,361,043
Year 5	-3,608,285
Year 6	407,166
Year 7	4,703,699
Year 8	9,300,989
Year 9	14,220,089
Year 10	19,483,526
Year 11	25,115,404

Overall, we see a valid model that can operate in current terms, and gradually evolve on 2 main sectors:

1. Input of new Biomass feedstock to produce local carbon dots (such as pine trees residuals)
2. Increase in the water sale for the municipality, industry and agricultural usage.

We have created a sensitivity analysis, to investigate the overall sale of re-use water to the model ROI.

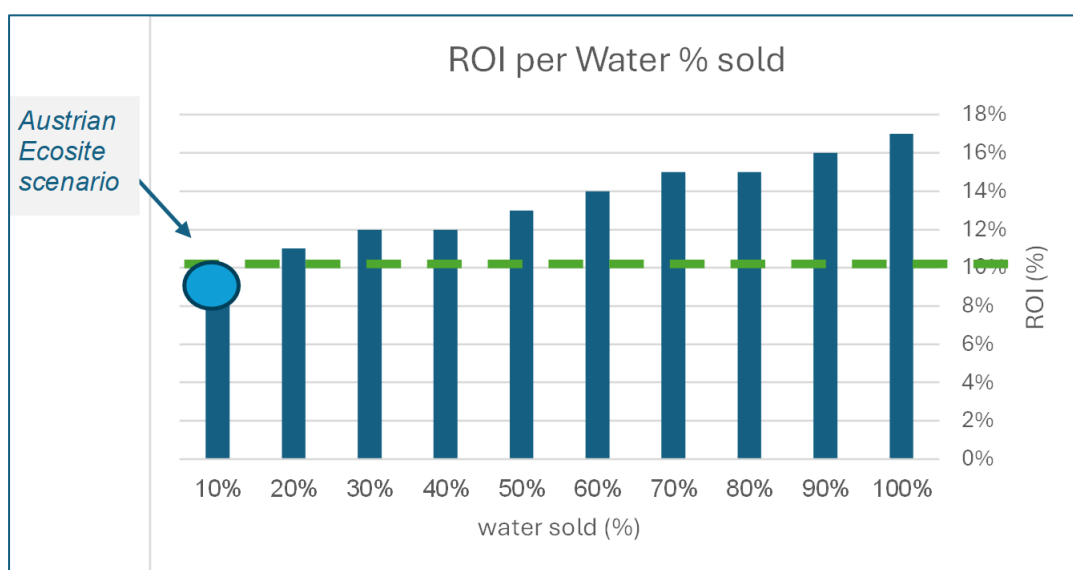


Figure 16: ROI per water % sold Tulln

3.4.4 Scenario 4: Spain (Alcoi)



Alcoi, in Alicante province, and Valencian Autonomous Community, is an industrial medium size city in mountainous surroundings. The city WWTP is already receiving industrial ww, therefore relatively high COD in streams. Also, as preformed in many parts of Spain, the usage for agricultural irrigation is already widespread. On the other hand, this scenario involves the highest population from the 4 Ecosites -and therefore a large qty of WW – Nearly 10,000,000 M³/ Year. This will produce the largest scale of "product" to be implemented, approx. 27,000 M³/day.

Table 33: In streams Alcoi

IN-STREAMS	Qty M ³	COD mg/l
Municipality WW	9,890,000	1,250 mg/l
Household, restaurants ton	5000	30,000 mg/l
Total	9,895,000	
Weighted COD		1,265 mg/l
Non-Recyclable Waste (NRW)	13,530	

Table 34: HVNRs selected Alcoi

HVNR	Choice
Hydrogen	1
Bioplastics	1
NH ₃ SO ₄	1
Char from Pyrolysis	1
Benzoic Acid	1
Acetic Acid	0
CO ₂ reduction	1
Carbon dots	1

Table 35: Revenue streams Alcoi

Annual	Annual qty	Unit	Price per unit (€)	Revenue (€)
Treatment fee (gate fee)	9,890,000	M ³	1	9,922,833
Treated water sold	8,905,500	M ³	1.4	12,338,570
Hydrogen	9,489	Kg	5	47,445
Bioplastics	658,079	Kg	3	1,974,238
NH ₃ SO ₄	150	ton	250	37,624
Activated carbon	4,434,000	Kg	2	8,868,000
Carbon dots	443,438		6	2,660,625
Benzoic acid	202,950	Kg	1.6	324,720
Gate fee NRW	13,530	ton	64	865,920
CO ₂ reduction	4,203	ton	70 €	294,228
		Total sales		37,334,203
Methane yield	2,128,376	M ³		

Table 36 HVNRs ratio and Energy Balance in Alcoi

HVNR's	37%
Energy Balance	37%

A Factor of 90% energy consumption per M³ was added (efficiency for scale).

Table 37: Profit/ loss analysis Alcoi (€)

Sales	37,400,121
Cost of goods sold	8,708,452
Gross profit	28,691,669
Gross profit %	77%
Management	1,572,010
Operations	7,601,617
Operational P/L	19,518,042
Operational profit %	52%
Income before tax	19,518,042
Income tax	3,903,608
Net profit (loss)	15,614,434
Roi	10%

Table 38: Accumulative cashflow (with 20% funding assumption) (€)

Year 0	-125,607,785
Year 1	-111,144,756
Year 2	-95,061,889
Year 3	-78,496,536
Year 4	-61,434,223
Year 5	-43,860,040
Year 6	-25,758,632
Year 7	-7,114,181
Year 8	12,089,603
Year 9	31,869,501
Year 10	52,242,795

MMV technology influence on system ROI

As described in the former deliverables – The Magnetic induced Membrane Vibration has proven to be highly efficient in the AnMBR process, due to less fouling⁴¹, and higher flux achieved. We have investigated how this will affect our EBITDA (which is directly related to OPEX efficiency) and Energy Balance.

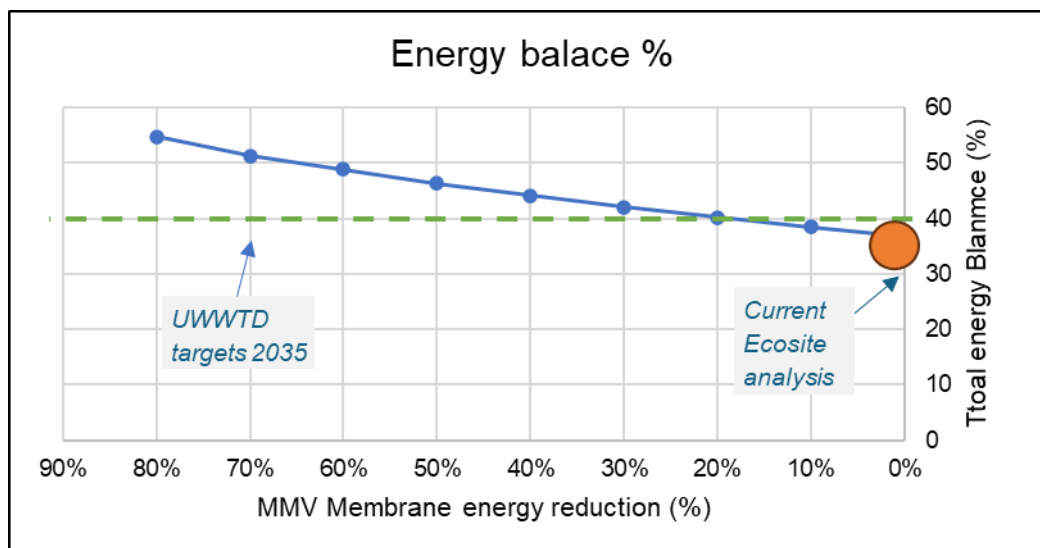


Figure 17: Energy balance Alcoi

⁴¹ Ilyas, A., M. Davenport, D., Dysserinc, B., Rombaut, K., & Vankelecom, I. F. J. (2025). Patterned Vibrating Membranes at Pilot-Scale: Membrane Preparation and Setup Design. *Separation and Purification Technology*, 369, 133143. <https://doi.org/https://doi.org/10.1016/j.seppur.2025.133143>

We see that without the MMV effect, at the current estimation the results in the Spanish model (due to the large qty of WW) do not reach the UWWTD regulation, therefore the MMV technology effect might be crucial to obtain this goal.

3.4.5 Results summary

Following is a summary of the yields, prices and expected cumulative calculation for the HVNRs contribution, taken from Bornholm scenario as reference for the scale analysis.

Table 39: Results summary table

Annual	Annual qty	Price per unit	Annual sales in Bornholm (€)	Strategy channel in model
Treated water sold	6,936,300	0.7	512,939	Sales to energy or irrigation when regulation allows. As an outlet- discharge.
Bio-hydrogen	48,411	5.0	242,055	Preferred for local trucks- e.g. 7-10 local waste service trucks in Bornholm
Bioplastics PHBV	1,414,509	3.0	4,243,526	Sales to a compound plant for commercialization. A local compound industry can leverage this into a regional advantage.
Activated char	1,867,643	2.0	3,735,285	Recommend the highest grades possible.
Benzoic acid	133,313	1.6	213,300	Sales to large suppliers in high grade, relatively small scale.
Ammonium sulphate	323	250	80,781	Small scale yields imply local sales and revenue from the H ₂ S treatment.
CO ₂ reduction	2,653	0.07	185,719	Sales in ETS, especially to WWTPs companies.
Bio methane	4,574,840	-----	-----	Self- sufficiency usage is highly prioritized factor.
Carbon dots/ lignin np	-----	-----	-----	Recommended in Greece, Spain or other sites proven with relevant biomass feedstock, such as pine trees.
Sludge	-----	-----	-----	Not-preferred as is. Recommend installing a complimentary hydro- thermal carbonization unit for nutrient recovery.

Annual	Annual qty	Price per unit	Annual sales in Bornholm (€)	Strategy channel in model
Char	-----	-----	-----	less recommended as is due to low prices
Acetic acid	-----	-----	-----	Preferred as feedstock for the pha production

As we see, the highest revenues come from:

1. Treatment fees
2. Tertiary Water sale
3. Activated Carbon sale
4. Bioplastic sale

Therefore, these are the preferred vectors for revenue streams.

Other production of HVNRs is important to:

1. Reach the EU energy targets and support independent tendency (Biomethane)
2. Support local transition for sustainable transportation (H₂)
3. Treatment of H₂S, (NH₃)₂SO₄)
4. Reaching higher levels of water purities (carbon dots)
5. Added value and transition to non-energy outputs from pyrolysis liquid phase (Benzoic Acid)

Comparison of 4 strategies in the different socio-economic sites:

As we have displayed, in each Ecosite a slightly diverse techno-economic strategy was developed.

- In Bornholm – "all in one", utilizing large volumes WW, high COD derived from BW, competitive pricing, yet without large utilization of water. ROI was demonstrated as relatively sensitive to gate fees, however due to competitive pricing, and the Island commitment, with the shared ownership of the facility by the public authorities- this model can be solid.
- In West Achaia - a smaller case study (focused on one large industrial WW stream, with water Permitted for irrigation., and high value from Olive residuals.
- In Tulln – a smaller unit (5,000 M³/day), still cost-effective to return the investment. This Unit shows dependence on medium level gate fees and production of activated carbon (optional also carbon dots from pine after further research).
- In Alcoi – largest system, providing water for irrigation and industry, while all the HVNRs (olives sources available), however the energy balance slightly low dependent on MMV development.

ROI in all our models is 9-14% (before governmental funding) which is a solid, reasonable figure. The energy Balance except in Demark is slightly on the threshold of the UWWTD, there more effort needs to be done to increase the weighted COD, and to enhance supportive technologies as Cd's, MMV and NP to lower the energy consumption and obtaining another competitive edge.

Table 40: Ecosites scale up model summary

	Denmark	Greece	Austria	Spain
Population	39,500	25,633	15,947	82,000
Qty WW all streams	7,707,000	2,089,000	2,030,023	9,895,000
Weighted Gate fee ww	3.6	1.5	2.9	1
NRW	8,888	3,845	4,545	13,530
weighted COD	3,490 mg/l	832 mg/l	781 mg/l	1,265 mg/l
HVNRs	Hydrogen, Bioplastics, Activated Carbon, Benzoic Acid NH ₃ SO ₄	Activated Carbon, Carbon dots, benzoic Acid	Activated Carbon, NH ₃ SO ₄ , Benzoic Acid	Hydrogen, Bioplastics, Activated Carbon, Carbon dots NH ₃ SO ₄ , Benzoic Acid
Water Usage	10% Municipal	Agriculture (50%)	10% municipal	Agricultural, Industry
WW energy Balance	91%	40.50%	38%	37%
HVNRs %	26%	41%	33%	37%
Methane Yield	4,574,840	406,340	385,068	2,128,376
Revenues (€)	32,261,000	7,785,000	8,860,000	37,334,000
OPEX (€)	14,773,125	4,322,000	4,620,978	17,882,078
EBITDA (€)	17,488,483	3,462,000	4,239,814	19,518,042
CAPEX (€)	103,087,000 €	32,489,000	33,150,170	157009731.1
ROI	14%	9%	10%	10%
Key Factors	High COD, Island, strategy 2030	CDs, BW sources	pricing, Water sales	Water sales, MMV

Table 41: Average "Meta-Ecosite"

	Meta-Ecosite
Population	40,770
Qty WW all streams	5,430,256
Weighted Gate fee ww	2.3
NRW	7,702
Weighted COD (Mg/L)	1,592
Methane Yield (M ³)	1,873,656
WW energy Balance	52%
Revenues (€)	21,560,000
OPEX (€)	10,399,545
EBITDA (€)	11,177,085
CAPEX (€)	81,433,975
ROI	11%

This overall average of 4 Ecosites, shows the "typical" targeted product as our core value proposition. It is designing a retrofit model for a ~40,000 population towns or small cities, with WW estimated as 5,000,000 M³/year. It requires an €83,000,000 Investment (with an expected 20% or more governmental funding), and yields an 11% average ROI, that can be promised to the local municipalities, investors, policy and decision makers and for the industry leaders.

3.4.6 Relevance of the LCA analysis to the I-US strategy

An overall strategy to reduce the environmental impact was shown and demonstrated in the project and in the model excel sheets. D4.6 has introduced the energy factor as the main contributor for climate change; therefore, our strategy focused on self-sufficiency of energy as much as possible. This seems like the 1st priority in our strategy.

Another point worth mentioning is the usage of solvents and other chemicals for extraction and production of HVNRs. SYMSITES makes the most of the self-available materials such as Sulphur and ammonium for the NH₃SO₄, and the carbon sources for activating carbon. Therefore, it can add more value proposition. Recycled solvents or bio-solvents can be used in the extraction unit, and highly valuable is the local sourcing of Cd's for the AC, also if replacement can occur occasionally.

3.4.7 Relevance to main EU directives

Our main benchmarking to EU directives is set to the revised WWTPs regulation.

Table 42: Main factors for analysis

Subject	Year	Target	SYMSITES assumed compliance	Standard CAS compliance
Water quality for 10,000 pe.	2027	Transposition in national laws	---	
Tertiary treatment for 10,000 PE – Only in places with risks or runoff water.	2033	20%	PASS	Pass only with more units
	2036	30%	PASS	Pass only with more units
	2039	60%	PASS	FAIL
	2045	100%	FAIL	FAIL
Quaternary for 50,000-100,000 PE	2039		FAIL	FAIL
Energy Balance (for water unit)	2030	20%	PASS	Pass with AD biogas
	2035	40%	PASS	PASS/ FAIL
	2040	70%	Only Denmark model PASS	FAIL
	2045	100%	Has not yet achieved	FAIL
Nutrients recovery			Need to be further explored. A favorable option might be usage of HTC technology to recover nutrients.	

- It should be noted that for this analysis PE for a large COD plant can be significant, and equivalent for a small town. Therefore, sites of SYMSITES ecosites can be related as much higher population equivalent.
- In general, we see that the energy regulations are stricter for the medium sized WWTPs, however as mentioned:
 1. Can be used for water sales.
 2. Some of these ecosites or similar locations can be referred to as >100,000 pe, due to higher codes from industries.

"Fit for 55"

Our estimations show approx. 0.4 kg CO₂ reduction per M³, which is a conservative, industry-based assumption. There are two main pillars in the reduction:

1. Methane utilization
2. NRW carbonization using pyrolysis and activation unit.

To this, added the increased efficiency by using the advanced KERs such as MMR, that might decrease further the system emissions. As mentioned in the preface, showing these parameters will attract green investments, both from public and private sectors.

3.4.8 Benchmarking with similar scenario

Benchmarking is quite difficult due to the complex scenario, and multi-complex criteria, moreover that this system is at development phase.

However, using some literature and the Bornholm case, we have estimated 2 similar scenarios of: 7,000,000M³ WW, 500,000 tons organic waste and 15,000 NRW. The first with "SYMSITES" system, and the other with "conventional" state of the art – which is also very diverse in Europe- but we choose a "medium market" comparison with: a. CAS standard WWTP b. biogas plant. c. NRW landfill.

Table 43: Benchmarks estimations

Parameter/system	SYMSITES (Bornholm case)	Reference model (CAS+Biogas+ NRW landfill)
Energy balance	~64.6%	30%
Circular Economy	Level 5 (full: energy + materials + water +)	Level 2 (partial: biogas + compost only)
Area footprint	~44,342 m ²	~60,000–90,000 m ²
HVNRs sales	~€10,000,000	~€1,500,000
ROI ⁴²	14%	n/a

⁴² ROI might be similar but higher grants as mentioned will divert the additional added value.

Part 4: Exploitation Strategy & Commercialization

4.1 Overall strategy

We address the SYMSITES model (“mother ship”) and the specific KERs as individuals’ achievements, to be synchronized and simultaneously developed.

The main goal is to demonstrate a full SYMSITES model application in TRL 8-9, in about 5-10 years' time range, with a private and public partnership. This strategic achievement will enable commercialization and entering multiple markets, in and outside the EU. Our main unique value proposition is to retrofit wastewater facilities in semi-urban regions, in capacities of 5,000-25,000 M³/day wastewater. This will enable the Fit-for-55 & UWWTD fully compliance, where also providing additional income, jobs and material resilience to adopters. To reach this goal, we suggest acting simultaneously on both channels:

1. Specific KERs roadmaps, as was achieved by the partners' input, and with the Horizon Results Booster support.
2. The SYMSITES entity progresses to engage with stakeholders, early investors, investors bodies both private and public and industry design strategic partners.

This will enable the following route:

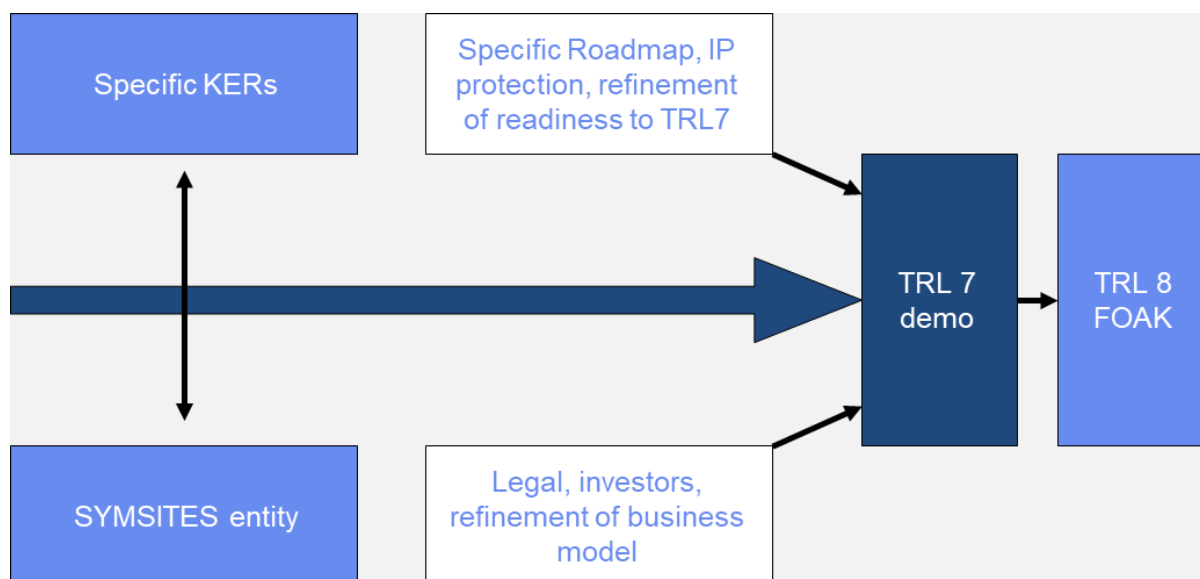


Figure 18: KERs relationship illustration

Figure 18 aligns our pro strategy, to work on 2 channels, both for specific KERs development and for the overall progress for SYMSITES combined achievement.

The partners will benefit from 2 channels of their contribution:

1. Licensing and exploitation of their achievements
2. Shared entity equity in the holistic product.

The KERs roadmap, that was advised and supported by the Booster service, is shown in table 44. Each KER holder has fulfilled its targets and suggestions for next steps, for alignment and preparing these achievements for next steps. The overall roadmaps filled with the Partners are attached in Annex C.

