ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

Deliverable 5.5:

A Marketplace for Water, Energy, Materials in a WSIS

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Technical References

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RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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0.4	05.05.2023	Anne Kleyböcker (KWB)	Review of the deliverable
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Executive Summary

The deliverable D5.5 refers to the online WE Marketplace, and this document accompanies it. The marketplace can be accessed at:

https://mp.watereurope.eu

The ULTIMATE project has successfully developed the WE Marketplace, a Water Smart Industrial Symbiosis-focused (WSIS-focused) platform for Water, Energy, and Materials, in line with Task 5.5 requirements. Building upon the existing NextGen Marketplace, the WE Marketplace introduces new features and enhancements to better support WSIS in various industries.

Key developments in the WE Marketplace include the integration of a new industrial ontology-based matchmaking functionality, the incorporation of the Technology Evidence Base (TEB) from WP1, and the addition of ULTIMATE tools, such as the WP2-developed Key Performance Indicator (KPI) tool for WSIS. The Application Programming Interface (API) between the WE Marketplace and the Industrial Wastes Matchmaking Tool, developed by NTUA, lays the groundwork for enhanced matchmaking in symbiotic arrangements among problem owners and solution providers. Upon implementation, the tool will boost the effectiveness of the WE Marketplace, streamlining the process of finding optimal matches for by-products and industrial waste demands and offers. These enhancements promote the sharing of knowledge related to the Circular Economy (CE) and facilitate symbiotic arrangements among multiple stakeholders.

Primarily, as envisioned in the project's concept, the WE Marketplace is ideally positioned to operate as a comprehensive knowledge repository for CE-related technologies, products, and case studies. Furthermore, it is designed to serve as a collaborative platform for all stakeholders contributing to the WSIS, facilitating an integrated approach to sustainability. From the viewpoint of stakeholders, three principal actors are represented in the WE Marketplace: Firstly, **Problem Owners** - typically utilities, authorities, or industries - aiming to transform linear processes within their organizations into circular ones, minimizing waste and reusing resources. They may seek advice on suitable technology or potential partners for resource transfer, adjustment, or upscaling. Secondly, **Solution Providers** are usually commercial entities offering technologies, products or services as part of a CE-enabling portfolio. Thirdly, **Investors** are constantly on the lookout for opportunities to maximize their investment revenues. In addition to these key players, other stakeholders, including representatives of regulatory bodies, NGOs, and academics, may have an interest in participating in the marketplace, each with their unique perspectives and interests.

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Overall, the goals that this platform serves are the following:

- Facilitation of user exploration of a diverse range of **technologies, tools, products** and **services** related to the CE through advanced search functionalities.
- Illustration of **successful CE case studies** as a means of promoting best practices in the field.
- Enhancement of **networking** among CE community members including project partners, collaborators, clients, suppliers and technology providers.
- Provision of support for online **meetings** and **events**, fostering collaboration and partnerships within the CE sphere.
- Delivery of personalized, targeted information to users by leveraging a **recommender system** based on user profiles, preferences and interests.
- **Promotion** and **funding** of innovative initiatives, aiding startups in securing funds and facilitating promotional activities.

The WE Marketplace has already collected results from three EU funded projects, NextGen, B-WaterSmart and ULTIMATE. It is expected to grow and evolve further as ULTIMATE and B-WaterSmart project partners continue to upload new tools, technologies, and case study factsheets, enriching the platform's content. Other projects relevant to CE and WSIS have been invited and are also anticipated to contribute additional content, providing added value to the platform. As this project progresses and the WE Marketplace continues to develop and expand, it is well-positioned to become an essential tool for industry professionals, solidifying its role as a cutting-edge resource for CE professionals while fostering innovation and collaboration within the industry. By leveraging the latest AI technology and implementing user-friendly features, the platform will ensure that it remains at the forefront of innovation in the CE and the WSIS. In the coming months and years, the WE Marketplace team will continue to focus