Table 44: KERs roadmap summary

KER	Title	Action	Revenue streams
KER 1.1	Lab-scale optimisation of the AnMBR plant to produce CH ₄ from WW and BW	To advance to TRL 8/9, the consortium will optimize lab-scale processes (pre-treatment, membrane fouling mitigation), validate pilot-scale systems (1-5 M ³ /day) across European sites, and scale up to semi-industrial (50-100 M ³ /day), while securing IP, licensing, and targeting early adopters with sludge reduction and energy autonomy benefits.	Licensing, Joint Ventures, Consultancy, Equipment Sales
KER 1.2	Lab-scale optimisation of an advanced co-treatment system of WW and BW to produce H ₂ (ANAEROBIC Fermentation)	Scale up to a 1,000 to 5,000 L demo reactor, secure IP protection (patents), finalise business models (licensing/B2B), and engage early adopters (waste operators, hydrogen buyers). Target TRL 8/9 in 2to3 years via AI-optimised continuous operation, regulatory approvals, and commercial pilot deployment.	Licensing the CSTR-AnMBR system, microbial consortia, or process know-how to waste treatment plants or energy firms.
KER 1.3	Lab-scale optimisation of an advanced co-treatment system of WW and BW to upgrade biogas	Transition to a pilot-scale AnTBR (Anaerobic trickle bed reactor) (500-1,000 L) to refine operational parameters (e.g., H ₂ /CO ₂ ratios, VFA control) and enhance CH ₄ yield using AI-driven monitoring. File patents for the integrated AnMBR-TBR system and microbial consortia, while finalising a business model (biogas plant upgrades/licensing). Secure biomethane certification and collaborate with wastewater plants/AD operators for demo trials. Target early adopters (biogas producers, utilities) with a TRL 8-9 system within 2-3 years, focusing on stability and cost-efficiency.	Licensing the AnTBR system, retrofit for WWTP, Sale of CH ₄ , Carbon credits
KER 2.1	Lab Scale development of C-dots coated membrane with	Develop scalable synthesis protocols for biowaste-derived C-dots and integrate them into membrane coating processes via ultrasonic (US) deposition. Validate antibacterial and antifouling performance in relevant wastewater pilot environments (e.g.,	Licensing of coating tech, membrane manufacturing partnerships, commercialisation via OEMs.

KER	Title	Action	Revenue streams
	antifouling properties	textile, olive oil sectors). Collaborate with early adopter MBR membrane manufacturers for co-development and field-scale trials. Involvement of membrane manufacturers (e.g. Alfa Laval)	
KER 2.2	Lab Scale development of MeO-coated membrane with antifouling properties	Scale up US-assisted CuO coating on polymeric membranes and assess durability in real wastewater conditions. Target applications in municipal and industrial treatment facilities with high biofouling risk. Engage membrane OEMs and component suppliers for pilot testing and early adoption. Involvement of membrane manufacturers (e.g. Alfa Laval)	Technology licensing, OEM co-development, and commercialisation via component sales.
KER 2.3	Lab Scale development of Magnetic membrane vibration process to produce membranes with antifouling properties.	Develop industrial-scale MMV modules integrating patterned membranes and synchronised magnetic drive systems. Demonstrate reduced fouling and energy efficiency gains in pilot-scale MBR plants (30+ membrane sheets). Partner with early adopters in water-intensive industries (e.g., food, pharma) for full-scale validation. Demonstrate reduction in maintenance cost and frequency, demonstrate higher operation efficiency in water filtration due to keeping membranes in optimal operating condition. Involve and validate with membrane manufacturers and with system integrators	MMV system licensing, custom manufacturing, integration services. Generate spin off company for MMV manufacturing
KER 3	New low costs char-based adsorption materials for tertiary treatments	Scale production of low-cost biochar from local waste streams tailored for tertiary treatment applications. Conduct pilot trials in tertiary polishing stages of wastewater treatment plants (WWTPs). Engage with municipalities and SMEs needing decentralised and low-cost nutrient polishing solutions. Involve WW treatment plants manufacturers.	Material supply, licensing to local manufacturers, and commercialisation via water tech integrators.

KER	Title	Action	Revenue streams
KER 4	Optimisation of the PMR (Protonic membrane reactors) Technology	Scale the production of 25 cm ² planar protonic cells to enable compact, modular PMR units for decentralised hydrogen production via steam methane reforming. Leverage the spatial and integration advantages of planar over tubular geometry to develop pilot-scale stacks for urban and industrial energy hubs. Engage early adopters in the distributed hydrogen sector and micro-refinery applications for real-world validation of modular PMR stacks. Validate with H ₂ gas producers	Licensing of planar PMR design/IP, manufacturing of cell stacks, commercialisation through system integrators and clean H ₂ producers.
KER 5	Optimisation of polyhydroxy alkenoates (PHAs) production	Scale up the PHA production process using robust mixed microbial cultures (MMC) adapted to real, variable effluents in both batch and fed-batch modes. Validate the system under non-sterile, nutrient-limited conditions with optimised C/N ratios, demonstrating high PHAs yield (up to 49%) and stable biomass accumulation. Target early adopters in sustainable packaging, agriculture, and circular bioplastics sectors seeking low-cost, waste-derived biopolymers.	Licensing of the MMC process IP, technology transfer to PHA producers, and internal use in symbiotic eco-industrial sites.
KER 6	Fertilizer production (NH ₄) ₂ SO ₄ , from nutrient recovery	Develop an integrated nutrient recovery system combining membrane contactors and RO/NF to recover ammonium and purify water from AnMBR permeates. Optimise the process using in-situ sulfuric acid (from biogas desulfurization) to adjust pH and concentrate ammonium into usable (NH ₄) ₂ SO ₄ solutions. Target decentralised treatment plants and eco-industrial parks focused on resource recovery from wastewater and sludge streams. Assess the economy of scale in fossil sources substitution strategy: identify locations for suitable and convenient installation	Sale/ licensing of Hollow fibre membrane modules/desulfurization column, fertiliser-grade concentrate production, and commercialisation via agro-cooperatives.

KER	Title	Action	Revenue streams
KER 7	Development of nano-enabled antimicrobial composite (CHAR) for water-absorbent columns	Scale up the production of biochar-lignin nanocomposites (AgPheLIG/cork), integrating adsorption and antimicrobial functions for decentralised water reuse. Deploy sustainable tertiary filtration units requiring no external energy or chemicals, ideal for low-resource and decentralised applications. Engage early adopters in off-grid sanitation systems, small WWTPs, and humanitarian infrastructure seeking green disinfection solutions.	Filter material supply, licensing to column manufacturers, NGO/internal deployment for water reuse.
KER 8	Upgrading of pyrolytic liquids to platform molecules	Scale up the selective extraction of benzoic acid and other platform molecules from pyrolysis oils using recyclable solvents like DME. Demonstrate the high extraction efficiency (75%) and purity (>88%) with 90% solvent recovery under phase separation and crystallisation protocols. Target chemical manufacturers and bio-refineries aiming to valorise pyrolysis side-streams into high-value intermediates.	Licensing of the solvent-extraction system, technology transfer to bio-refiners, and commercialisation of extracted compounds.
KER 9	SDSS (Social Decision Support System)	Scale the k-SDSS from pilot to regional use by engaging municipalities and regional authorities seeking socially inclusive I-US planning. Promote adoption through policy-driven pilot projects and regional circular economy initiatives. Integrate k-SDSS with territorial planning platforms to support participatory decision-making.	Licensing to public authorities and urban planners; service contracts for implementation and training.
KER 10	Design and Development of the IIoT management platform (IIoTMP)	Advance the IIoTMP from prototype to commercial deployment in pilot EcoSites with modular upgrades for industrial clients. Collaborate with early adopters in the smart water and waste treatment sectors to demonstrate value in real-time monitoring. Package as a SaaS tool integrated with predictive analytics to attract infrastructure operators.	SaaS licensing, consulting services, and platform customisation for industrial partners.

KER	Title	Action	Revenue streams
KER 11	Design and development of ITRMP	Bundle ITRMP with IloTMP and k-SDSS for a full digital twin suite for EcoSite management. Target regional authorities and industrial clusters for piloting data-driven I-US planning and monitoring. Enable modular deployment for replication across EU regions.	Platform subscriptions, public procurement, and integration service contracts.
KER 13	Life cycle cost assessment and life cycle assessment of the EcoSites	Leverage LCA-LCC-SLCA results to develop benchmark databases for Industrial Urban symbiotic processes. Collaborate with certification bodies and sustainability consultants to embed results in industrial best practices. Use results to advise on investment and policy decisions at the regional level.	Consulting services, sale of LCA-LCC-SLCA datasets, and integration into certification services. Development of ecosites sustainability simulation tools to find optimal configurations, supporting assessment and dedicated business and sustainability plans development. Development of tools for self-assessment and monitoring of sustainability performance,
KER 14.1	Social Spin-off	Use findings to establish replicable social engagement models for new I-US initiatives in other EU regions. Collaborate with social innovation incubators and NGOs to co-create community-aligned I-US models. Enable early testing in cities with high circular economy ambitions.	Consultancy, partnerships with social innovation hubs, and public funding for social replication.
KER 14.2	Training Materials	Convert training materials into a multilingual digital course targeting municipalities, SMEs, and industrial parks. Partner with universities and vocational institutions for certification and outreach. Pilot use in Horizon Europe and LIFE projects for capacity building.	E-learning licenses, workshops, and EU training contracts. Disseminate the culture of UI symbiosis
KER 14.3	Replication Package	Package the replication toolkit as a self-service portal for companies and regions seeking to replicate	Paid replication support services, online toolkit subscription, and

KER	Title	Action	Revenue streams
		SYMSITES. Offer guided workshops and virtual tours as part of a consulting package. Promote early adoption through European networks like ERRIN, ACR+, and EIT Circular Economy.	training modules. Also based on tools for system virtualisation and simulation
KER 15	Virtual I-US game - trials and conclusions	Gamify the I-US concept to educate local authorities, students, and SMEs about symbiosis scenarios. Deploy the game in EU-funded capacity-building programs and digital twin demonstrations. Refine the simulation engine to offer customised versions per region or sector.	Licensing to educational institutions and municipalities, EU public outreach contracts. Merge the agent-based systems with ecosite virtualisation tools to leverage simulation capabilities and decision support tools

Critical mass with multiple SYMSITES in a region:

From analysis of the yield's assumptions, revenue per HVNRs and overall potential, we see a big advantage in creating "clusters" of several SYMSITES MaRREEF's in the same region. These can optimize the I-US model in several aspects, such as: Hydrogen utilization, redundancy and technical support, higher management qualities, optimization of regional installations, reaching market demand in low-carbon commodities such as PHA and fertilizers, and more. This can be optimized with our ITRMP platform.

Regional Facilitator:

As mentioned repeatedly in former IS or I-US projects, and also with in our discussions with ECOP project⁴³ it is crucial to have "hands-on" facilitation management that ensures agreements and implementation. Therefore, SYMSITES projects should place a local regional facilitator for each cluster of SYMSITES MaRREEF locations, to ensure this implementation. The ITRMP will be monitored and used both from the users' perspectives for daily operation and tracking, but also from System management of SYMSITES operation

4.2 IP Strategy Suggested

IP Data was analyzed, both in the IP databases, and by the consortium agreement.

IP service of Horizon Booster held one meeting with 20 of the consortium members, and the 2nd meeting will be held in May 2026.

Overall, there is one direct patent (of KUL), and 2 relevant patents (of BIU, GREENE). However, as was explained in the 1st meeting, the IP strategy and assets can hold various channels such as: Trademark, design, copyrights and more. Therefore, the consortium will choose in the end of the project its next steps. As recommended, we suggest holding 2 vectors:

1. Specific IPR as elaborated in the KER analysis.
2. Joint "soft IP" or LOI (on- patent) , as a integrating vehicle that can support the mutual work and have some benefits.

4.3 Regional Symbiosis mechanism suggested

A few mechanisms that can help to stabilize and de-risk the I-US are:

1. **Offtake agreement** – signing a contract, MOU or other of commitment to purchase a specific number of commodities or energy before the production, or even the construction, begins.
2. **Long-term agreements** - a minimum of 5-year agreement and even 10-25 years depending on the purchase, is vital for stability and trust building.
3. **Subsidies** – governments, or regional entities, can support greatly the viability of the symbiosis route, by subsidizing a portion of the investment and/or the operation. Recycled water is of course a main example, providing large incentives to farmers to use the water. But also, other materials can be subsidized in the transition to low carbon economy.
4. **In-situ usage:** in situ self-usage of resources can save a major factor of costs which is logistics, transportation, storage, supply-demand synchronization, and more factors. Energy, water and materials can be used locally for the infrastructure.
5. **Local Symbiosis** – another version can be a short distance symbiosis. This is the first and original version of symbiosis (also in nature). Partnering with neighbors and community industries and urban leaders is a key factor. This model is favored also by the trust and long-time mutual respect that can lead to these agreements.
6. **Pre-design and co-design** – defining the exact quality and features of the end-products together with the recipient, leads to optimized results.
7. **Shared investment** – it is a crucial factor as noted. Shared investment can be from all sides – from several plants with the same problem, from the government with the local authority, and for several end-product consumers – like bioplastics, that can benefit together from these materials. This co-investment model, especially in the industrial sector, takes courage and change of perception for collaboration.
8. **Carbon credits** - carbon reduction (or CDR) mechanisms are re-emerging as an important factor in the green finance transition. Where the market and prices are

still in fluctuation, the overall process has reembarked and will support the coming years ventures, both in CAPEX and OPEX balance.

4.4 SYMSITES Commercialization

The product- SYMSITES' MaREEF Ecosystem is a retrofit-for-55 turnkey solution, for underutilized WWTP's all over Europe. It's the 3rd Generation evolution, from WTP to WRRF To MaREEF - Industrial-Urban Symbiosis (I-US) facility, that integrates hard-to-abate streams of high COD WW, Biowaste and NRW into Upgraded products (HVNRS). It combines key pillars such as AnMBR, AC, and Pyrolysis with Beyond State-of-the-art improvements, and a regional platform to analyze the optimal design.

Our product targets both Municipal and Industrial entities, that can benefit from both sides - better and optimized treatment of waste, while

The Challenge: The "Fit for 55" And Resilience while generating positive revenue

New regulations (UWWTD Recast, Fit-for-55) demand that Wastewater Treatment Plants (WWTPs) become energy-neutral and dramatically reduce emissions. Traditional retrofits are prohibitively expensive and offer no return on investment, leaving operators with stranded assets and rising costs.

The "product" of our consortium -SYMSITES MaREEF Ecosystem is recommended as a combined technical proven abilities, digital regional AI platform, regional symbiosis skills, and optionally also proprietary hardware for the HVNRs production and system optimization. These will be sold as a pack -of single payment for installation and yearly symbiosis payments for transactions and EU Carbon credits (ETS).

The Business Model: "Asset Light" Licensing

MaREEF operates as a Technology Licensor & System Developer. We align our success with the project's performance via four distinct revenue streams:

1. **Development Fee (3% of CAPEX):** Upfront cash flow for Feasibility & Design.
2. **Product Revenue Share (10% of HVNRS sales):** facilitation fee (ongoing) on sales of Green Hydrogen, Bioplastics, carbon credits etc.

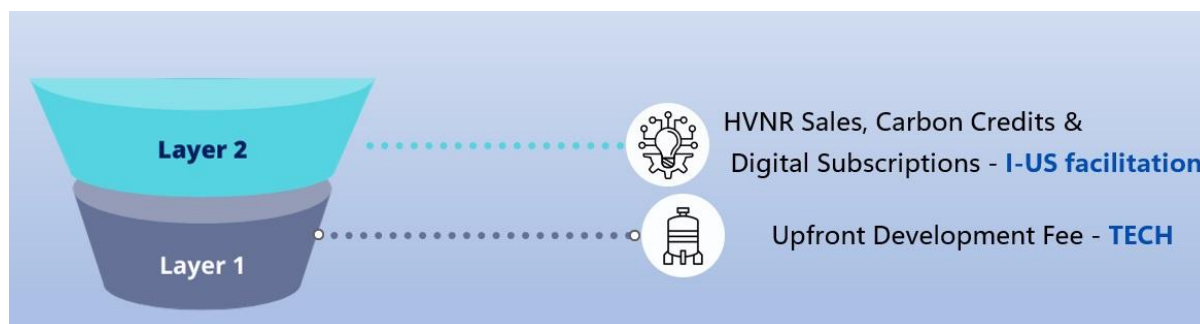


Figure 19 Bornholm example for two layers

Simulation based on SYMSITES Bornholm Project Data



Figure 20 Two layers of proposed monetized service by SYMSITES

Scalability & Vision

With **~10,000 municipalities** in Europe (15k-120k inhabitants) facing the exact same regulatory hurdles, SYMSITES is positioned to capture a massive market.

- **Risk Mitigation:** No heavy machinery ownership.
- **Recurring Revenue:** Long-term contracts tied to essential utility services.
- **Impact:** Real, measurable decarbonization for the water sector.

Urban Sector

We address the markets from the "black box" perspective, viewing the system as a whole. Most focus goes to the integrative product ("KER 12") however specific markets can be derived and are elaborated through the market analysis. Overall, as mentioned in the introduction, waste and wastewater treatment is a huge market, representing a total of nearly **1 Trillion \$** market. Moreover, as mentioned – still most of the WW worldwide is not treated!

Here is a brief review of the main potential markets:

Table 45: Municipal Markets Overview

Population Range	Estimated Municipalities (EU)	Community Type	Key Industries (Including Farms)
0–5,000	~90,000 (75% of EU municipalities)	Rural villages, hamlets	Agriculture (farms, dairy, vineyards), small agri-businesses (local breweries, mills), crafts, family-run workshops.
5,001–15,000	~20,000 (17%)	Small towns	Food processing (slaughterhouses, canneries), textiles, light

Population Range	Estimated Municipalities (EU)	Community Type	Key Industries (Including Farms)
			manufacturing, local tourism, small-scale chemical plants.
15,001–25,000	~5,000 (4%)	Medium towns	Automotive suppliers, medium-sized food processors, paper mills, tanneries, wastewater-intensive SMEs.
25,001–50,000	~3,000 (2.5%)	Large towns/small cities	Pharmaceuticals, chemical production, advanced manufacturing, regional hospitals, and universities.
50,001–120,000	~1,500 (1%)	Medium-sized cities	Tech parks, heavy machinery, large breweries, industrial hubs, centralized healthcare facilities.
Over 120,000	~500 (0.5%)	Large cities	Diverse industries (tech, finance, logistics), large hospitals, and research centers, WTPs often already advanced.

We targeted towns and small cities as our main urban markets. (15,000-120,000 inhabitants) – this, for the combination of several factors:

1. Balanced ratio of high COD materials with domestic low COD influences.
2. Proximity to agro-industries and food industries that are rich in COD
3. Small-medium facilities that are easier to transform or be upgraded.

Here is a brief overview of the population by settlement type in Europe:

Approximations derived from Eurostat's LAU2 (Local Administrative Units) classifications and typical industrial distributions.

If we focus on 15,000-120,000 Inhabitants market- we reach a total of approx. 10,000 WWTP's in Europe!

WWTP type disperse

The vast majority of WWTP's, especially in our target markets, are CAS type. (Conventional Activated Sludge). However, the larger cities already use and prefer MBR technology due to better COD removal and reaching higher standards of health and water safety. If we check Austria, Spain, Greece and Denmark – we estimate that only the centralized largest 2% of WWTPs have MBR technologies or similar, whereas the other 98% are CAS, often with aging infrastructure.

Industrial Waste Treatment

The global industrial wastewater treatment market size was valued at USD 20.01 billion in 2025 and is projected to grow from USD 21.05 billion in 2026 to USD 32.22 billion by 2034 at a CAGR of 5.50% during the forecast period.⁴⁴ Industrial wastewater often contains a wide range of pollutants, such as heavy metals, toxic chemicals, oils, organic matter, and suspended solids, depending on the type of industry, such as chemical manufacturing, textiles, pharmaceuticals, food processing, or mining. It should be noted that higher EPR schemes, especially for textile, cosmetics and pharma – will be in place during the coming years, therefore the need for higher compliance rates will be intensified. It might be that some pollutants will still need in-situ treatment for the special hazards' removal. However, high COD and nutrients can be much easier to treat in the local SYMSITES MaREEF' Site.

From our review of the Ecosites' regions – it seems that the industries already are using the WWTP services – the Meat, olive, and textile – but in many other regions it is not the case, yet.

Technology Providers

Main different kinds of markets are the technology providers, EPC companies, and consultation offices.

Overall, concerning the core technology of SYMSITES, AnMBR - projections show that the AnMBR is now standing on approx. 1-1.4 Bn \$ market and it is growing at a CAGR of approximately 8.5% (although other sources cite a CAGR of 12% to 15%).

Among the leading companies that supply and/or operate AnMBR systems, or other large numbers of WWTP's services, we can point:

1. **Kubota Corporation (Japan):** Kubota is a major manufacturer of membrane bioreactors, including anaerobic systems. They provide a range of AnMBR solutions for wastewater treatment across various industries.
2. **Pentair (USA):** Pentair offers a variety of water and wastewater treatment technologies, including anaerobic membrane bioreactor systems. Their AnMBR systems are designed for energy efficiency and biogas production.
3. **GE Water & Process Technologies (USA): Now part of SUEZ,** GE has developed advanced membrane technologies for anaerobic digestion processes. They focus on innovative solutions **to reduce energy consumption and optimize performance.**
4. **SUEZ (France):** SUEZ offers a range of water treatment solutions, including anaerobic MBR systems. They provide technologies for energy-efficient wastewater treatment, focusing on biogas production and resource recovery.
5. **Evoqua Water Technologies (USA):** Evoqua provides a range of water treatment solutions, including AnMBR systems, particularly for industrial wastewater applications.
6. **Toray Industries, Inc. (Japan):** Toray manufactures membrane bioreactor systems, including anaerobic variants, and supplies these technologies globally.

⁴⁴ <https://www.fortunebusinessinsights.com/industry-reports/industrial-wastewater-treatment-market-101456>

They focus on high-performance membranes and systems for sustainable wastewater management.

7. **Veolia Water Technologies (France):** Veolia is a global leader in water and wastewater treatment, offering anaerobic MBR systems for municipal and industrial applications. Their solutions often include energy recovery and nutrient recycling.
8. **X-Flow (Netherlands):** Part of **Pentair** (see above), X-Flow specializes in membrane technologies, including anaerobic membrane bioreactors. They provide systems for a range of industrial wastewater applications, focusing on high separation efficiency and reliability.
9. **Biothane (USA/Netherlands):** A subsidiary of **Veolia**, Biothane specializes in anaerobic technologies, including anaerobic membrane bioreactors. They are known for their expertise in designing systems for high-strength industrial wastewater.
10. **Aqua-Aerobic Systems, Inc. (USA):** This company provides various wastewater treatment solutions, including AnMBR systems. They focus on low-energy processes and high-efficiency membranes.

4.5 HVNR Procurement

We have analyzed the various HVNRs market and trends to measure and define the sun-markets and how to operate optimally in those environments.

Overall, these findings support the strategy of SYMSITES and show a steady growth on all HVNRs and, of course, the water sector. Of course, the yields are different on magnitudes, therefore as investigated in Section 3, a multiplying vector of $qty \cdot price$ is needed to set the realistic strategy. However, as we suggest, some adjustments can be made to increase or decrease certain products.

Hydrogen

Europe treats renewable hydrogen as a core decarbonization tool for industry and heavy transport, targeting 10 Mt of domestic renewable hydrogen production and 10 Mt of imports by 2030 under Repower EU.⁴⁵ Germany has allocated €7 billion to support green hydrogen production, infrastructure and industrial use, as part of its national hydrogen strategy⁴⁶. Analyses show that near-term economics favor locally produced hydrogen directly connected to industrial off-takers, rather than long-distance import and reconversion. Europe is nonetheless planning a large hydrogen network, with more than 50,000 km of pipelines proposed or in development, including major build-outs in Germany and Spain⁴⁷. EU-wide modelling places offshore green hydrogen production costs from about 90 €/MWh in favorable North Sea sites to more than 300 €/MWh in higher-cost Mediterranean locations. In transport,

⁴⁵https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en#:~:text=The%20priority%20for%20the%20EU,10%20million%20tonnes%20by%202030.

⁴⁶<https://www.bundesrechnungshof.de/SharedDocs/Pressemitteilungen/DE/2025/wasserstoffstrategie.html?nn=23102>

⁴⁷[Countries with longest hydrogen transmission pipeline network under development in Europe 2025](#)

technical overviews for heavy-duty trucks report typical fuel consumption around 7–8 kg H₂ per 100 km at 350 bar storage, depending on duty cycle and loading⁴⁸. For primary steelmaking with hydrogen-based direct reduction, sector studies indicate a hydrogen demand of roughly 50–60 kg H₂ per ton of crude steel⁴⁹.

Ammonium Sulfate

Ammonium sulfate is an inorganic salt used for a variety of purposes, including as a nitrogen and sulfur fertilizer and is especially effective on alkaline soils, primarily found in countries such as Spain, southern France, Italy, Croatia, and Greece⁵⁰. It is used in three main forms; powdered, as a fast-dissolving solution for fertigation and top dressing on established crops, liquid form for precision irrigation and granulated for pre-seeding or tree crop use. In Europe typical field use ranges from 150–900 kg/ha for cereals and industrial crops, and 400–900 kg/ha for fruit trees and vines⁵¹. In 2023 the World Integrated Trade Solution reported that the EU imported over 767 million kg of ammonium sulfate for an average import price of roughly \$321 per ton⁵². As of 2025, the price has dropped to roughly €245 per ton.

Beyond agriculture it is used as a controlled feed ingredient in livestock, a PH adjusting agent in chemical and manufacturing industries, and as a food additive. It is forecast that the worldwide market value of this product will increase to 4.4 billion USD by 2027⁵³. The low-carbon ammonium sulfate market is developing as part of the global shift toward cleaner ammonia production. By replacing fossil-based hydrogen with renewable hydrogen or incorporating carbon capture technologies, producers can significantly cut emissions while maintaining identical product performance. This decarbonized variant is gaining value through its compliance with emerging sustainability frameworks and its potential to reduce supply-chain emissions in fertilizer and chemical applications. Although production volumes remain low due to the high cost of renewable energy and CCS, global capacity is expected to expand rapidly as investment and policy support grow, with demand projected to reach about 20 million metric tons per year by 2030⁵⁴.

Biomethane

The global Biomethane market is valued at around 15.5 billion USD in 2025 and is expected to reach 25.2 billion USD by 2032. In 2023 Biomethane production in the European Union avoided the need to import around 15 thousand barrels per day (kb/d) of oil and 2 **billion cubic meters** of natural gas,⁵⁵ highlighting its strategic importance for the EU energy security and circular economy goals. In 2023, combined biogas and biomethane production in Europe reached 22 billion cubic meters (234 TWh), equivalent to 7% of EU natural gas consumption, with biomethane alone accounting for 4.9 billion cubic meters and an installed capacity of 6.4

⁴⁸ [Fuel cell electric tractor-trailers: Technology overview and fuel economy](#)

⁴⁹ [Hydrogen-Based Reduction Technologies in Low-Carbon Sustainable Ironmaking and Steelmaking](#)

⁵⁰ [Patterns and thresholds for soil pH across Europe in relation to soil health and degradation](#)

⁵¹ [Deliso](#)

⁵² [WITS](#)

⁵³ [Statista](#)

⁵⁴ [The Market for Low-Carbon-Intensity Ammonia](#)

⁵⁵ IEA (2025), *Outlook for Biogas and Biomethane*, IEA, Paris <https://www.iea.org/reports/outlook-for-biogas-and-biomethane>

billion cubic meters per year⁵⁶. JRC projections for bioenergy technologies foresee about 7% CAPEX and 15% OPEX reductions for biogas-based biomethane plants by 2030. In combination with recent price dynamics, these analyses suggest that upgrading biogas to biomethane for grid injection or fuel use is often more cost-effective than using raw biogas solely for electricity generation⁵⁷.

Bioplastic (Focus on PHA)

As innovation in sustainability and waste management evolves, polyhydroxyalkanoates (PHA) are emerging as a dynamic solution in the market of biodegradable plastics. The European PHA market, projected to increase from USD 21.76 million in 2024 to USD 57.77 million by 2033, is driven by regulatory pressures and technological advancements that allow PHA to serve across multiple industries⁵⁸. PHBHV (Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)) offers superior flexibility, toughness, and processability compared to other biodegradable plastics, due to the inclusion of 3-hydroxyvalerate, which reduces brittleness and enhances impact resistance⁵⁹. PHBHV, with its superior properties, is a premium product within this market, despite challenges posed by production costs and infrastructure gaps. Current prices for PHBHV typically range from €5.00 to €8.00 per kilogram, although large-scale production from organic and waste feedstocks may reduce costs to €2.00–€4.00/kg, making it competitive with fossil-based alternatives. The PHBHV market will likely grow as initiatives such as the EU Single-Use Plastics Directive promote biodegradable plastics. In parallel, Germany is emerging as a leader in PHBHV production. Additional European actors such as France, Italy, Spain and the UK have followed and are projecting growing demand for PHBHV⁶⁰.

⁵⁶ [EBPA Statistical Report 2024](#)

⁵⁷ [Bioenergy in the European Union](#)

⁵⁸ [European PHA Market Growth: Key Trends, Challenges, and Opportunities](#)

⁵⁹ [Polyhydroxyalkanoates \(PHAs\): Key Challenges in production and sustainable strategies for cost reduction within a circular economy framework](#)

⁶⁰ [Europe Polyhydroxyalkanoate \(PHA\) Market](#)

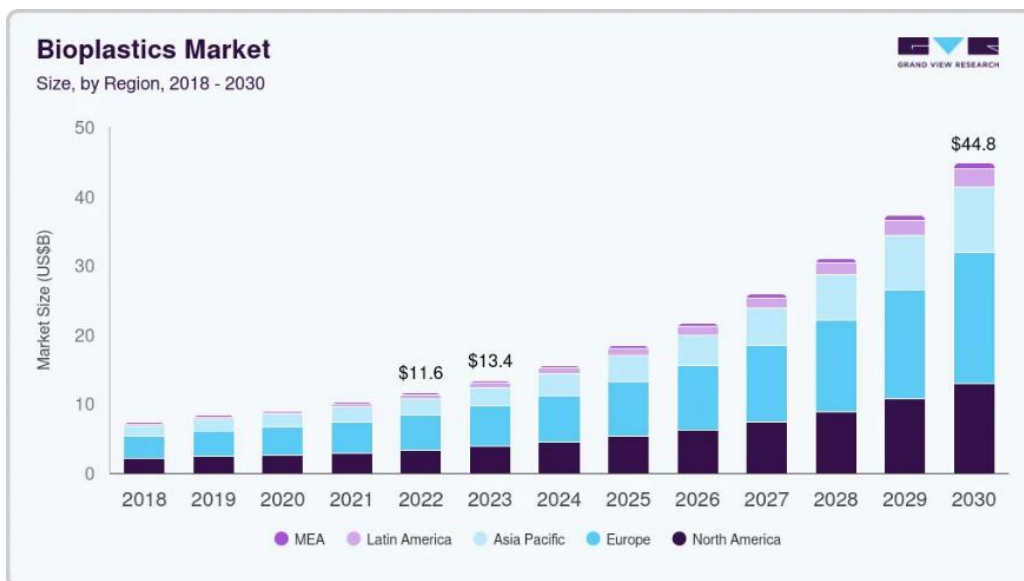


Figure 21: Bioplastics market projection⁶¹

Activated Carbon for Water Treatment

Activated carbon can be produced from biomass residues, sludge-derived char, or other waste lignocellulosic materials, making it particularly suitable for circular resource recovery models. It functions as a rigid sponge capable of capturing a wide range of organic and inorganic contaminants from water and industrial effluents. Due to its renderability, relatively low operating cost, and compatibility with existing treatment infrastructure, activated carbon is one of the most used materials for drinking water treatment, wastewater polishing, and site remediation. In comparison, alternatives such as reverse osmosis are significantly more energy-intensive and require PFOS elimination from the reject stream, resulting in very high operating expenses. While ion-exchange systems have high capacity, they often involve higher capital costs and limited regeneration potential. These positions activated carbon as a cost-effective and scalable solution for European water and industrial treatment needs within symbiotic resource networks. The European activated carbon market for water treatment is expected to grow from approximately USD 371.4 million in 2024 to around USD 825 million by 2035⁶².

Benzoic & Acetic Acid

In the EU, benzoic acid is primarily an intermediate industrial chemical (platform molecules) for producing benzoate plasticizers and alkyd resins used in paints and adhesives. It is also widely used as a key preservative in food, beverages, cosmetics, and pharmaceuticals. As of Q3 of 2024, Benzoic acid was priced at €1,381 per metric ton⁶³. Acetic acid is a fundamental bulk chemical, with its dominant use as a raw material and solvent in the production of

⁶¹ [Grand View Market Research](#)

⁶² [Europe Activated Carbon for Water Treatment Research Report 2025-2035](#)

⁶³ [Benzoic Acid Exp price](#)

polymers, which are vital for manufacturing plastics and synthetic fibers. Its secondary uses include pharmaceuticals and the food industry⁶⁴. In recent years EU legislation has been supporting the use of these acids as they convert local organic waste into high-value chemicals, reducing reliance on petrochemical imports and lowering carbon intensity in regional supply chains. Recent reports indicate that the average price in 2025 is €502.00 per metric ton⁶⁵.

Water

Water is essential for all economies and societies worldwide. Stress on European water resources can trigger cascading effects across the economy. Dry soils lower agricultural productivity, water shortages disrupt manufacturing and raise production costs, and declining river levels reduce hydropower potential, limit electricity generation, and delay transport. An EU Central Bank analysis of 2,500 banks shows that over 34% of their total outstanding loans, roughly €1.3 trillion, are directed toward sectors highly exposed to water scarcity risks. Within these, manufacturing accounts for the largest share, followed by wholesale and retail trade, real estate, construction, and electricity production. Beyond surface water shortages, groundwater depletion, reduced floodplain capacity, and chemical pollution also threaten Europe's water security. Declining water quality has already led to significant reductions in

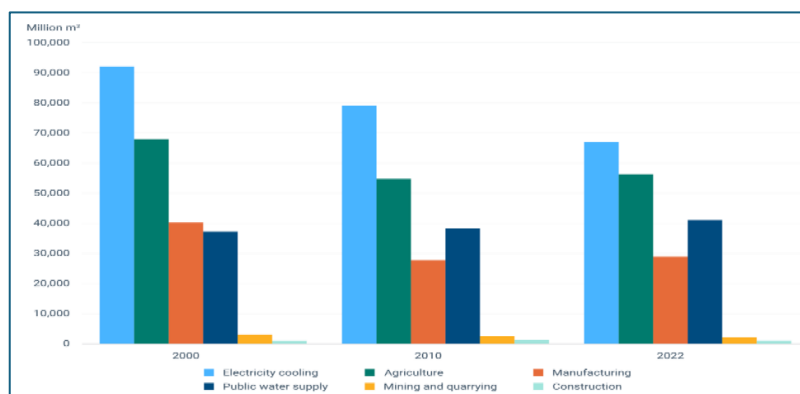


Figure 22: Water abstraction by source and economic sector in Europe

recreation and tourism, causing estimated economic losses exceeding €100 billion annually⁶⁶. This points to an urgent need to accelerate large-scale water reuse deployment in the EU, particularly for high-demand industrial and agricultural applications. Recent assessments indicate that only around 1 billion m³ of treated urban wastewater is currently reused each year, while the technically and economically reusable volume is estimated to be up to six times higher than current utilization levels⁶⁷.

Water scarcity also reflects a shifting pattern in Europe's water sourcing. Between 2000 and 2022, total freshwater abstraction in the EU-27 fell by 19%, from 242,000 to 197,000 million m³ per year. Yet dependence on groundwater increased as its share rose from 20% to 26%, driven by higher demand from public water supply (up 18%) and agriculture (up 17%), particularly in southern Europe. In 2022, groundwater provided 62% of all public water and

⁶⁴ [S&P Global: Chemical Economics Handbook](#)

⁶⁵ [Acetic Acid price trend and forecast](#)

⁶⁶ [The European economy is not drought-proof](#)

⁶⁷ [Member States where water reuse for agricultural irrigation is allowed](#)

33% of agricultural use. As seen in Figure 23, Across all sectors, cooling for electricity generation remained the largest source of abstraction (34%), followed by agriculture (29%), public supply (21%), and manufacturing (15%), while construction and mining each accounted for about 1%⁶⁸ (See figure below). Water prices for irrigation and industry in the EU vary significantly by region, irrigation water can range from approximately €0.05 to €1.50 per cubic meter.

4.6 ECOP Market targeting analysis

Another support for the market analysis was made with the collaboration within ECOP project, and especially with Partner STRANE. A GIS analysis has analyzed the potential replication in this scenario, according to PRTR data available –

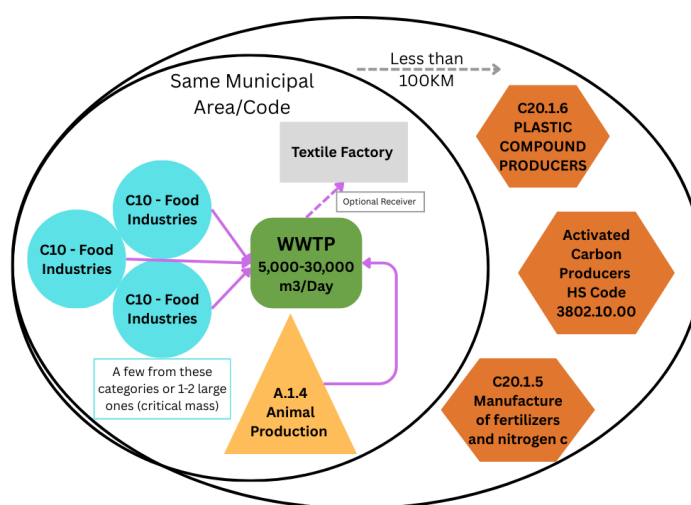


Figure 23: Market targeting analysis (ECOP)

As we see in figure 23, the scenario suggested and collaborated with partner STRANE, was to check the possibilities of regional I-US hubs consist of:

Waste producers

1. Medium sized WWTP
2. Food industry
3. Animal production (livestock)
4. Optional textile

HVNRs receivers (in 100 km perimeter)

1. Plastic compounds
2. Fertilizer production
3. Activated carbon producers

This analysis has yielded an interesting overview of the potential to replicate SYMSITES ecosystem in Europe.

⁶⁸ Water abstraction by source and economic sector in Europe

In the following example we can find a scenario in Romania:

This example shows the proximity of relevant industries (food sector) to a urban WWTP within the perimeter that was set. Also, relevant industries to buy the HVNRs are marked. These scenarios have been quantified by country (where data is available). Overall, 820 (!) potential networks have been detected to create the following basic structure of SYMSITES – reaching at least 2 medium - large producers of food industry, 1 Animal production, medium size WWTP (in 15 km proximity) , and plastic compounder OR fertilizer producer (in 100 km proximity).

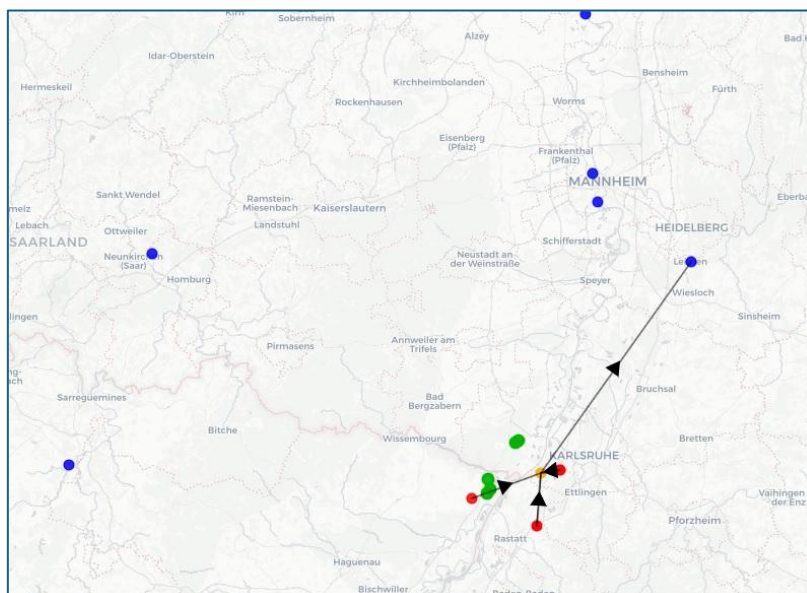


Figure 24: Potential network diagram by GIS analysis

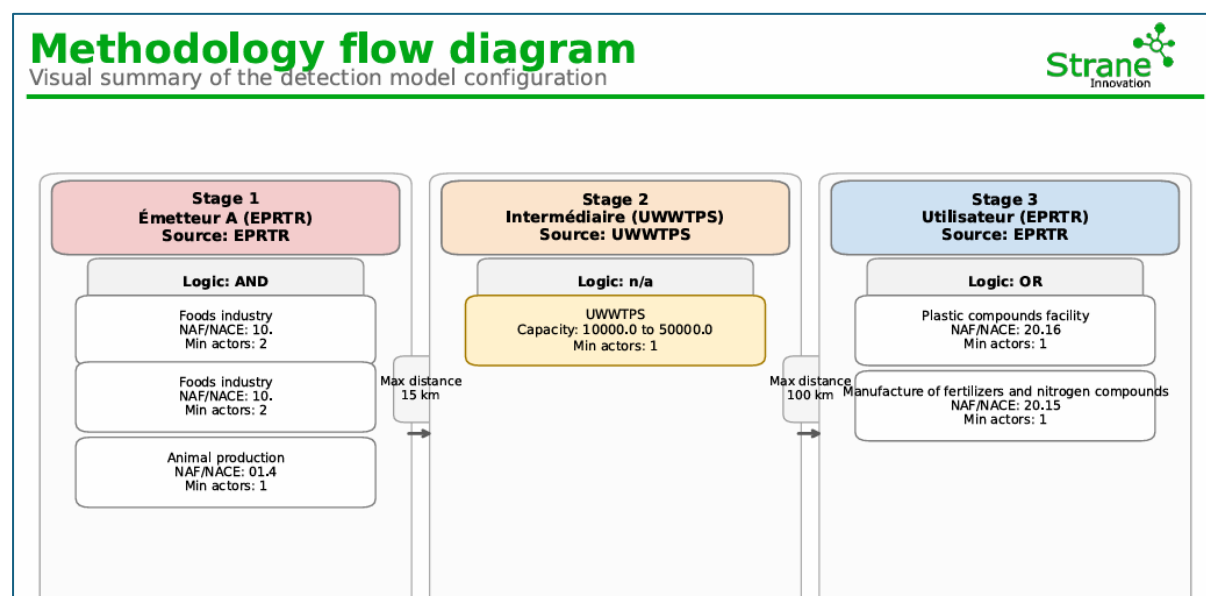


Figure 25: Methodology of GIS analysis

here are some of the "Hot spots" analyzed⁶⁹ :

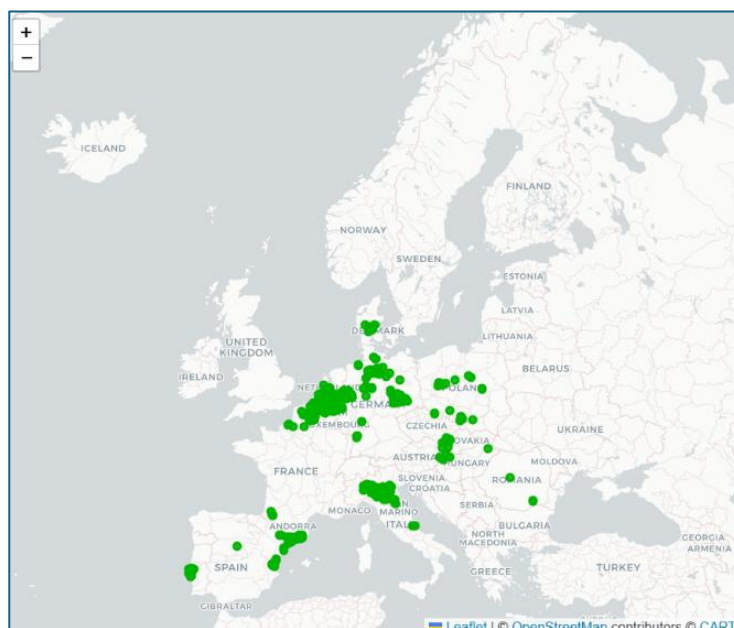


Figure 26: Hot spots analysed by GIS (partial data by PRTR)

4.7 Business strategy

This Business plan go-to-market strategy was designed with the support of Horizon Results Booster Service, Provided by Mr. Julian Manzanas (Cofi solutions) and coordinated by Meta service provider.

SYMSITES will be structured as a **business-oriented spin-off / joint venture** emerging from the Horizon Europe SYMSITES project. The envisioned organization brings together 3–5 leading partners as a steering committee and a broader group of approximately 30–35 shareholders representing the project consortium. The steering committee will be mandated to develop the business opportunity funnel, govern the IP and licensing framework, and lead commercial negotiations and strategic partnerships.

The **mission** of the organization is to turn conventional wastewater treatment plants into profitable Industrial-Urban Symbiosis hubs that simultaneously deliver regulatory compliance, decarbonization and local economic value. Its **vision** is to become the reference European platform for 3rd-generation wastewater facilities, offering a standardized yet configurable retrofit model that can be replicated across medium-sized towns and industrial regions. In the short term, the priority is to formalize the entity, secure initial funding, and complete the first investment-grade business cases. In the medium term, the focus shifts to implementing TRL 7–8 demonstration plants. In the long term, the goal is to establish MaRREEF as a recognized “retrofit-for-55” label deployed across Europe.

The core product is the SYMSITES MaRREEF Ecosystem, a turnkey retrofit pack that upgrades existing wastewater treatment plants into 3rd-generation Industrial-Urban Symbiosis facilities. It is designed for medium-sized municipal and industrial WWTPs that need to meet stricter EU requirements while improving energy performance and resource recovery. MaRREEF is fully aligned with the recast Urban Wastewater Treatment Directive, which raises

⁶⁹ It should be noted that in some countries the data of PRTR was perhaps less developed

standards on nutrient and micropollutant removal and pushes utilities towards energy-neutral, resource-efficient operation.

MaRREE is structured in three layers. The mandatory core is based on AnMBR-enabled co-treatment of municipal wastewater, biowaste and high-COD industrial streams. This layer integrates mass, energy and financial balances to ensure regulatory compliance, energy self-sufficiency and robust sludge management. On top of this, configurable value modules can be added according to local conditions and partner capabilities: nutrient recovery units, bioplastic (PHA) production, pyrolysis for syngas, biochar and activated carbon, water reuse trains for tertiary/quaternary effluent quality, and specific NRW valorization routes. Finally, the digital and decision-support layer provides LCA/LCC analysis, regional planning tools, optimization algorithms and reporting dashboards for both operators and policymakers.

Today, the constituent technologies and modelling tools are at advanced pilot and demonstration stages within SYMSITES EcoSites. The short-term roadmap is to consolidate these results into a validated MaRREEF™ template, document reference designs for representative plant sizes, and complete investment-grade business cases for the first demonstration sites. The medium-term roadmap foresees TRL 7–8 demonstration plants, with the MaRREEF™ pack being “ready for replication” from 2030 onwards. Over time, additional modules (e.g. advanced quaternary treatments, new HVNR routes, digital twins) can be integrated into the ecosystem, ensuring continuous innovation and adaptability.

In summary, MaRREEF™ is not a single piece of equipment but a modular, configurable system product: a repeatable blueprint that can be tailored to local constraints while remaining recognizably “SYMSITES” in its architecture, performance and branding.

Total Addressable Market (TAM): any municipal or industrial wastewater asset where there is a need to move from simple treatment and discharge towards integrated recovery of water, energy and materials.

Serviceable Available Market (SAM) on Europe: The European wastewater treatment and reuse market represents a multi-billion-euro annual opportunity, with steady growth of around 5% per year as utilities and industries upgrade assets to meet new EU requirements and deal with water stress, energy prices and circularity targets. Inside this, we narrow our lens to the advanced reuse and resource-recovery segment (water reuse, energy and nutrient/material recovery in and around WWTPs). This niche already represents several billion euros per year in Europe and is growing at high single- to low double-digit CAGRs, clearly faster than the broader water sector.

Serviceable Obtainable Market (SOM): medium and large WWTPs and associated industrial clusters where a full Industrial-Urban Symbiosis approach is justified economically and politically. In the EU there are more than 20,000 urban WWTPs; a significant minority of them fall into this “priority” category in terms of size, impact and regulatory pressure. Our working assumption for this Business Plan is that, over the next 8–10 years after reaching technology maturity (TRL 9), MaRREEF can be deployed in 50–100 high-impact sites across Europe. Given the expected mix of one-off design/licensing fees and recurring performance-linked revenues per site, this translates into an achievable SOM in the range of €50–200 million per year in revenues at maturity, corresponding to approximately 0.3–1.5% of the advanced reuse and recovery market in Europe.

At the heart of this vision is a compact management nucleus:

- CEO / Managing Director with a clear mandate to drive the go-to-market strategy and navigate public–private ecosystems,

- Chief Scientist to safeguard the technological integrity of MaRREEF and continuously translate SYMSITES research into bankable solutions,
- VP Business Development dedicated to building and converting a pipeline of regions, utilities, industrial partners and investors, and
- Chief Engineer responsible for turning each opportunity into a robust, integrated technical solution that can be delivered at scale.

In the first years, we explicitly envisage a transition phase: many of these functions will be covered part-time by people from partner institutions, under service agreements and secondments. The shared objective is to use this period to identify and consolidate a committed core team, and then gradually move towards dedicated hires as the pipeline grows and recurring revenues start to materialize. Critical gaps—especially in finance, legal/IP and large-scale project delivery—will be filled through targeted recruitment and partnerships with specialized firms.

Finally, we aim to create a decision-making culture that is both focused and enabling. A central board will have the authority to approve deals, manage IP and allocate resources, but delivery will be decentralized to local project consortia with clear autonomy to adapt MaRREEF™ to each context. Standard processes for project selection, risk assessment and partner onboarding will ensure consistency, while leaving enough space for innovation at site level.

In short, the objective of this management structure is to secure a motivated, cross-organizational team that is genuinely invested in the go-to-market journey of MaRREEF™, and to give that team the mandate, tools and governance needed to turn the SYMSITES vision into a portfolio of real, operating projects.

4.8 Main Proposed Actions

- **Recommendation 1:** Establish a Legal & Commercial Entity. Immediately establish a Joint Venture (JV) or Special Purpose Vehicle (SPV) to consolidate all SYMSITES intellectual property, providing a single legal and commercial entity to lead investor engagement and contracting.
- **Recommendation 2:** Secure a Strategic Demonstration Partner. Prioritize securing a partnership with a forward-thinking municipality or industrial cluster to serve as the 'First-of-a-Kind' (FOAK) commercial demonstration site. This is the most critical step to de-risk the technology at scale and validate the compelling financial projections of the Bornholm model.
- **Recommendation 3:** Proceed with Investor Engagement, based on the robust financial model, and the immense market pull from EU regulations. Initiate immediate and targeted engagement with strategic investors and public funding bodies to secure capital for the demonstration and commercial launch phases outlined in the roadmap.



4.9 10 Years roadmap

A clear, phased roadmap has been developed to guide the project from its current stage to full commercial rollout.

- **Phase 1 (2026):** Foundation & Investment. The primary objective is to establish a Joint Venture to own the project's intellectual property, validate the holistic KER 12 model, finalize the business plan, and secure the initial round of investment.
- **Phase 2 (2027-2030):** Demonstration & Scaling. This phase will focus on forming strategic partnerships with regional authorities and industries, launching a TRL 7 demonstration site, and scaling the core technologies to TRL 7-8.
- **Phase 3 (2031-2033):** Commercial Launch. The goal is to launch the First-of-a-Kind (FOAK) commercial plant at TRL 8-9. This includes securing the first licensing, sales, and offtake agreements for HVNRs.
- **Phase 4 (2032-2036):** Regional Rollout. Following the successful launch of the FOAK plant, this phase will focus on executing the first regional implementations and strategically expanding the commercial consortium.

Table 46 : 10 Years SYMSITES exploitation revenues, expenses, cashflow projection (€)

Revenue/ Year	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Total
Funds / Grants	50,000	300,000	2,500,000	2,500,000	2,500,000	2,500,000						10,350,000
Industrial partner	50,000	300,000	1,000,000	1,000,000	1,000,000	1,000,000						4,350,000
VC / Investors				5,000,000		10,000,000						15,000,000
Urban - Industrial clients - Development							3,000,000		3,000,000	6,000,000	9,000,000	21,000,000
Urban - Industrial clients - Recurring Symbiosis								1,000,000	1,500,000	2,500,000	3,500,000	8,500,000
TRL	6	6	7	7	8	8	9	9	9	9	10	N/A
# SYMSITES Commercial Installations	0	0	0	0	0	0	1	0	1	2	3	N/A
Total Revenues	100,000	600,000	3,500,000	8,500,000	3,500,000	13,500,000	3,000,000	1,000,000	4,500,000	8,500,000	12,500,000	59,200,000
Expenses												
IP, legal,decks	50,000	50,000	50,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	
Management	20,000	50,000	200,000	200,000	250,000	300,000	500,000	500,000	500,000	1,000,000	1,000,000	
Marketing	10,000	50,000	100,000	100,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	
Licensing specific KERs							500,000	0	500,000	1,000,000	1,000,000	
TRL 6-8 Operations		200,000	2,500,000	4,500,000	3,000,000	4,500,000						
Total Expenses	80,000	350,000	2,850,000	4,820,000	3,770,000	5,320,000	1,520,000	1,020,000	1,520,000	2,520,000	2,520,000	26,290,000
Annual Balance for SYMSITES consortium	20,000	250,000	650,000	3,680,000	-270,000	8,180,000	1,480,000	-20,000	2,980,000	5,980,000	9,980,000	32,910,000
Accumulated cash flow	20,000	270,000	920,000	4,600,000	4,330,000	12,510,000	13,990,000	13,970,000	16,950,000 €	22,930,000	32,910,000	

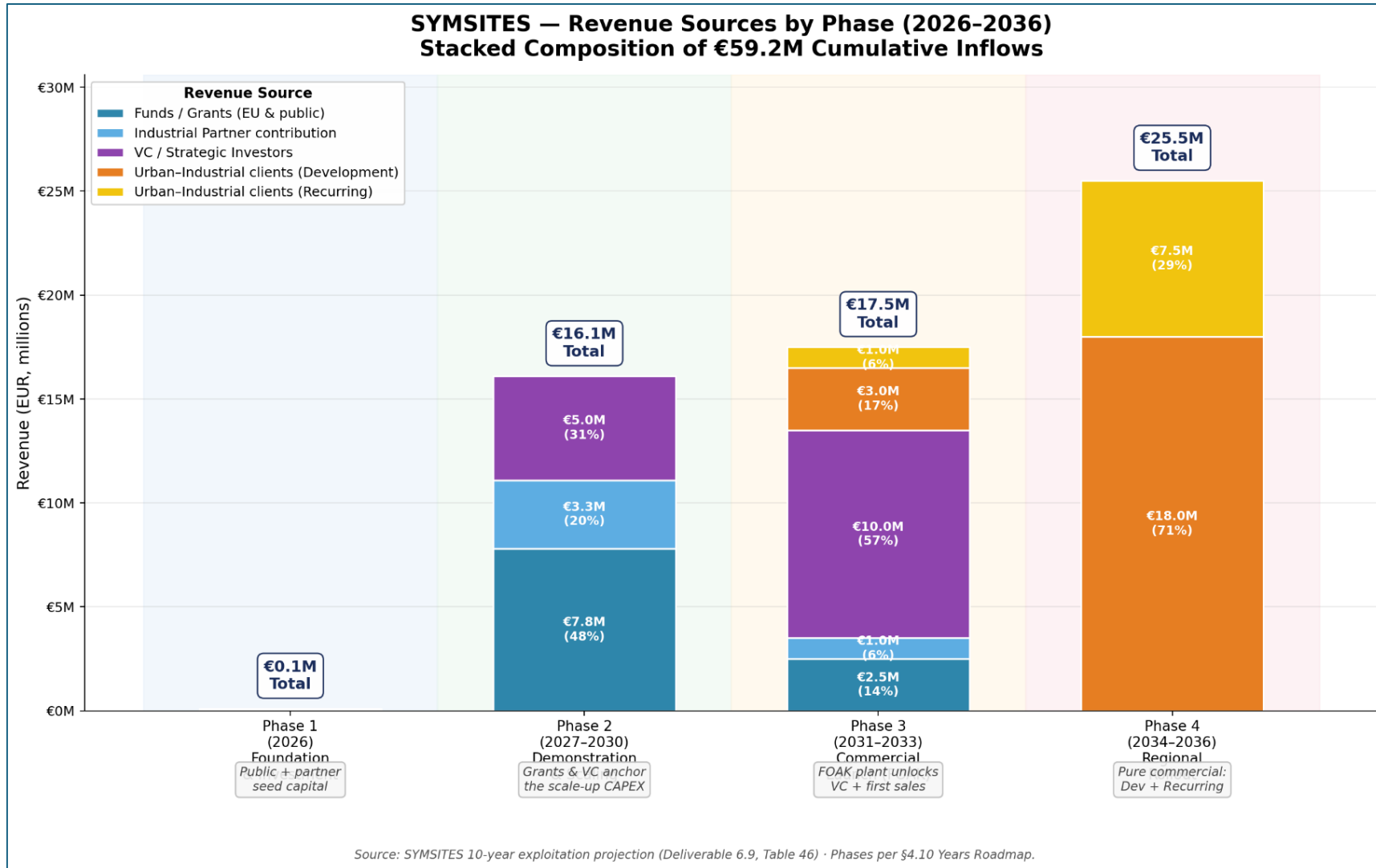


Figure 27 Revenue sources by phase

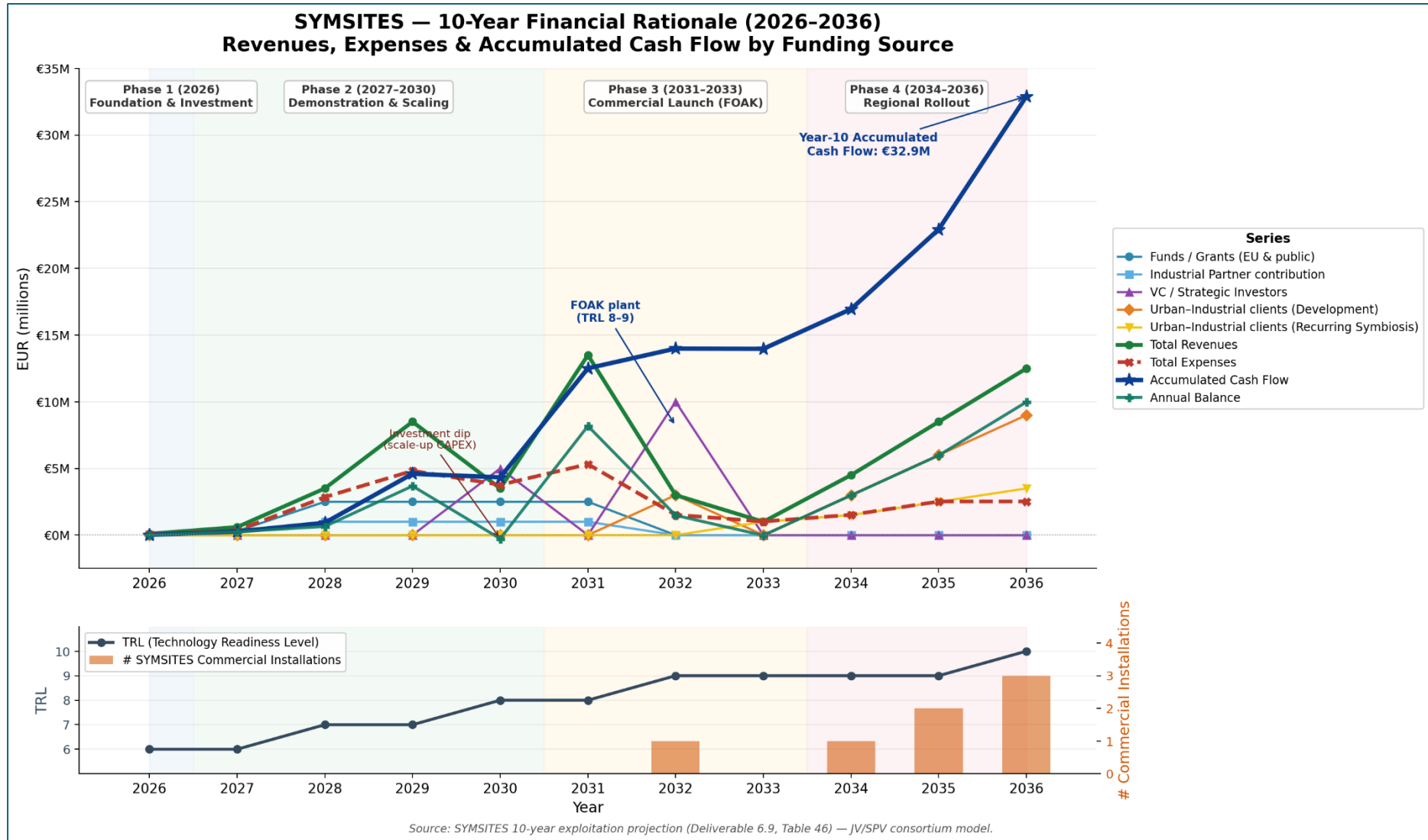


Figure 28 10 Years projection revenues and accumulated cash flow



Conclusion

SYMSITES has presented a unique, cohesive approach to utilize 3 main streams – Wastewater, Biowaste and Non-Recyclable Waste. This approach is aligned with some of the most urgent challenges in Resource recovery, Water supply and Energy resilience. The overall system demonstration, in TRL 5 & 6, was successful, and the economic models show a promising model, on different scenarios. Some key factors are important to address and they are: reaching all compliance standards of UWWTD directive by 2035, and validation of the market willingness to make the shift for 3rd generation of WWTP's, and the procurement of HVNRs at large scale. With these backings, and the proper steps as suggested, to implement a robust structure of the agreements, IP strategy and revenue allocation- these achievements as individuals SYMSITES can create a large scale competitive innovation in the EU market and beyond. Engineering and model optimization will be the next steps.

Annex A: KERs Analysis and Ownership

This table was designed, prepared and managed by Partner PRJ, and was a major part in our process to identify the key achievements and suggested exploitation strategy. This table is only partial from the overall detailed work in analysis of each KER, were Leader/ Partner analysis, suggested exploitation method, IP findings, and more- were in detail, and most of their outcomes are developed in the document on several parts, as well as in Annex C.

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
1.1	Lab scale optimization of the AnMBR plant to produce CH ₄ from WW and BW	Optimization concerning the methane production and preventing fouling of the membrane.	3	4	5	1	BOKU: Anaerobic digestion and biogas production. NTUA: Anaerobic digestion, upgrade of methane, and production of CH ₄ and H ₂	BOKU: AnMBR usage for treating BW and WW and producing CH ₄ . NTUA: AnMBR usage for production of CH ₄ , H ₂ , upgrade of Methane in lab scale (Trickle bed reactor to produce CH ₄ and convert CO ₂)	SIRMET, NTUA, BEOF, FACSA, AAT, BOKU, SP, EEP (for the recirculation of waste)	Engineering companies (who want pilots build pilot), WW treatment who has to operate, other universities	The design and the process (to prevent the membrane fouling and cotreatment of waste) in the lab scale, two-stage process of production of CH ₄ and H ₂ , and upgrade of CH ₄ . Co-digestion of three different waste (WW municipality, liquid phase of food waste, olive oil waste). In the Austrian eco site (blood from

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
											slaughterhouse, and WW) and producing more CH ₄ using the antifouling membrane. Also using non-food waste-
1.2	Lab-scale optimization of an advanced co-treatment system of WW and BW to produce H ₂	Optimization in the cotreatment of wastes and using CSTR to produce H ₂ .	3	4	5	1	Production of H ₂ via hydrolysis process and dark fermentation.	NTUA: Co-treatment of municipal industrial waste and wastewater to produce H ₂ . The optimized result will be used in the WP4 pilot scale ecosite.	SIRMET, NTUA, BEOF, BOKU, FACSA (For the knowledge that is being developed)	Engineering companies (who want to build pilots), WW treatment who has to operate, other universities	Co-treatment and (CSTR) H ₂ produced in the first stage. The digestate will be fed to the AnMBR reactor to produce CH ₄ (second stage).
1.3	Lab-scale optimization of an advanced co-treatment system of WW and BW to upgrade biogas	Optimization of an Anaerobic trickle bed reactor (AnTBR), converting CO ₂ and H ₂ to CH ₄ under various operating conditions, leading to biogas enrichment.	2	3	5	2	Biogas upgrade using amines.	The project will allow the development of a microbial-based process for converting CO ₂ to methane, leading to a more efficient and less costly biogas upgrading.	NTUA, SIRMET, MWA, the partners responsible for the other 3 ecosites	The biogas sector	Innovation is anticipated in the design and operation of the anaerobic trickle bed.

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
2.1	Lab Scale development of C-dots coated membrane with antifouling properties	Cdots are synthesized from biowaste from the olive and textile industry. The formed Cdots have the potential to serve as antibacterial agents. The next step is US deposition of Cdots on water membranes	2	3	4	1	Producing C-dots	Coating C-dots on the membrane	eco sites providers	water membrane producers	New technology
2.2	Lab Scale development of MeO-coated membrane with antifouling properties	CuO particles are known for their antibacterial and antibiofilm properties. The idea is the coating of CuO on water membranes by the US to impart antibiofilm properties to the membrane	4	5	6	1	Coating CuO particles on water membrane in the project PROTECT	Usage of CuO coated membranes for antifouling application	eco sites providers	water membrane producers	Integration of known and new
2.3	Lab Scale development of Magnetic membrane vibration process to produce membranes with antifouling properties.	Membranes with topological patterns were combined with an axial vibration produced via magnetic induction (MMV) to reduce foulant deposition in MBRs. The patterns above the membrane provide extra surface area as	4	7	7	0	Introduction of patterned membranes and membrane vibration could help in minimizing the foulants deposition during MBR operations	Hands-on experience of producing lab-scale membranes onto pilot scale membrane. Performance of patterned membranes in an ANMBR environment.	Prof. Ivo Vankelecom	Pantarein Water Bvba, Blue foot membranes,	Based on Hauschildt's model it is a medium-innovated Innovation where using patterned membranes and vibration has been combined for the first time to be used

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
		well as create local turbulence above the surface to minimize of foulants. The MMV system is driven by an electric motor which drives the 1-dimensional motion of membranes. 30 membrane envelopes are installed in the MMV system, with 15 each mounted to two drive bars. Membrane sheets are arranged so that alternating sheets move in opposite directions to maximize hydrodynamic turbulence.									in wastewater treatment
3	New low costs char-based adsorption materials for tertiary treatments	This result concerns the research and experimentation of new low-cost char-based adsorption materials for the adsorption column	3	4	6.5	2.5	Preparation of char from wastes (GREENE)	Preparation of char wastes for the next steps exploitation of material (GREENE)	FACSA, all EcoSites' managers, NTUA, BOKU	waste water treatment plants; companies that provide activated carbon (components manufacturers)	new materials (nanoparticles) with specific antibacterial and antiviral functionalities. Possible also activated carbon activated with NPs new and extended functionality!

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
4	Optimization of the PMR (Protonic membrane reactors) Technology	This result concerns the changing of the geometry of the protonic cells to optimize the PMR technology for better H ₂ production by steam methane reforming	1	1.5	4.5	3	Testing of PMR cells at lab scale tubular geometry (tubular cells) and manufacturing technique	Production of new cells, operability to be tested	EcoSites members/partners	1st end user: PMR manufacturer; 2nd Companies that want to produce H ₂ from CH ₄	the way the cells will be manufactured (technique) the geometry; from tubular to planar geometry.
5	Optimization of polyhydroxy alkenoates (PHAs) production	Maximizing the accumulation of PHAs and optimizing their composition.	3	4	5	1	Production from mixed microbial cultures (MMCs) and different substrates (synthetic feeds, food and industrial wastes)/Culturing strategies for the development of efficient MMCs/Pretreatment of wastes to optimize yields and composition of PHAs/Recovery from freeze-dried biomass via conventional methodologies/ Evaluation of properties	Cultivation strategies to achieve stable microbial communities and products of consistent composition and properties, suitable for use as food packaging materials, using waste mixtures from the Greek ECOSITE with variable composition and load / load /Low cost and environmentally friendly methodologies for efficient recovery of	NTUA, SIRMET, MUNICIPALITY OF WEST ACHAIA	The bioplastics sector	It is a relatively new technology that needs to be made more robust to find its way to application. It is important to determine how the final PHA properties depend on (a) the feedstock used and (b) the culturing conditions in a robust way. The project will allow a better understanding of this important issue and will be a good step for the application of the technology

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
								PHAs from wet biomass			
6	Fertilizer production (NH ₄) ₂ SO ₄) from nutrient recovery	This result consists of the production of (NH ₄) ₂ SO ₄ , as an inorganic fertilizer, by the stripping of the NH ₃ , coming as a subproduct of the AnMBR treatment.	1.5	2	5	3	Experience with ammonia removal technology with membranes and desulphurization (bioconversion process by bacteria) column already proven in the lab	combine the desulphurization and stripping process with the AnMBR process.	Austrian ecosite partners	farmers for desulphurization process and for obtaining fertilizer. Also waste waters streams from animals at farms can be treated put into biogas fermenter and to use	NH ₃ removal // H ₂ S use after removal from CH ₄ stream // the combination of both ammonia stripping process and desulphurization to get a valuable output. Unique solutions are no combination of these processes.
7	Development of nano-enabled antimicrobial composite (CHAR) for water-absorbent columns	This result consists of the development of a tertiary treatment that eliminates pathogenic bacteria and viruses after AnMBR treatment. This tertiary treatment consists of using subproducts (Biochar) of pyrolyzing treatment in an absorption column combined with lignin-based NPs.	3.5	4.5	5.5	1	UPC: Previous knowledge in terms of metal phenolic Lignin NPs, several systems already developed in combination with Lignin, also lignin alone as an antimicrobial agent, Composite material based on Lignin NPs in combination with biopolymers. BIU Bg of producing c dots from	UPC: Antimicrobial additives in absorption column for water treatment (UPC will be patenting). BIU uses biowaste to produce Cdots, and their addition in the absorption columns for water treatment. GREENE: Use of Char in the absorption column.	Ecosite FACSA, NTUA, BEOF, BOKU.	Composite material producers (Polymer composites, Lignin NPs and Cdots), water treatment companies (final system), biomedical industry. Companies that produce/sell char. Ceramic industry.	An entire system and its individual components are not commercially available. Improvements in terms of functionality: Usage of antimicrobial columns using NPs and C dots is novel (not common), in comparison to conventional antimicrobial columns. One of the

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
							bioresources. GREENE: preparation OF CHAR FROM PYROLYSIs. CSIC:				challenges is, the particles are too small so they get washed away with water.
8	Upgrading of pyrolytic liquids to platform molecules	This result consists in the research of an ideal extracting solvent that allows the extraction of high value compounds (benzoic acid, acetic acid, etc.) and recover them separately.	2	4	5.5	1.5	Oils obtained by pyrolytic process (Greene) // Extraction process (CSIC)	Application of platform molecules in textile products (AITEK, JOV) // Characterization of functional textiles (AITEK)	JOV	Textile companies, companies that provide extraction processes (chemical industry), companies manufacturing extraction reactors, and pyrolytic units' manufacturers	Innovation of the pyrolytic process application resides in the type of waste streams that are addressed in this application (use of pyrolytic oils for the process)
9	SDSS (Social Decision Support System)	This result consists of the implementation of a new tool to support policymakers and practitioners' access, interpretation and understanding of information from data, analyses and models. (Complete system or part of the system may constitute an exploitable solution).	5	5	7	2	KLINK: Background of the Policy sciences and policy issues, which are to be implemented into the tools. Knowledge of Agent-based modelling (ABM) and Fuzzy Cognitive Mapping (FCM). Experience in creating User Experience centric designs of products	KLINK: Usage of ABM and FCM in the decision-making process of social aspects and assessing its impact in the long term. Using FCM in the model allows users to co-model according to the new changes. Foresight capabilities on the consequence effect	AGRA for Investment decision-making after assessing the social impact. Ecosite managers to benefit the implementation in ecosites. If replication can be supported using this analysis. ITG for them to develop this ER and put it in the market. PRJ	Academic environment and perhaps the area of consultants and facilitators for example for H4C. Town managers, Politicians, etc., who need to assess the long-term impact of social elements.	Measuring the social aspects of an I-US using an indicator. Two-dimensional innovation (scientific and technological innovation)-usage of social dimension focused tools for industrial innovation. Integration of FCM and ABM, and using

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
							ECO SITE MANAGERS: Local rules and regulations, cost-benefit analysis and the policy-making scenario in the respective site or countries.	of the I-US configuration.	can utilize it for their consulting business. ICLEI, as they oversee understanding the technological barriers.		them for social decision support
10	Design and Development of the IIoT (Industrial internet of things) management platform (IIoTMP)	This result consists of an online tool for monitoring the quality, quantity and disruption of the treated WW Flows supporting the management of the water streams.	4.5	4.5	7	2.5	IoT solutions and systems have already developed in the past. AI background	Deeper knowledge of symbiotic processes; a deeper knowledge of limitations of AI and new challenges for AI	eco site managers and partners, technology providers of water treatment	(tbd)	the possibility of integrating the system and model into real-world processes. Integration (more specific features have to be analyzed) The complete system which realized the holistic approach
11	Design and development of ITRMP (IT Regional Management Platform)	This result consists of the creation of a new tool to optimize the dynamic control process of the EcoSites integrating an SDSS and IIoTMP	3	3	5	2	Background in web-based and innovative multi-stakeholder Decision Support System. Knowledge of complementary skills (for example,	Modulization techniques of innovative business opportunities at the regional level (focused on I-US).	ECOSITE MANAGERS. MWA (they have knowledge of their region, can utilize this tool), Eng Companies (SIRMET, AAT, GST, SP)	Public authorities linked to waste, water management and Economic Development	The possibility to evaluate the potential of a geographic area to foster and even to implement and to replicate the I-US model of SYMSITES project

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
							Artificial Intelligence)				
13	Life cycle cost assessment and life cycle assessment of the EcoSites	This result concerns a deep analysis of the four eco sites to verify their environmental, economic and social sustainability obtained by LCA, LCC and SLCA methodologies	0	0	0	0	Specific knowledge of LCA, LCC and SLCA methodology based on ISO 14040-44. previous knowledge on analyzing waste waters water treatment plants. Modelling of circular processes and assessing the sustainability of products and processes based on the circular approach.	In-depth knowledge of the sustainability assessment of the process and product developed within the project. Assessing and analyzing the harmonic integration of the technologies in an eco-site, accounting for its environmental, social and economic aspects. Developing a comprehensive model that allows quick analysis of the integrated system for the treatment of BW and WW on a large scale.	All Ecosite managers, BIU, UPC, CSIC, KUL, GREENE, DAVO	Scientific Community, Ecosite managers of the replicated ecosite, parties interested in the technologies developed in SYMSITES	Assessing the sustainability of the Industrial Urban Symbiosis (I-US) of 4 specific case studies (ecosites)

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
14.1	Social Spin off	Identifying the Symbiotic relationship with other regions. This result will be useful to ensure that all the outputs will reach the communities.	1	1	6	5	BOFA has knowledge from previous projects on working with citizens in a collective way and know-how on how to involve citizens from the WASTEMAN project. Citizens to come up with and co-design solutions for waste sorting.	BOFA will be gaining knowledge from citizens on symbiosis. After the project, updated knowledge on the citizen's behavior towards urban symbiosis. This can be useful in utilizing resources better on I-US for knowledge sharing.	Danish ecosite. The methods could be utilized at other ecosites to identify the citizen behaviors towards I-US. SMEs within the consortium	Citizens in Denmark. At replicated ecosites. The SMEs can utilize this methodology in identifying the problems to implementing I-US.	
14.2	Training Materials	To support the implementation of symbiotic processes, a set of training materials to expand the stakeholder's knowledge in I-US and expose them to the benefits of project EcoSites	0	0	0	0	As a cities and regions network, ICLEI understands how to develop materials suited to informing public bodies. Task partners, including AGRA; KLINK; and ITG have relevant experience in providing materials to the industry.	Training materials directed to local governments and municipalities, industries and SMEs will be developed, expanding their knowledge in I-US and exposing them to the project EcoSites and their environmental, economic and social co-benefits.	The municipalities connected to the Ecosites, industries/SMEs potentially relevant to the Ecosites to build further symbiotic relationships with	local governments and municipalities, industries and SMEs across EU	Training materials directed to local governments and municipalities, industries and SMEs will be developed, expanding their knowledge in I-US and exposing them to the project EcoSites and their environmental, economic and social co-benefits.

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
14.3	Replication Package	A comprehensive replication guidance package will be developed, comprising a self-assessment tool and recorded virtual tours from the project's EcoSites, for companies seeking to replicate the SYMSITES symbiotic processes.	0	0	0	0	ICLEI has a wealth of experience in compiling the learnings from the implementation of pilots, in written and video format. Experience in conveying the barriers and enablers to successful replication and packaging that information in a usable guide.	Self-assessment tool, replication guide and virtual Ecosite tour materials to enable the implementation of similar I-US processes.	Ecosite partners for dissemination of pilots	Waste associations and other city utility companies	Replication package to enable city utilities to replicate SYMSITES' innovative symbiotic processes.
15	Virtual I-US game - trials and conclusions	An ICT-based tool developed I) to demonstrate virtually I-US and II) to boost the I-US concept.	5	5	7.5	2.5	Definition, design and development of Complex Multi-Stakeholder decision support systems. Mathematical capabilities focused on Classical Statistical and AI (Deep Learning, Machine Learning or Agent-Based Modelling among others)	Definition of Serious Game applied to I-US concept	Consortium Members (Considering the Game as a tool to foster I-US concept) Specifically, WP 3 and WP5 partners	Society and Citizens in General and Key Stakeholders, especially Policy Makers	Easy to use ICT tool applied to Stakeholder Engagement

KER No.	Exploitable Result (**)	Brief description (**)	TRL				Background and Foreground		Beneficiaries		Innovation Level
			Beginning	Current	End	GAP	Background knowledge	Foreground knowledge	Internal Beneficiaries	External beneficiaries	
12.1	Deploying a cutting-edge AnMBRs pilot system for the on-site treatment of Biowaste and Wastewater, addressing both urban and industrial needs with advanced efficiency and environmental impact.	It involves the on-site implementation of an advanced AnMBRs (Anaerobic Membrane Bioreactors) pilot system. This system is designed to efficiently treat Biowaste and Wastewater, addressing the needs of both urban and industrial environments. The project focuses on deploying cutting-edge technology to enhance treatment processes, improve overall efficiency, and promote sustainable practices in waste management.	5	5	6	1	SIRMET: Anaerobic digestion and biogas production. NTUA: Anaerobic digestion, upgrade of methane, and production of CH ₄ and H ₂ . EEP: Industrial waste treatment	SIRMET AnMBR usage for treating BW and WW and producing CH ₄ . NTUA: AnMBR usage for production of CH ₄ , H ₂			

Annex B: Ecosites Results

This internal table was made in order to view several issues for the upsacle vision, such as biogas yield, membrane type, sieve type, reactors, COD and more. some of this data is only a sample of various tests.

Parameter	Spain	Greece	Austria	Denmark
Pre-treatment process	Shredding, 0.1 mm rotary drum filter (removed 0.5 mm pre-filter)	Shredding, drying, screw press; dark fermentation reactor for food waste	Not specified in Second Tech Report B	Shredder, pre-filter 500 µm drum filter for solids; food waste shredding is not fully optimal
Biowaste particle size	0.1 mm, post-shredding by rotor filter	Not specified quantitatively (general "fine" particle size, see CSTR1)	Not specified	Some coarse fibers for raw food waste reduce efficacy; not fully quantified
Average COD range options tested	28,419 mg/L in feed (28,419 = 28.4 g/L)	Ranges given: Period 2 up to 8,500 mg/L, Period 3 up to 10,000 mg/L (tCOD)	2.25 kg COD/M ³ Table 11 p 47 Or 4.52 ± 1.29 (g/kg)	Ranged between ~2,500 (early periods) to ~9,384 mg/L in periods 3–5; brewery adds up to 7,464 mg/L
Waste (biowaste) QTY per day	133 L/day during inoculation	"Up to 120 kg of solid waste," typically combined [p.49, Greek EcoSite schematic]	Not specified	Various: mix MWW, BWW, FW; see Table 27 (periods 4–5: 13–25 L FW/day, periods 1–3 only MWW+BWW)
Wastewater QTY per day	200 L/day (during start-up); regular operation volume: 1.8 m ³	Reactor treats 3 M ³ wastewater/day combined with food waste	400 liters	Varied: 75–500 L/day MWW+BWW+BWW; typically, 200–500 L/day during high-COD periods
CSTR1 reactor details	Used Alcoy WWTP digested sludge for inoculum; 1.8 m ³ volume, SRT 70 days, OLR 2.7 g COD/L/d [p.108–109]	CSTR1: dark fermentation and acidogenic biowaste breakdown; typically, 1.2 mol H ₂ /mol sugar yield	Not specified	Anaerobic digester integrated with membrane; details not distinct for CSTR1, system

<i>Parameter</i>	Spain	Greece	Austria	Denmark
Membrane type	UF (KOCH); commercial ultrafiltration 0.03 µm pore size; novel MF variant tested [p.110]	UF and PES Polyether sulfone (Nadir UP150 T membranes), tested with/without coatings [p.49–51]	UF system consists of four identical ceramic ultrafiltration crossflow membranes, operational in either a 2x2 or 4x1 configuration. The ultrafiltration permeate is subsequently prepared for further processing through nanofiltration (NF) or reverse osmosis (RO).	Flat sheet membrane (KOCH, PVDF), used with a pre-treatment filter [p.228, membrane details]
Membrane pore size	0.03 µm (commercial UF)	40 nm (0.04 µm) for tested PES membranes	0.2 µm	0.5 mm prefilter; membrane type not specified in µm, but KOCH/PVDF membrane typical 0.03 µm
Average pressure (operation)	0.2–0.3 bar	Not specified quantitatively; general description "operated under vacuum"	Not specified	Not specified; operation monitored, but no bar value given
Biogas yield	0.35 NM ³ CH ₄ /kg COD (pilot); up to 3,900 L/d in period 2	0.25–0.30 NM ³ CH ₄ /kg COD (period 2–3); 3.2 m ³ /day biogas combined,	Not specified	In high-COD periods, up to 657 L/d CH ₄ (period 7); (varies by period & substrate)
Water quality (reuse regulation)	Complies with EU Dir. 91/271/EEC, generally Class A irrigation;	EU Regulation 741/2020, Class A – for agricultural reuse	The water after reverse osmosis treatment is qualitatively congruent with the EU	Complies with EU 741/2020, Class B ("B" in data), TSS 1.9–2.1 mg/L, E. coli < 100 MPN/100ml



<i>Parameter</i>	Spain	Greece	Austria	Denmark
	permeate TSS < 10.7 mg/L		REGULATION 2020/741	
COD removal (%)	95% (from inlet COD 2,841 mg/L to effluent 133.9 mg/L) [p.113 discussion]	85–90% in periods tested [p.40]	< 50 mg/L [p. 69]	Not specified in percentage; data for inlet/outlet COD not explicit, but high removal rate inferred [p.226–233]

Annex C: KERs Roadmaps with the Booster Support

Exploitation roadmap for KER 1.1 Lab scale development of AnMBR to produce CH ₄	
Actions	Current declared TRL=4, targeted TRL=5. Assuming TRL 5 is achieved by the end of the project. To advance the AnMBR technology from TRL 5 to TRL 8/9, the consortium will first optimize lab-scale processes by addressing industrial wastewater inhibition through pre-treatment (e.g., ozonation, bioaugmentation), mitigating membrane fouling via ceramic/polymeric hybrid systems, and acclimatizing microbial consortia to high-sulphate loads. Pilot-scale validation (TRL 6 to 7) will involve deploying 1-5 m³/day systems across Spanish, Greek, and Austrian ecosites, testing co-digestion of urban, industrial, and food waste streams while integrating AI-driven process control and H₂S scrubbing to ensure >90% CH₄ purity. Semi-industrial scale-up (TRL 7 to 8/9) will demonstrate a 50–100 m³/day unit over 6-12 months, targeting membrane lifespans >2 years and OPEX <€0.10/m³, supported by techno-economic and LCA models confirming payback <5 years. Concurrently, the business plan will priorities IP protection (patents for membrane/feedstock synergies), revenue streams from licensing to WWTP, and O&M services, while targeting early adopters like municipal WWTPs and food processors with a value proposition of 70% sludge reduction and energy autonomy.
Roles	NTUA will advance the research by improving the COD conversion rate, and accommodation of Mixed waste containing COD greater than 10g/L. BOKU will enhance the biogas production to reach an industrial scale, while maintaining the methane content above 80%
Milestones	M3: Initiate lab-scale optimization and file first patent. M6: Validate TRL6 with >50% methane recovery from inhibited wastewater. M9: Finalize and fabricate 1-5 m³/day pilot systems. M12: Deploy and operate pilots at all three ecosites. M15: Integrate pre-treated industrial wastewater into Austrian and Greek pilot. M18: Achieve 90-day stable operation across all pilots. M21: Complete design for 50-100 m³/day demonstration unit. M24: Launch semi-industrial demo at Alcoy WWTP. M27: Finalise techno-economic analysis and O&M training. M30: Install first commercial-scale (100 m³/day) unit. M33: Onboard industrial clients and launch carbon credits. M36: Demonstrate 12-month commercial reliability and reach €3M revenue.
Costs	Expected costs for performing lab scale optimization and upscaling NTUA activities: €350k Expected costs for BOKU: €350k Costs for Patents for Patent Application (specific technological application): €30k
Revenues	<i>Licensing: Charge fees for patented AnMBR membrane tech and microbial consortia</i> <i>Joint Ventures: Partner with utilities/membrane manufacturers for shared biogas projects.</i> <i>Consultancy: Offer waste stream optimization services</i> <i>Equipment Sales: Sell modular AnMBR units</i>

	<i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	Resources are needed to bridge the investment needs to increase TRL and ensure the result is used. Financial resources to cover costs incurred before collecting the first revenues: - Further Horizon funding for upscaling - Local regional grants funding the industrialization of new technologies - Fundraising - Crowdfunding

Exploitation roadmap for KER 1.2 Lab scale development of AnMBR to produce H ₂	
Actions	In the 3-6 months following project completion, we will transition from lab-scale validation to commercialization readiness by finalising the business plan, securing IP protection (patents for co-treatment processes and reactor designs), and initiating regulatory approvals for pilot deployment. Concurrently, stakeholder engagement will expand via MOUs with wastewater plants and waste aggregators to secure feedstock and validate market demand. To advance from TRL 5 to TRL 8/9, we will focus on scientific and technical scaling over 3-4 years. A pilot-scale reactor (100 to 1,000 L) will be developed to test hydrodynamic stability, feedstock variability, and real-time monitoring under semi-industrial conditions. Microbial optimization will involve metagenomic studies and synthetic consortia engineering to suppress H₂-consuming organisms and enhance yield. Process integration will couple H₂ and CH₄ recovery for maximal energy output, supported by LCA and LCC to confirm environmental and economic sustainability. Material innovations will address corrosion resistance and safe H₂ handling. Field trials at wastewater facilities will validate performance, leading to certifications (ATEX, ISO 14001) and full-scale commercialization. This phased approach ensures robust technology maturation while aligning with circular economy policies and investor readiness.
Roles	SIRMET (Exploitation Lead): Commercialises KER, develops/installs AnMBR, handles IP & market strategy. NTUA: R&D Lead: Conducts research, optimises microbes, validates processes, generates IP. MWA: Site & Waste Provider: Supplies waste, hosts pilot/commercial plants, secures permits. PRJ: Performs lifecycle assessments for sustainability validation. Collaboration: NTUA+SIRMET optimise tech; SIRMET+MWA deploy systems; all partners align on policy/scale-up.
Milestones	6M: Finalise business model, file patents, initiate permits, secure MOUs. 12M: Design 100L pilot, optimise microbes, draft H₂ safety protocols. 18M: Deploy pilot, test feedstocks, integrate H₂+CH₄ recovery. 24M: Achieve >25% H₂, design 1,000L reactor. 30M: Test 1,000L system, validate >90% COD, secure off-takers. 36M: Obtain certifications, complete patents, and gain pre-orders. 42M: Run 6-month industrial demo, finalise investor pitch. 48M: Launch commercial plant, produce 500kg H₂/month, expand partnerships.
Costs	SIRMET (Exploitation Lead): €500k (IP patents, pilot/commercial deployment, market strategy, stakeholder MOUs). NTUA (R&D Lead): €350K (microbial optimization, metagenomics, process validation). MWA (Site/Waste Provider): €450k (feedstock supply, pilot site prep, permits, field trials). PRJ (LCA Specialist): €200K (lifecycle assessments, sustainability/cost modelling). Shared Costs (Collaboration): €300K (joint scaling studies, policy alignment, certifications).
Revenues	SIRMET, NTUA and MWA: Licensing the AnMBR system, microbial consortia, or process know-how to waste treatment plants or energy firms. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>

Other sources of coverage	Resources are needed to bridge the investment needs to increase TRL and ensure the result is used. Financial resources to cover costs incurred before collecting the first revenues: - Further Horizon funding for upscaling - Local regional grants funding industrialization of new technologies - Fundraising - Crowdfunding
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Exploitation roadmap for KER 1.3 Lab scale development of Trickle bed reactor	
Actions	To advance the Trickle Bed Reactor (TBR) technology from TRL 5 to commercialization (TRL 8/9), a phased approach will be implemented. Phase 1 focuses on prototype optimization and pilot testing, including reactor enhancements such as biocarrier material testing, automated nutrient dosing, and improved gas injection to boost H_2/CO_2 transfer. A modular 500 to 1,000 L pilot system will undergo 6 to 12 months of testing at a biogas or wastewater facility to validate performance under real-world conditions, including intermittent hydrogen feeding to simulate renewable energy fluctuations. Phase 2 involves scaling up to a 5,000 to 10,000 L industrial system, operating continuously for 12+ months to assess long-term efficiency, maintenance needs, and safety compliance, while integrating with gas grids or storage. Phase 3 drives market entry by targeting biogas upgrading and Power-to-Gas applications, with secondary opportunities in landfill gas and industrial CO_2 utilisation. Two business models will be pursued: turnkey solutions and licensing agreements. Standardised modular designs and bulk biocarrier production will reduce costs, while policy incentives (e.g., EU Green Deal) and partnerships with energy consortia will support large-scale adoption. This strategy ensures TBR technology becomes a competitive, scalable solution for renewable energy-integrated biological methanation.
Roles	NTUA will lead the R&D efforts, focusing on optimizing the TBR technology, improving biofilm stability, and conducting lab and pilot-scale testing to refine reactor performance and dynamic operations. SIRMET will support in scaling up the technology, designing and building the industrial-scale TBR system, and exploring retrofit solutions for existing wastewater treatment plants to integrate the technology into real-world applications. MWA will use the technology internally within their WWTP PRJ will assess economic and environmental sustainability
Milestones	M3 Start testing alternative biocarrier materials for improved biofilm adhesion and reduced channelling. M6 Optimise gas injection design and develop an automated nutrient/pH control system. M9 Finalise and install modular pilot-scale TBR (500-1,000 L) at a biogas or wastewater facility. M12 Monitor pilot performance; aim for $>2.5 \text{ L CH}_4/\text{L reactor/day}$ and validate stability under real-world conditions. M15 Conclude pilot testing; verify $>85\% \text{ CH}_4$ purity and define parameters for scale-up. M18 Begin fabrication of full-scale demo unit (5,000-10,000 L) and secure ATEX/ISO certification engagement. M21 Install and commission full-scale TBR at industrial partner site; begin continuous operation. M24 Achieve $>90\% \text{ CH}_4$ purity and validate 3-4 L/L reactor/day yield under industrial conditions. M27 Implement AI-driven safety protocols; begin full techno-economic and maintenance evaluation. M30 Finalise commercialization models (turnkey & licensing); validate 30% lower OPEX than alternatives. M33 Launch marketing campaign and secure funding support (EU Green Deal, U.S. IRA, etc.). M36 Complete first commercial sale of TBR system and establish market presence in 2+ regions.

Costs	NTUA (R&D, lab/pilot testing): €950K for biocarrier optimization, automated systems, and pilot validation. SIRMET (scale-up, industrial design): €900K for full-scale TBR fabrication and retrofit integration. MWA (internal WWTP deployment): €800K for pilot installation, monitoring, and staff training. PRJ (sustainability assessment): €120K for LCA, cost-benefit analysis, and certification support.
Revenues	<i>The commercialization of the Trickling Bed Reactor (TBR) for biological methanation presents multiple revenue opportunities, including direct sales, licensing, and service-based models.</i> <i>NTUA: Licensing patents, selling optimized biocarrier materials, and offering R&D consultancy for biofilm-based systems.</i> <i>SIRMET: Selling turnkey TBR systems, retrofit kits for WWTPs, and earning service/maintenance contracts.</i> <i>MWA: Monetizing upgraded biogas (CH₄) sales, reducing operational costs, and leasing pilot infrastructure to third parties.</i> <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	- Further Horizon funding for upscaling - Local regional grants funding industrialization of new technologies - Fundraising - Crowdfunding

Exploitation roadmap for KER 2.1 Lab scale development of C-dots coated membrane with anti fouling properties	
Actions	The KER is projected to achieve Technology Readiness Level (TRL) 4 by the conclusion of the project, corresponding to the successful validation of the technology in a controlled laboratory setting. In the 3 to 6 months following project completion, the focus will shift toward defining a structured and technically robust pathway to advance the technology through TRLs 5 to 9. This will begin with the formulation of a detailed R&D roadmap outlining the necessary experimental procedures and process adaptations required for technology validation and demonstration in increasingly realistic conditions. Achieving TRL 5 will require the synthesis of C-dots using biomass-derived char under optimised conditions and the application of these Nano Particles onto full-scale commercial membrane substrates (e.g., KOCH and Alfa Laval membranes) using scalable coating techniques. Subsequent evaluation of membrane performance, specifically antibacterial efficacy ($\log \text{CFU}/\text{cm}^2 \geq 2$), fouling resistance, and structural integrity, will be carried out under industrially relevant environments, such as bench-scale filtration systems handling representative wastewater matrices. Progression to TRL 6 will necessitate the demonstration of coated membrane modules under operational conditions mimicking real-world process parameters (e.g., flow rate, transmembrane pressure, organic load). This includes establishing pilot-scale experimental setups to assess membrane lifetime, mechanical durability, and antimicrobial persistence over extended periods. At TRL 7, the coated membranes must be integrated into functional system prototypes deployed within operational water treatment infrastructures. Performance metrics will include flux stability, fouling dynamics, cleaning protocol compatibility, and antimicrobial effectiveness under fluctuating environmental conditions. Upon successful prototype validation, the technology can advance to TRL 8, which involves complete system qualification, including conformity with relevant regulatory frameworks (e.g., ISO 22196 for antibacterial activity, REACH, and EU water treatment regulations), and robustness testing under continuous operational cycles. Reaching TRL 9 will involve large-scale deployment in a competitive operational setting, with the system demonstrating repeatability, reliability, and cost-efficiency across full operational lifecycles.
Roles	• BIU (Leading Partner): Leads the upscaling of C-dot synthesis from biochar, optimizes membrane coating techniques for commercial membrane formats, and oversees TRL advancement activities. Also responsible for data analysis and performance evaluation during pilot and field trials. • GREENE: Supplies pyrolysed char derived from olive waste using its proprietary pyrolysis technology. Ensures consistency and quality of feedstock used for C-dot synthesis. Supports scale-up feasibility and environmental impact assessments. • AITEX: Conducts antibacterial performance testing and physical-chemical characterization of coated membranes. Leads alignment with regulatory and certification frameworks (e.g., ISO, REACH), and supports pilot demonstration planning and validation. • BEOF: Provide commercial membranes for testing and integration. Offer technical input to ensure coated membranes are compatible with existing filtration systems and support scale-up validation efforts. Facilitates access to pilot and operational testing environments (e.g., small-scale water treatment units). Supports deployment and

	monitoring of coated membranes under real-world conditions. Provides user feedback to inform prototype optimization.
Milestones	M3: Finalize TRL advancement roadmap (from TRL 4 to TRL 9) M6: Optimize C-dot coating process at bench scale for larger membrane sheets M9: Initiate TRL 5 validation in industrially relevant lab-scale systems M15: Develop full-scale coated membrane prototypes ($\geq 0.5 \text{ m}^2$) M18: Complete TRL 6 demonstration in semi-operational filtration environment M21: Finalize business and commercialization plan M24: Demonstrate TRL 7 prototype in actual operational water treatment setup M27: Begin certification and regulatory compliance procedures (e.g., ISO, REACH) M30: Engage stakeholders and submit funding or industrial partnership proposals M33: Complete TRL 8 qualification testing, including long-term performance validation M36: Achieve TRL 9 proven technology deployed in an operational industrial environment
Costs	BIU: €480,000 (C-dot synthesis, coating optimization, TRL advancement leadership). GREENE: €400,000 (biochar supply, feedstock QA, environmental assessments). AITEX: €450,000 (antibacterial testing, regulatory compliance, pilot support). BEOF: €420,000 (membrane supply, pilot integration, field testing). PRJ: LCA/TEA of the membranes
Revenues	BIU: Technology licensing, royalty shares, and R&D grants. GREENE: Biochar sales, pyrolysis licensing, and carbon credits. AITEX: Certification services, regulatory consulting. BEOF: Coated membrane sales, pilot deployment contracts, and maintenance solutions. Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.
Other sources of coverage	Resources are needed to bridge the investment needs to increase TRL and ensure the result is used. Financial resources to cover costs incurred before collecting the first revenues: - Further Horizon funding for upscaling - Local regional grants funding the industrialization of new technologies - Fundraising - Crowdfunding
Exploitation roadmap for KER 2.2	
Actions	Current declared TRL=5, targeted TRL=6. Assuming TRL6 is achieved by the end of the project. After the project accomplishment the technology needs to be further improved to reach TRL8-9 in order to achieve the exploitation stage. Membranes coating will need to be proven at industrial scale by validating production capacity, replicability and homogeneity of membrane coating with MeO nanoparticles (NPs). Higher speeds associated with higher tensile stress will be tested in order to guarantee that the membrane will not be damaged. Industrial scale coating will imply extending the surface membrane height to be treated at higher speed. Drying phase at regime operating speed will prove to preserve the membrane polymer, morphology and porosity, without suffering thermal and mechanical stress during coating and drying. Energy demand per unit surface will also be tested to validate economic and environmental sustainability of the coating process.

	<i>The membrane operation in AnMBR system will also imply temperatures at which the membrane may fail. Validation tests at regime operation will be necessary.</i>
Roles	<i>BIU will adapt the coating parameters and recipe according to the scaled-up coating process.</i> <i>DAVO with the support of ultrasound system designers and integrators will promote the setting up of a industrial up-scaled coating unit for running industrial testing campaigns</i> <i>DAVO will promote testing campaigns on a scale up unit in collaboration with BIU for devising the best coating conditions and recipes for membranes MeO NPs coating.</i> <i>FACSA, NTUA and BOKU will oversee running operation tests in different conditions with waste streams with different p-chem properties to assess the effective benefit extent of the MeO coated membranes such as:</i> - Prolonged service life - Reduced maintenance interventions - Reduction in maintenance costs. <i>PRJ will assess economic and environmental sustainability</i>
Milestones	<i>M1- design a proper industrial scale unit to demonstrate industrial performance (3rdM+)</i> <i>M2- industrial scale unit ready for testing campaigns (9thM+)</i> <i>M3- first testing campaign accomplished (12thM+)</i> <i>M4- membranes samples characterized (15thM+)</i> <i>M5- second testing campaign for performance improvement (18thM+)</i> <i>M6- membranes and coating process optimised at industrial scale (24thM+)</i> <i>M7- Validation of technology and membranes coated products for the specific AnMBR application. Sustainability performance qualified and quantified.</i>
Costs	<i>Expected costs for performing BIU activities: 250k</i> <i>Expected costs for obtaining an industrial scale unit by DAVO: 500k€</i> <i>Expected costs for in operation membrane testing in AnMBR system:</i> <i>NTUA: 250k</i> <i>BOKU: 250k</i> <i>FACSA: 250k€</i> <i>PRJ: 120k€</i> <i>Costs for Patents for Patent Application (specific technological application): 30k€</i>
Revenues	<i>CSIC: Licensing IP, consulting, and EU grants for PMR commercialization.</i> <i>BOKU/NTUA/FACSA/BEOf: Operational savings and pilot testing fees from PMR integration.</i> <i>PRJ: Revenue from LCA/TEA consulting for industrial partners.</i> <i>Industrial SMEs: Manufacturing/selling PMR components or systems under license.</i>
Other sources of coverage	<i>Resources are needed to bridge the investment needs to increase TRL and ensure the result is used. Financial resources to cover costs incurred before collecting the first revenues:</i> - Further Horizon funding for upscaling - Local regional grants funding industrialisation of new technologies - Fundraising - Crowdfunding

Exploitation roadmap for KER 2.3 Magnetic Membrane Vibration	
Actions	Current declared TRL=7, targeted TRL=9. Three to six months after the end of the project, activities will focus on advancing the Magnetic Membrane Vibration (MMV) system toward TRL 8 to 9, validating the technology under operational conditions and preparing for market entry. Building upon KU Leuven's existing patent on the membrane technology, further efforts will center on the techno-economic optimization of membrane materials and configurations at industrial scale. Specifically, polysulfone (PSf) and polyacrylonitrile (PAN) membranes will undergo comparative testing to evaluate long-term performance metrics, such as permeability (LMH/bar), fouling resistance, chemical stability, and mechanical strength, as well as their scalability and cost-effectiveness in full-scale manufacturing. The goal is to identify the most viable membrane composition for commercial deployment, considering both process performance and lifecycle cost. On technical front, extended validation studies will focus on dynamic module operation, including vibrational stability, shear stress control, and enhanced vortex generation within the boundary layer. Computational fluid dynamics (CFD) models will be refined based on pilot data to improve predictions of shear-induced turbulence, concentration polarization mitigation, and foulant detachment across different membrane geometries. Structural assessments of membrane envelope bonding integrity, tolerance to axial displacement, and long-term fatigue behavior under cyclic loading will also be performed. In parallel, energy performance (kWh/m³), cleaning frequency, and transmembrane pressure (TMP) evolution will be tracked under realistic sludge conditions to support full environmental and operational benchmarking. Non-technical actions will include the finalization of a comprehensive business plan integrating updated CAPEX/OPEX models, go-to-market strategy, and stakeholder engagement roadmap. The legal team will conduct a freedom-to-operate (FTO) analysis and initiate any necessary patent extension procedures, particularly around the roll-to-roll fabrication of patterned membranes and vibration-assisted MBR modules. Work will begin on regulatory compliance and certification, targeting ISO 14034 Environmental Technology Verification (ETV) and conformity with the Urban Wastewater Treatment Directive (UWWTD). Standard operating procedures (SOPs), digital control integration with industrial SCADA/PLC systems, and system reliability documentation will be completed to enable commercial readiness and industrial adoption.
Roles	KUL: will develop the design parameters for scaled up MMV module FACSA will play an instrumental role in validating the development. PRJ will carry out the Sustainability assessment to analyze the Environmental impact and cost effectiveness NTUA/SIRMET, BOKU and BEOF: Technology integrators as they are the MBR manufacturers Manufacturing: Potential collaboration with custom membrane fabricators
Milestones	M6: Complete integration and operational validation of MMV system at WWTP pilot site. M12: Finalize performance optimization and complete techno-economic comparison of PAN vs. PSf membranes. M18: Select optimal membrane type and develop SOPs for scale-up and pre-commercial design. M24: Finalize industrial prototype design and submit regulatory and certification documents. M30: Install and validate full-scale demo system at external WWTP under real conditions.

	<i>M36: Achieve TRL 9 and launch MMV system commercially with finalized IP and go-to-market strategy.</i>
Costs	KU Leuven (KUL): €550k (MMV module scale-up design, membrane optimization, CFD refinement). FACSA: €450K (operational validation at WWTP, pilot testing, performance benchmarking). PRJ: €120K (sustainability assessment, LCA, cost-effectiveness analysis). NTUA/SIRMET: €250K (technology integration, MBR manufacturing adaptation). BOKU: €250K (process integration, fouling/energy performance studies). BEOF: €250K (industrial prototyping, vibration system optimization).
Revenues	<i>KUL: Licensing of membrane design and vibration system to MBR manufacturers</i> <i>KUL: Joint venture with a membrane production company</i> <i>KUL: Product-Service System offering MMV systems as part of retrofitting services</i> <i>FACSA: for internal use as a retrofit</i> <i>Early adopters: WWTP, Membrane fabricators, Decentralized Waste water treatment units</i> <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	<i>EU Green Deal Innovation Funding</i> <i>EIC Accelerator (for deep-tech scaling)</i> <i>National water innovation programs in Spain, Belgium, and the Netherlands</i>
Exploitation roadmap for KER3 New low costs char for tertiary treatments	
Actions	At the end of the SYMSITES project, the low-cost char production technology will be at TRL 6 (pilot-scale validation in a relevant environment). The focus is on scaling up the pyrolysis process to produce high-yield, low-cost char from non-recyclable waste (NRW) for adsorption applications. Over the next four years, the goal is to advance to TRL 8-9 (commercial deployment) by optimizing feedstock processing, increasing production capacity, and securing industrial adoption. In the beginning, Finalize feedstock pre-treatment protocols (drying, shredding) to maximize char yield from textile scraps and olive biomass. Conduct large-batch pyrolysis trials (100+ kg) to refine operational parameters (temperature, residence time, gas flow). Establish quality control standards for char consistency. Deploy a semi-industrial pyrolysis unit (200 to 500 kg/h) at a partner facility (e.g., a wastewater treatment plant or biomass processor) to demonstrate cost-efficiency and reliability. Secure certifications for char use in water/air filtration. Engage early adopters (municipalities, industrial waste processors) through pilot agreements. Later, scale to 1+ ton/h continuous production, targeting integration with activated carbon manufacturers and waste valorization hubs. License the pyrolysis technology to regional operators, emphasizing circular economy benefits. Explore carbon credit revenue for biochar's carbon sequestration potential. Revenue will stem from selling char directly to adsorption system suppliers, licensing pyrolysis technology to waste processors, and offering turnkey solutions for localized char production. Partnerships with waste management companies (e.g., textile recyclers, agri-food processors) will secure low-cost feedstock, while collaborations with water treatment firms will drive demand. By Year 3, the focus shifts to global scalability, adapting the process to region-specific NRW streams (e.g., agricultural residues in Southern Europe, brewery waste in Northern Europe). Cost reductions will be achieved through automated

	feedstock sorting and energy-efficient reactor designs, ensuring competitiveness against conventional activated carbon.
Roles	GREENE (Main Exploiter): Lead scale-up, reactor optimization, and commercialization. CSIC: Support char characterization and adsorption efficiency studies. BIU: Develop value-added applications (C-Dots, activated carbon). Municipal WWTPs (Early Adopters): Pilot testing and feedback. Water Tech Integrators (Veolia, SUEZ): Market deployment and sales.
Milestones	M6: Prototype optimization completed, patent filed. M12: Pilot unit (50 kg/h) operational at a WWTP. M18: Regulatory approvals obtained, first efficiency reports. M24: Commercial prototype (200 kg/h) ready, first contracts signed. M36: Full-scale unit (1 ton/h) deployed, revenue generation starts. M48: Expansion to 3+ EU markets, licensing agreements in place.
Costs	GREENE: €800k (pilot-to-industrial reactor scale-up, process optimization, feedstock testing). CSIC: €300K (char characterization, adsorption efficiency studies, quality control protocols). BIU: €200K (C-Dots/activated carbon R&D, high-value applications). Municipal/WWTP Partners: €150K (pilot integration, regulatory compliance, performance monitoring). Water Tech Integrators (e.g., Veolia, SUEZ): €500K (commercial prototyping, market deployment support).
Revenues	GREENE: Licensing pyrolysis technology and selling modular reactors to waste processors and biochar producers. CSIC: Earning royalties from joint IP licensing and offering char characterization/certification services. BIU: Commercializing high-value C-Dots and specialty activated carbon from waste-derived char. Municipalities/WWTPs: Saving costs through waste diversion and selling excess char to local industries. Water Tech Integrators: Profiting from char-integrated filtration systems and long-term service contracts. Waste Management Companies: Charging for pre-processed waste feedstock supply to char producers. Local Manufacturers: Generating revenue through regional char production licenses and B2B sales. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	Grants: Horizon Europe, EIC Accelerator, national green tech funds. Private Investment: Venture capital, strategic partners (water tech firms). Loans/Subsidies: EU green transition loans, circular economy incentives.

Exploitation roadmap for KER4: Optimisation of the PMR (Protonic membrane reactors) Technology	
Actions	At the conclusion of the SYMSITES project, the optimization of the Protonic Membrane Reactor (PMR) for Steam Methane Reforming (SMR) is expected to reach the Technology Readiness Level (TRL) 4, with validated planar half-cell designs at 25 cm² and consistent electrochemical performance. The next four years will focus on advancing the technology to TRL 8/9, enabling commercial deployment. Within the first 6 months post-project, CSIC will lead efforts to finalize a comprehensive business plan that includes market analysis (hydrogen production, chemical industries, modular fuel systems), intellectual property strategy, and potential licensing pathways. Simultaneously, a patent application will be filed covering the novel planar geometry and sequential tape-casting process. A non-disclosure agreement (NDA) framework will be prepared for potential industry collaborators. From months 6 to 18, the technical focus will shift to the fabrication and integration of complete protonic cells at 25 cm² scale using screen-printed Ni-BZCY electrodes. A laboratory-scale PMR prototype with real SMR feedstock (including CO₂ and H₂S contaminants) will be constructed and tested under varying conditions (T, P, feed composition) to assess conversion rates, selectivity, and stability. In parallel, Life Cycle Assessment (LCA) and techno-economic analysis (TEA) will be conducted to benchmark against existing SMR units. Between months 18 and 36, two directions will be pursued: (i) scaling up to pilot-level stack modules (up to 500 cm²) and (ii) initiating certification procedures for pressure-based systems, emissions, and material handling. Field testing at Ecosite demonstrator sites will be planned, evaluating hydrogen output, integration with waste-derived methane sources, and system compatibility. From month 36 onwards, CSIC will coordinate market entry preparation, including the identification of commercial partners (e.g., SMR operators, hydrogen integrators), drafting licensing agreements, and engaging in fundraising activities (EU Green Deal instruments, EIC Accelerator, industrial partners) to support full commercialization.
Roles	CSIC will be the main responsible for exploitation and further development of the PMR technology, managing IP, lab-scale scale-up, and coordination of certification. Ecosite managers (BEOF/BOKU/FACSA/NTUA) will act as early adopters, offering testing environments for the pilot units and operational feedback. PRJ will support in LCA/TEA, to assess the sustainability of the scaled up membrane/catalyst in comparison with the current catalysts used in the market Industrial advisors or hydrogen-focused SMEs will be engaged to evaluate manufacturing scalability and potential go-to-market strategies.
Milestones	M6: Patent filed; business plan finalized; NDA template shared with potential partners. M12: Screen-printed Ni-BZCY full cells fabricated at 25 cm²; lab PMR prototype assembled. M18: Electrochemical performance validated under real feedstock; LCA and TEA completed. M24: Pilot module design (500 cm²) ready; manufacturing partners shortlisted. M30: Field testing started at Ecosite; stability under continuous H₂S exposure validated. M36: Certification pathway initiated; market-entry feasibility report completed. M42: Licensing agreement drafts prepared; investor pitch deck and VC outreach initiated. M48: Technology at TRL 8/9; pre-commercial units ready for deployment.
Costs	Patent filing and IP strategy: €25,000 Full cell production (materials + processing): €260,000

	Lab-scale prototype and performance testing: €185,000 Business development and LCA/TEA: €100,000 Pilot module development and integration: €200,000 Field testing and certification: €250,000 Licensing/legal framework and commercialization prep: €70,000
Revenues	CSIC: Licensing IP, consulting, and EU grants for PMR commercialization. BOKU/NTUA/FACSA/BEOF: Operational savings and pilot testing fees from PMR integration. PRJ: Revenue from LCA/TEA consulting for industrial partners. Industrial SMEs: Manufacturing/selling PMR components or systems under license. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	EU Innovation Fund / EIC Pathfinder/Accelerator: Regional/national innovation agencies Collaborative industrial R&D projects

Exploitation roadmap for KER5 Optimization of polyhydroxy alkanoates (PHAs) production	
Actions	By the end of the SYMSITES project, the polyhydroxyalkanoates (PHA) production technology using mixed microbial cultures (MMC) and real, variable effluents will have reached Technology Readiness Level (TRL) 4, having been validated in a laboratory environment. From the end of the project, over the next four years, this technology will be scaled to TRL 8/9, making it ready for commercial deployment. A comprehensive techno-economic and market feasibility analysis will be conducted to determine the most viable business model, whether through the sale of bioplastics or the licensing of the technology. Intellectual property (IP) protection will be secured, including process patents for MMC-based PHA synthesis from waste effluents and associated operational strategies. Early discussions will be initiated with potential adopters, such as bioplastics manufacturers, municipalities managing wastewater plants, and wastewater utilities. A bench-scale pilot bioreactor (30 to 50 L) will be set up to simulate continuous flow operation using real acidified wastewater. Process performance, including yields, PHA quality, robustness across different effluents, and polymer extraction efficiencies will be evaluated. Life cycle assessment (LCA) and life cycle costing (LCC) studies will be initiated to compare technology with petroleum-based plastics and other bioplastic production methods. Protocols for PHA purification, packaging, and quality assurance will be developed, and initial industrial partnerships with PHA compounders, sustainable packaging companies, and wastewater utilities will be established. Later, the technology will be scaled to a semi-industrial demonstration unit (500 to 1000 L) within an operational wastewater treatment facility. Long-term operability and reproducibility of MMC under non-sterile, real-world conditions will be tested. The business plan and go-to-market strategy will be refined, and regulatory compliance will be finalized. Licensing partners and investors will be engaged to support final scale-up efforts. Once the pilot scale is achieved, an industrial-scale validation system (1 to 2 m³) will be launched to demonstrate continuous operation with real effluents and assess product performance in real-use applications, such as films, packaging, and agricultural products. The commercial PHA product portfolio will be finalized in collaboration with end-users, and the technology will either be licensed or spin off into a startup (if pursued by NTUA or commercial partners). Finally, findings and benefits will be communicated to policymakers to advocate for bioeconomy incentives and position the technology for public procurement opportunities.
Roles	NTUA (National Technical University of Athens): Main responsible for technical development, pilot testing, and IP protection. Will lead upscaling and optimization. PRJ: Support in carrying out comparative Sustainability assessment of the system at each stage. Ecosite managers: Provide real effluent streams, collaborate on on-site testing Industrial Partners (PHA compounders, bioplastics converters): Collaborate in material testing, market deployment, and feedback. Business/Innovation Consultants: Support IP, market strategy, and funding applications. Regulatory Advisors: Ensure REACH compliance.
Milestones	M6: IP protection filed, business model validated (licensing or product sale). M12: Bench-scale bioreactor operating continuously; early PHA yields and composition validated. M18: LCA/LCC completed; preliminary PHA purification strategy developed.

	<i>M24: First industrial partner engaged; pilot demonstration site selected.</i> <i>M30: Semi-industrial demo reactor built; sustained operation demonstrated; PHA application tests begun.</i> <i>M36: Regulatory pathway mapped (REACH, compost ability); business plan finalized.</i> <i>M42: First licensing discussions or spin-off registration initiated.</i> <i>M48: Full-scale demo validated; commercialization strategy implemented.</i>
Costs	<i>Techno-economic & market analysis, IP filing: €75,000</i> <i>Bench-scale reactor & testing: €125,000</i> <i>Pilot reactor construction and operation: €200,000</i> <i>LCA/LCC, polymer testing: €120,000</i> <i>Semi-industrial unit, validation in real WWTP: €300,000</i> <i>Regulatory compliance, QA system setup: €75,000</i> <i>Full-scale validation, product testing, dissemination: €400,000</i> <i>Commercialization preparation (legal, marketing, licensing): €100,000</i>
Revenues	<i>NTUA: Licensing fees, IP royalties, or spin-off equity from technology commercialization.</i> <i>PRJ: Consulting fees for sustainability assessments and LCA/LCC studies.</i> <i>Ecosite Managers: Revenue-sharing from PHA production or service fees for effluent supply/testing.</i> <i>Industrial Partners: Profits from PHA-based product sales or cost savings from licensed technology.</i> <i>Business/Innovation Consultants: Fees for IP, market strategy, and funding support.</i> <i>Regulatory Advisors: Service fees for compliance and certification guidance.</i> <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	<i>EU Innovation Fund, LIFE Program, Horizon Europe EIC Transition</i> <i>Seed capital from sustainability-oriented funds or cleantech incubators.</i> <i>Utilities hosting pilot/demonstration facilities.</i> <i>Industrial partners co-investing in polymer testing.</i>

Exploitation roadmap for KER6: Fertilizer production ((NH ₄) ₂ SO ₄) from nutrient recovery	
Actions	At the end of the SYMSITES project, the ammonium sulphate production process will stand at TRL 4, having demonstrated successful nutrient recovery from anaerobic wastewater using integrated biological and membrane technologies at lab scale. In the first 6 months post-project, efforts will focus on refining a detailed exploitation roadmap, including a techno-economic feasibility study, business model definition, and exploration of intellectual property protection for the integrated recovery system. Simultaneously, BOKU will begin the design and upscaling of a pilot prototype tailored for continuous operation within the Spanish EcoSite, managed by FACSA. FACSA will initiate preliminary site adaptations, permitting, and safety clearances for the installation of membrane contactors. By Month 12, the prototype will be installed and commissioned at the Spanish pilot, allowing continuous testing for real-site validation under varying effluent compositions. PRJ will initiate a lifecycle assessment (LCA) and lifecycle cost (LCC) analysis of the integrated system, refining the environmental and economic impact profile. Later, optimization of the membrane and desulphurization modules will be carried out in collaboration with FACSA, exploring integration into decentralized wastewater treatment and EcoSite operations. Parallel to this, stakeholders will work on certification and authorization processes for fertilizer use in agricultural markets and finalize a go-to-market strategy, identifying key customers (e.g., organic farms, municipalities, and industrial parks). A final demonstration under real industrial-urban symbiosis conditions will be executed at TRL 8/9, including a performance guarantee trial with early adopters. Strategic dissemination, customer engagement, and potential licensing or spin-off opportunities will be developed to ensure long-term sustainability.
Roles	BOKU: Lead developer of nutrient recovery technology; responsible for laboratory refinement, prototype design, and initial upscaling activities. FACSA: Spanish EcoSite manager and early adopter; responsible for on-site implementation, pilot plant adaptation, system integration, and feedback for real-site validation. PRJ: Responsible for carrying out detailed LCA and LCC studies, supporting sustainability assessments and business case development. EcoSite Managers (Greece, Austria, Denmark): Potential early adopters and testbeds for expanded trials at later TRL stages. Exploitation Lead: BOKU (in collaboration with FACSA), coordinating the roadmap toward commercialization.
Milestones	M6: Completion of techno-economic feasibility study, business plan outline, and IP review M12: Design and installation of TRL 5 prototype at Spanish EcoSite, initiation of on-site validation M18: Mid-term evaluation of prototype performance and process optimization plan M24: Completion of LCA/LCC studies and adaptation of system for continuous operation M30: TRL 7 reached, stable performance in operational conditions, fertilizer quality testing M36: Initiation of authorisation processes and certification for agricultural use M42: TRL 8 pilot validation with early adopters, market testing of product (NH₄)₂SO₄ M48: At TRL 9 technology readiness for full commercial exploitation, final market deployment plan
Costs	€150,000: Prototype development and lab-to-pilot scaling (BOKU) €150,000: Site preparation, permitting, and installation (FACSA)

	€120,000: LCA/LCC studies (PRJ) €30,000: Business plan, IP, and regulatory planning (All) €200,000: Pilot optimization, real-environment validation, and adjustments €80,000: Certification, safety, and fertilizer quality testing €70,000: Dissemination, customer engagement, and commercialization strategy
Revenues	BOKU: revenues through technology licensing, commercial fertilizer sales and scaled-up system advisory services. FACSA: Integrated wastewater treatment solutions. PRJ: Specialized sustainability assessments and lifecycle analysis services. EcoSite Managers: pilot hosting fees and regional fertilizer distribution. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	• EU Innovation Fund, LIFE Programme, Horizon Europe EIC Transition • Seed capital from sustainability-oriented funds or cleantech incubators. • Engage with circular bioeconomy clusters and sustainability accelerators (e.g., EIT Climate-KIC) • Early sales revenue from pilot implementation to be reinvested in expanding TRL and market preparation activities

Exploitation roadmap for KER 7-Development of nano enabled antimicrobial composite for absorbent column

Actions	In the immediate post-project phase, we will undertake a series of strategic, technical, and business-oriented activities to pave the way for commercialization. Technically, we will initiate the upscaling of the lab-tested composite materials (C-AgPLN and Olive stones) to a pilot-scale adsorption column capable of treating significantly larger volumes of effluent under continuous flow conditions. Parallely, an industrial design of the adsorption column will be developed to integrate the nano-enabled material into modular filtration systems. In parallel, we will prepare and submit a European patent application covering the novel nano-functionalized cork composite (C-AgPLN) and its integration in activated carbon columns. We will assess freedom-to-operate (FTO) and carry out IP landscaping. On the business side, a comprehensive business plan will be finalised, including a detailed market analysis, stakeholder mapping, cost-benefit analysis, and pricing model. Early engagement with potential adopters, such as wastewater treatment plant operators, industrial park utility managers, and decentralized water treatment providers, will begin through targeted dissemination and networking. Regulatory pathways will also be analyzed, and initial steps will be taken to certify the technology according to water treatment standards (e.g., EU Drinking Water Directive and ISO 22241).
Roles	UPC will lead the exploitation roadmap as the principal owner and developer of the technology. UPC will manage IP protection and coordinate pilot scaling in their labs. GREENE will provide the necessary activated carbon to UPC for setting up the Activated carbon filtration column. EEP will provide olive waste to GREENE to produce activated carbon, and send Olive stones to UPC for preparing the antimicrobial composite JOV will be responsible for sending textile waste to GREENE for producing activated carbon NTUA/FACSA/BEOF/BOKU, the ecosite managers will provide UPC with the parameters to develop the scaled-up Adsorption column, based on the requirement of the scaled up ecosite in each of the ecosite in principle, these ecosite managers will be the early adopters of this technology.
Milestones	M3: Patent application filed M9: Pilot-scale prototype designed and tested M15: Field testing initiated at industrial/municipal site M18: Regulatory pre-approval steps completed M24: Business model validated with early adopters M30: Commercial-ready product developed (TRL 8/9) M36: Licensing agreement signed or spin-off company launched
Costs	UPC: €450k (IP protection, pilot-scale column development, lab testing, and regulatory compliance). GREENE: €300k (Production and supply of activated carbon from textile and olive waste.) EEP: €150k (Supply of olive waste to GREENE and olive stones to UPC.) JOV: €120k (Collection and supply of textile waste to GREENE.) NTUA/FACSA/BEOF/BOKU: €250k (Ecosite parameter analysis, field testing, and early adoption support.)
Revenues	UPC: Licensing fees, patents, spin-off profits, and commercialized technology sales. GREENE: Sales of activated carbon and potential royalties from composite materials.

	EEP: Revenue from supplying raw materials (olive waste/stones) and potential partnerships. JOV: Revenue from textile waste supply agreements and circular economy partnerships. NTUA/FACSA/BEOF/BOKU: Cost savings from improved wastewater treatment, operational efficiencies, and potential licensing. Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.
Other sources of coverage	EU Innovation Fund or LIFE Programme for scaling water innovation. EIC Transition or Eurostars Catalan regional innovation funds (ACCIO, CDTI). Private investors and impact venture capital, particularly those targeting green and water tech solutions.

Exploitation roadmap for KER 8-Upgrading of pyrolytic liquids to platform molecules	
Actions	Post-project, the technology (TRL 5) will be advanced through pilot-scale optimization (50-100L batches) to validate extraction efficiency (>75% yield, >88% purity) and solvent recovery (>90% DME). Robustness testing across biomass and textile waste feedstocks will ensure process reliability, while initial automation and crystallization improvements will enhance scalability. Early industry engagement will identify pilot partners for integration with pyrolysis plants. Years 2-3 will focus on industrial validation, including long-term stability tests (500+ cycles) and continuous process optimization. Downstream applications will be demonstrated through partnerships, particularly in textile antifungal treatments, while IP protection and regulatory approvals are secured. A flexible business model (licensing vs. unit sales) will be finalized, supported by market analysis and funding strategies (grants, investors). By Year 4, commercialization will begin with full-scale deployment of modular extraction units or licensed technology. Supply chains for DME and purified platform molecules will be established, targeting bio-refineries and chemical manufacturers. Revenue streams will shift from R&D grants to product sales/licensing, achieving TRL 8/9 and market entry within four years.
Roles	GREENE (Lead Exploiter): Process scale-up, pilot testing, IP management. CSIC: Technical validation, crystallization optimization. Ecosite managers: Integration with pyrolysis plants, market testing. Business/Commercial Partner: Licensing, sales strategy, regulatory compliance.
Milestones	M6: Pilot extraction unit design finalized; feedstock variability tests begin. M12: First pilot runs (50L scale) completed; extraction efficiency confirmed. M18: Automated control system prototype developed; solvent recyclability tested (100+ cycles). M24: Industrial partner secured for integration; preliminary IP filed. M30: Long-term stability tests (500 cycles) completed; purity benchmarks met. M36: First commercial agreement signed (licensing or unit sale). M42: Regulatory approvals obtained; full-scale deployment begins. M48: Revenue generation from licensing/sales; market expansion.
Costs	GREENE: €600K (pilot scaling, automation, IP) CSIC: €300K (process optimization, crystallization R&D) Industrial Partners: €400K (integration testing, market validation) Business Partner: €200K (commercialization, regulatory compliance)
Revenues	GREENE: Revenue from technology licensing and engineering services for extraction system deployment. Ecosite managers: Revenue from valorized platform molecule sales and optimized waste processing services. Business Partner: Income from commercialization contracts, distribution agreements, and market expansion services. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	Public Grants: Horizon Europe, national bioeconomy funds. Private Investment: Venture capital, industry partners. Loans/Subsidies: Green technology incentives.

Exploitation roadmap for KER 9 Social Decision Support System	
Actions	At the conclusion of the SYMSITES project, the SDSS will reach TRL 7, having been piloted in selected territories. KLINK will develop a commercialization roadmap, finalize a business model and pricing strategy, with support from AGRA and PRJ. ITG and KLINK will enhance the software interface using pilot feedback. The full-featured SDSS tool will be finalized, with performance improvements, semantic navigation refinements, and a user support system. A GDPR and public procurement compliance audit will be conducted, alongside the creation of marketing materials. Later a market entry campaign will launch, offering pilot licenses to early adopters, while SDSS advances to TRL 8 in live environments. A SaaS deployment will be developed for smaller clients. From months 24 to 48, full commercial deployment will begin, with framework agreements, PPI proposals, and service contracts. New modules will be added, and subscriptions and consulting packages will be offered. Expansion into broader European markets will focus on circular economy and urban sustainability, aiming for TRL 9 by month 48 with a sustainable, scalable business model.
Roles	• KLINK will serve as the primary exploitation lead, responsible for the overall commercialization roadmap, business development, and coordination of go-to-market activities. KLINK will also lead further development and exploitation of the ABM-based employment impact indicator integrated within the SDSS. • ITG will be responsible for the technical upgrade of the SDSS software, ensuring seamless integration with existing SYMSITES modules (SMCO, MATCH, IUSM). ITG will also manage system scalability, user interface enhancements, and SaaS deployment. • AITEX will contribute to the alignment of the SDSS with industrial symbiosis contexts, ensuring that social and environmental dimensions related to material flows are well-integrated and validated within new territories. • Pilot Municipalities and Regional Agencies (engaged during SYMSITES) will continue their role as testbeds and early adopters, providing validation environments, stakeholder feedback, and references for wider deployment. • External Policy & Legal Consultants may be subcontracted for regulatory compliance, public sector procurement strategy, and support for GDPR and digital services certification.
Milestones	M6: Finalize business model, design SaaS architecture. M12: Release SDSS v1.0, complete compliance audits, secure 3 early adopters. M18: Refine software based on feedback, launch SaaS, expand to new regions. M24: Achieve TRL 8, deploy customer support system. M30: Secure first public contract, launch targeted outreach. M36: Release next-gen modules, onboard 5+ paying clients. M42: Apply for EU innovation catalogues, partner with consultancies. M48: Achieve TRL 9, establish cash-flow-positive operations.
Costs	KLINK: €120,000 (business development, commercialization roadmap, ABM-based indicator exploitation). ITG: €180,000 (software upgrades, SaaS deployment, scalability enhancements). AITEX: €50,000 (industrial symbiosis alignment, validation in new territories).

	Pilot Municipalities/Regional Agencies: €30,000 (testbed operations, feedback collection). External Policy & Legal Consultants: €45,000 (GDPR compliance, procurement strategy).
Revenues	KLINK: licensing fees, business model consulting ITG: SaaS subscriptions, technical customization AITEX: specialized consulting on material flows Pilot Municipalities/Regional Agencies: pilot licensing, stakeholder referrals External Policy & Legal Consultants: ongoing compliance services <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	Partners' Funds: KLINK & ITG allocate R&D budgets for 6-9 months. EU/National Grants: Apply to EIC Transition, Horizon Europe, and national innovation schemes. PCP/PPI: Secure early adopter contracts such as LOI. Impact Investors: Engage ESG-focused funds or civic tech accelerators. Partnerships: Collaborate with consultancies to share costs and accelerate sales.
Exploitation roadmap for KER 10 Design and Development of IIoTMT	
Actions	As the SYMSITES project concludes, the IIoT Management Platform (IIoTMP) has reached Technology Readiness Level (TRL) 7, demonstrating system prototype validation in an operational environment. The strategic exploitation roadmap over the next four years aims to raise this technology to TRL 9, achieving full commercial deployment and sustainable revenue generation. In the first month's post-project, the focus will be on finalising the business plan and preparing for commercial readiness. This includes conducting a market and competitive analysis to identify early adopters, use cases (e.g., municipal water treatment plants, industrial wastewater handlers), and pricing models (SaaS, licensing, etc.). Additionally, an IP protection strategy will be finalised, assessing copyright and licensing opportunities for the software stack. Concurrently, a beta version of the commercial-ready IIoTMP will be deployed at existing EcoSites under extended support contracts to collect advanced user feedback and refine the simulation and optimization modules. The data acquisition and modelling strategy will also be upgraded to enable real-time analytics, automated alert systems, and cross-site benchmarking features. By the end of Year 1, a certification and compliance check (e.g., ISO/IEC 27001 for data security, GDPR compliance for data privacy) will be completed to ensure the platform meets requirements for municipal and industrial procurement. A commercialization package will be prepared, including sales materials, demo videos, and a landing website. Simultaneously, potential customers and integrators in Europe will be engaged through trade fairs and targeted B2B events. In Year 2, commercial pilots will be launched with at least three new clients outside the consortium. Customer feedback and operational KPIs will drive iterative updates of the IIoTMP. The backend engine will also be enhanced to include predictive analytics, ML-based disruption forecasting, and cross-site optimization recommendations. The tool will gradually transition into a commercial SaaS product, supported by a digital onboarding portal and API documentation for integration with other industrial platforms.

	Later, the business model will expand to include tiered subscriptions, white-labelling options for consulting firms, and revenue-sharing licensing schemes with EcoSite technology integrators.
Roles	• ITG (Lead Exploitation Partner): Main responsible for commercial exploitation, business planning, software development, DevOps, and commercial SaaS deployment. • KLINK: Support in the integration of AI and ML models • NTUA, BOKU, FACSA and BEOF (EcoSite Managers): Early adopters and pilot testers, offering real-world feedback and beta site access. • AITEX: Simulation validation.
Milestones	M6: Business plan & IP finalized; beta at 2-4 Ecosites. M12: Certifications done; 3 pilots live. M18: First paid deployment; feedback system active. M24: Predictive analytics added; 5 customers secured. M30: ERP/SCADA integration tested; 2 sales partners. M36: Break-even; 10 deployments; white-labelling ready. M42: New sectors entered; tiered pricing launched. M48: Full rollout; support & upgrades ongoing.
Costs	ITG: €320K (technical dev, sales, operations, certifications). KLINK: €250K (AI/ML model integration support). NTUA/BOKU/FACSA/BEOF: €250K (pilot testing, feedback, site access). AITEX: €30K (simulation validation).
Revenues	ITG: Primary income from SaaS subscriptions, licensing fees, and white-label partnerships as the platform scales commercially. KLINK: Earnings from AI/ML model integration services and ongoing support for predictive analytics features. NTUA/BOKU/FACSA/BEOF: Revenue through beta-site royalties, shared savings from operational optimizations, and potential referral incentives. AITEX: Consulting fees for data integration advisory and validation services, with potential upsell opportunities. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	• Partners' own resources: ITG invest up to €80,000 in Year 1 from internal innovation budgets. • Public funding: Application for national innovation grants (e.g., CDTI Spain, EIC Transition, or Digital Europe programme). • New EU project proposals: Integrate IIoTMP into future Horizon Europe proposals (e.g., for circular economy or digital twin platforms). • Private capital: Explore regional venture capital or angel investment rounds focused on cleantech SaaS tools.

Exploitation roadmap for KER 11 Design and Development of ITRMP	
Actions	Towards the end of SYMSITES project, the ITRMP will have achieved TRL 7. A four-year commercialization plan has been established to reach TRL 9, covering technical refinement, market strategy, regulatory compliance, and business model finalization. Initial activities will include forming a commercialization taskforce (ITG/KLINK), conducting market studies, optimizing the system through pilot testing, and ensuring GDPR compliance while assessing IP protection for core algorithms (MATCH, IUSM, k-SDSS). By Year 2, a commercial MVP will launch featuring cloud deployment and optional integrations with waste registries/geospatial systems. The team will complete certification processes while engaging early adopters through targeted campaigns. Years 2-3 focus on signing deployment contracts with EcoSite regions, implementing a hybrid licensing model (subscriptions for public authorities, consultancy for private networks), and establishing technical support/training programs. User feedback will drive continuous improvements through an integrated feedback loop. The final phase (Years 3 to 4) delivers ITRMP v2.0 with analytics dashboards, real-time SDSS, and enhanced modelling tools (ABM/FCM). Scaling efforts will target EU Green Deal participants and Horizon Europe clusters through franchising and partnerships. The strategy includes aligning with European data space initiatives while exploring risk capital investments to ensure long-term revenue sustainability and global expansion.
Roles	ITG (Main Exploiting Partner): Will lead the commercialization roadmap, technical refinement, product packaging, and coordination with regional authorities. KLINK: Responsible for k-SDSS module refinement, ontology and knowledge management, and scientific support. AITEX: Will support stakeholder engagement, validation with industrial partners, and alignment with regional smart specialization priorities. EcoSite Managers: Will act as reference cases and provide testimonials, host extended pilots and serve as regional ambassadors. Support Actors: Legal/IP consultants, business advisors, digital compliance experts, and innovation agencies.
Milestones	M6: Final business plan, IP/data governance, and market analysis completed. M12: TRL 8 pilots started; MVP v1 launched; GDPR compliance initiated. M18: Pilot feedback integrated; licensing model finalized; partnerships advanced. M24: Commercial MVP v1.5 deployed; first contract signed. M30: Impact metrics evaluated; new stakeholders onboard; marketing toolkit ready. M36: ITRMP v2.0 released with new features; 3–5 regional licenses secured. M42: 100+ active users; localization efforts began. M48: Full commercial scaling; user community platform live.
Costs	ITG: €210,000 (leading commercialization & technical refinement) KLINK: €144,000 (k-SDSS refinement & scientific support) AITEX: €22,000 (Stakeholder engagement & validation) EcoSite Managers: €250,000 (pilot hosting)
Revenues	ITG: Leads commercialization, earning through software licenses, consultancy, and premium feature subscriptions. KLINK: Generates revenue from specialized k-SDSS module licensing and ontology-related scientific services. AITEX: Monetizes via industry-specific customizations, validation services, and stakeholder partnership deals.

	EcoSite Managers: Earns through pilot hosting fees, regional deployment contracts, and ambassador partnerships. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	• Partner Contributions: ITG will dedicate in-kind resources and development capacity for the first 12 months post-project. • EU/National Grants: Applications to EIC Transition, Digital Europe, or Life Programme for TRL 8 to 9 scaling. • Regional Innovation Support: Application to regional innovation accelerators (e.g., Galicia, Valencia). • Private Investment: Exploration of seed funding from sustainability/cleantech venture funds for commercial scaling from M24 onwards. • Public Procurement for Innovation (PPI): Engagement with public authorities to procure the solution under innovation procurement schemes.

Exploitation roadmap for KER 12	
Actions	- Finalize and validate the regional I-US business plan integrating KER12 - - Establish SYMSITES joint venture by 3 leading partners (among them at least one Ecosite leader) to represent the KER 12 achievements. Conduct licensing scheme with the technical KERs' leaders to optimize SYMSITES value proposition and market positioning with strong licenses and/or exclusivity. - Develop funding strategy with EU grants, and at least one private/public investment. Institute. - Develop the KERs specifications. - Develop commercial business offers to each segment. - Start offtake agreements with early adopters.
Roles	- Main responsible: SYMSITES Joint venture (3 leading partners as representatives) or will lead the strategy and agreements - Each technical KER leader will be responsible to reach the technical milestone set. - Research/Technical partners: TRL advancement - Municipalities: Infrastructure and adoption, the 4 Ecosites regions will be addressed as the first early adopters with revenue opportunity, and generous terms for the early adopters. - Industrial partners: after partnership agreement with the joint venture - Co-investment and O&M support. - Business/Finance experts: Business planning and funding. To be contracted with the Joint venture budget for the project development.
Milestones	(F – project finish) - Joint venture agreement (F+3) - Finalised Business Plan (F+9) - IP Protection Measures (M+12) - Stakeholder Roundtables (M36-48, F+12) - Funding Applications (M36-48, F+12) - Industrial partnerships (F+9) - First Service Agreement (M+15) - TRL 7-8 (F+36) - Biogas validation (F + 12) - Irrigation water quality targets lab scale (F+12)
Costs	1-Year: - IP & legal: €30,000 - business verified plan: €50,000 - Business dev.: €100,000 - Coordination: €80,000 - Compliance, lab improvements: €60,000 Total: €320,000

	• 3-Year <i>including</i> TRL 7-8: - Total: €5,000,000 • 6 Year – 1st FOAK – TRL 9 + Service agreement: 20,000,000 e
Revenues	• Year 1: ○ 3 Leading partners – 100.000 e ○ 20 Consortium Partners -150,000 e ○ 2 municipalities (Eco-site or others) -80,000 • Year 3: ○ Total: blend financing: EU + Industry : 6,000,000 • Year 6 – service agreement – 15,000,000 + + EU investment support: 10,000,000 ○ HVNRs sales – 5,000,000 e / 2nd year
Other sources of coverage	• Clean tech VC funding support • NGO/government UN SDG • EIB/development banks

Exploitation roadmap for KER 14.1 Social Spin off	
Actions	Within the first 3 to 6 months post-project, BOFA will lead the finalization of the Go-SYM spin-off business plan, define its legal structure (e.g. cooperative or foundation), and formalize a governance model involving key local actors such as Solhvervsfonden and AGRA. Letters of Intent will be signed with local stakeholders (schools, municipalities, SMEs), and applications will be submitted for national/regional circular economy funding. Awareness campaigns and stakeholder outreach will continue to build local engagement. Educational tools (board game and modular curriculum) will be adapted and introduced in additional schools and municipalities. Infrastructure development at the Svaneke Plantation will begin, supporting the launch of a regenerative living lab. In year 2, BOFA will coordinate the replication of the model in at least one other European EcoSite, supported by the 7-step guide. Licensing options for the educational materials will be explored, while partnerships with regional authorities and donors will be expanded. In years 3 to 4 after the end of the project, the Go-SYM initiative will consolidate into a revenue-generating social enterprise offering education, training, and community engagement services. The regenerative lab will scale with circular construction demonstrations, local food production, and skills-based residencies.
Roles	BOFA: Lead exploitation partner, spin-off coordinator, community facilitator AGRA & BEOF: Regional stakeholder integration, support local action planning AITEX & NTUA: Technical replication support and resource flow mapping in new regions BOKU: Methodological and educational content evaluator FACSA: Connect with water/resource-related industries for potential synergies Behave Green: Support co-creation, outreach design, and educational material rollout Solvhervsfonden: Manage Svaneke Plantation regenerative lab and training infrastructure
Milestones	M6: Business plan finalized; legal registration of spin-off completed; LOIs signed; initial funding applications submitted M12: Two new local symbiosis cases launched; educational tools deployed in two new schools; Svaneke Plantation upgrades begin M18: Regional replication pilot launched in a second EU site; board game and curriculum ready for licensing M24: Go-SYM generates first revenues from compost sales, residencies, and training; school outreach expanded to 5 institutions M30: Service agreements signed with regional/national bodies; infrastructure of regenerative lab fully operational M36: Educational tools licensed to external providers; replication guide adopted by 3 new municipalities M48: Social enterprise operational with recurring income; Go-SYM recognized as a regional demonstration hub for community-based circular transitions
Costs	BOFA: €40,000 (staff costs for part-time coordination + outreach; lead role in spin-off setup and replication). AITEX: €25,000 (technical replication support; included in pilot infrastructure and educational tool adaptation). Ecsoite Managers: €5,000 (industry synergy outreach; part of communication / promotion budget). Behave Green: €20,000 (co-creation and educational rollout; split between outreach and tool adaptation).

	Solhvervsfonden: €30,000 (Svaneke Plantation lab management; direct infrastructure costs).
Revenues	BOFA: Revenues from spin-off consultancy, training services, and governance model licensing). Ecosite Managers (FACSA, BEOF, NTUA, BOKU): technical replication fees, water/resource synergies, and educational content licensing). AITEX: Regional stakeholder engagement fees and local action planning support Behave Green: board game/curriculum licensing and outreach co-design services Solhvervsfonden: regenerative lab residencies, compost sales, and training programs). <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	BOFA and Partner Contributions National Education Grants EU Regional Development Funds (Interreg, LIFE) Local Sponsorships and Donations Crowdfunding & Mission-Aligned Investors

Exploitation roadmap for KER 14.2 Training materials	
Actions	Within the first 3 to 6 months after project closure, the consortium will finalise the full training package (PDFs and webinar videos), including all chapters and stakeholder-specific modules. A dedicated section on the SYMSITES website will be launched to host these materials, integrated with the virtual I-US game. A licensing model will be defined to allow municipalities, industrial parks, and education providers to access the content for structured learning. ICLEI, as the lead exploiter, will develop a business model and promotion plan targeting early adopters, such as members of the H4C community and local government networks. Partnerships with training institutions (e.g., universities, vocational centers) will be formalized to pilot and adapt the content for wider uptake. The exploitation team will also explore IP protection (e.g., Creative Commons licensing), submit funding proposals to extend the content, and initiate monitoring to gather feedback for content upgrades.
Roles	ICLEI (Lead Exploitation Partner): Business model development, stakeholder engagement, and hosting platform. Ecosite managers (BOKU, FACSA, NTUA and BEOF): Content finalization, educational adaptation, and case study integration. ITG: Maintain compatibility with the virtual game platform
Milestones	M6: Final training package (PDFs + videos) online on SYMSITES website. M12: First 3 pilot trainings conducted with local authorities/industry clusters. M18: Licensing and partnership model defined; 2 training partners onboarded. M24: Online training course with certification launched. M30: Content revised based on feedback; integration with virtual game evaluated. M36: Scaled dissemination through ICLEI and H4C networks. M48: Sustainable business model in place, training included in 3 city/regional learning agendas.
Costs	ICLEI (Lead): €30,000 (business model, hosting, marketing, outreach) + €10,000 (dissemination Y2-3). Ecosite Managers (BOKU, FACSA, NTUA, BEOF): €20,000 (content finalization, case studies) + €20,000 (staff/trainer costs Y2-3). ITG: €10,000 (platform maintenance Y1-3) + €5,000 (game integration updates).
Revenues	<i>ICLEI: Revenue from licensing, certified courses, and tailored training services for municipalities and institutions.</i> <i>Ecosite Managers (BOKU, FACSA, NTUA, BEOF): Revenue from training delivery, educational partnerships, and consultancy on module adaptation.</i> <i>ITG: Revenue from platform maintenance, virtual game integration services, and technical upgrades.</i> <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	ICLEI operational budget Horizon Europe Cluster 6 and LIFE+ project proposals to expand scope and content Regional/national green transition and capacity-building grants (e.g., Interreg, Just Transition Funds) H4C Community of Practice: in-kind support for dissemination and capacity building Erasmus+ or university partnerships for educational integration

Exploitation roadmap for KER 14.3 Replication package	
Actions	Following the project's conclusion, the main actions will focus on operationalizing and disseminating the Replication Package to targeted users, namely primarily municipalities, utility companies, and I-US facilitators. First, the Replication Package will be finalized and formatted into a downloadable web-based resource, including the self-assessment tool. A business and sustainability plan will be finalized, mapping long-term hosting, updates, and capacity-building services (e.g., training webinars, consultancy offerings). Intellectual property considerations (copyrights on videos, branding, methodology of the self-assessment tool) will be addressed. Outreach campaigns will be intensified through the Waste Association Network and partner networks. Piloting with 3 to 5 early adopter municipalities will be initiated to collect user feedback, adjust content, and document success stories. Efforts will begin to identify funding opportunities and strategic partners to sustain the Replication Package as a service.
Roles	ICLEI (Lead Exploiting Partner): Main responsibility for the exploitation roadmap; hosts and maintains the Replication Package platform; leads dissemination and stakeholder engagement. FACSA, BEOF, BOKU & NTUA (Ecosite managers): Provide scientific input, maintain replicability methodology, support updates to the self-assessment tool. AGRA: Engage local/regional stakeholders; coordinate piloting activities with interested municipalities or utilities; support documentation of regional replication cases.
Milestones	M6: Launch final Replication Package, onboard 3+ pilot municipalities, announce webinar series. M12: Complete pilot testing, update tool content, outreach to 50+ EU municipalities/utilities. M18: Sign MoU with 2 replication facilitators, secure 2-year hosting/update plan. M24: Integrate with EU support mechanism, 10+ municipalities submit case docs. M36: Start paid services (consulting, training), publish 5 case studies. M48: Release 2nd edition (new tools, stories), support 25+ replications.
Costs	ICLEI: €180k (Platform hosting, dissemination, stakeholder engagement, and maintenance). FACSA, BEOF, BOKU & NTUA: €25k (scientific input, methodology updates, self-assessment tool support). AGRA: €15k (local stakeholder engagement, pilot coordination, replication case documentation).
Revenues	ICLEI: Through paid consulting services, training webinars, and licensing agreements for the replication package. FACSA, BEOF, BOKU & NTUA: Benefit from expanded research impact, academic collaborations, and potential follow-up project opportunities. AGRA: Gains regional influence, strengthens municipal partnerships, and enhances its role as a facilitator for sustainable urban solutions. Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.

Other sources of coverage	• Partner Budget Contributions (in-kind): Staff time and internal dissemination resources • European/National Funding: Applications for follow-up EU grants (e.g., Interreg, Horizon Europe CSA calls), LIFE program on circular economy, I-US, and replication support under new Green Deal initiatives • City and Regional-Level Co-Funding: Leverage funds from interested municipalities (cost-sharing for pilot replication) • Private Sponsorship and CSR Programs: From corporates involved in circular economy or utilities sector, potentially supporting tool distribution or training • Synergies with Related Projects: Integration with other platforms from H4C ecosystem to reduce hosting and outreach costs
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Exploitation roadmap for KER 15 Virtual I-US game	
Actions	In the first 3to 6 months after SYMSITES concludes, the exploitation of the Virtual I-US Game will begin with consolidation and refinement of the platform for public deployment. This includes final testing and UI/UX adjustments based on initial trial feedback. A focused communication and dissemination campaign targeting educational institutions, municipalities, environmental agencies, and circular economy clusters will be launched. The game will be piloted with 3to5 early adopter municipalities and secondary schools to gather detailed user feedback and build credibility. Simultaneously, a business plan will be finalized, evaluating licensing models (e.g., annual school access or municipal packages), IP protection (trademarking the game name and content), and potential certifications for educational use. Grant applications and partnership outreach will be initiated to ensure medium-term sustainability and broader EU-wide replication.
Roles	ITG (Lead Exploiter) - Responsible for maintenance, technical improvements, hosting, and content updates. - Finalizes and implements the business model. - Oversees IP protection and coordinates exploitation roadmap. KLINK - Supports educational outreach and co-develops pedagogical materials. - Assists in content localization and game testing in school and community environments. ICLEI - Leverages municipal networks to connect the game with local authorities. - Supports promotional activities and documentation of use cases. - Municipalities & Early Adopter Schools (external stakeholders) - Pilot users and feedback providers for real-world application validation. - Potential co-promoters through local communication channels.
Milestones	M6: Piloted in 3–5 schools/municipalities; launched v1.1; finalized business plan. M12: Distributed educational package; partnered with regional authority; trademark registered. M18: Secured 10 paying customers; released v1.2; applied for educational certification. M24: Migrated to scalable server; launched EU marketing in 3 countries. M30: Translations to 3 additional EU languages completed, with 100 active users/year (institutions) reached M36: Revenues cover 50% of costs (progress toward 80%) M42: Revenues reach 80% cost coverage M48: Included in at least one regional/national university curriculum or circular economy toolkit across Europe
Costs	ITG: €55,000 (Year 1) + €60,000/year (Years 2 to 3) for technical maintenance, business plan finalization, IP protection, hosting, and coordination. KLINK: €12,000 (Year 1) + €15,000/year (Years 2 to 3) for educational material development, localization, and school testing support.

	ICLEI: €10,000 (Year 1) + €15,000/year (Years 2 to 3) for municipal outreach, promotional activities, and use-case documentation.
Revenues	ITG: Licensing fees from schools/municipalities, sponsorships, and potential EU/national grants for scaling. KLINK: Revenue-sharing from educational material sales, co-branded training programs, and grant-funded pedagogical expansions. ICLEI: Co-promotion fees from municipal partnerships, sponsored replication projects, and consultancy on circular economy adoption. <i>Revenues: to be assessed based on the economic value of the technology applied within the perimeter of the ecosite from which financial plan with P&L may be obtained.</i>
Other sources of coverage	• Partner in-kind contribution (ITG, KLINK) for maintenance and dissemination during Year 1 • EU/national grant applications (e.g., Erasmus+, LIFE, Interreg) for scaling and translation • Regional education or innovation funding • Crowdfunding or CSR sponsorships from companies in circular economy/waste sectors • Revenue-sharing models with municipalities or NGOs that promote or license the tool

Annex D: Main actions taken During the Project

1. Exploitation Committee

Was established in order to discuss Exploitation issues on a regular basis and discuss potential decisions to be brought for the GA voting. We have conducted 5 EC in various forums, including an open EC for the Whole consortium, with approximately half of the partners being represented.

2. KERs Workshop

Was Held at GA 30 by Partner PRJ, in order to discuss KERs ownership, background and fore-ground knowledge and more.

3. Booster service- UVP

Was held in 2025 Q1, aiming to refine mostly the UVP per segment of KER12.

4. Booster service - G2M

Was held in 2025 Q1, mostly to review the current status of business vision and development.

5. Booster service – BP

Was held in Q1 2026, to prepare the market-oriented business plan, and the proposed structure for the consortium.

6. Booster service – Networking

To be delivered in May 2026, to prepare a list of relevant contacts in the Urban and Industrial markets.

7. Booster IP service – the 1st meeting was held in Q1 2026, and the 2nd meeting to discuss the actual relevant IP strategy is due to May 2026.

***** End of Document *****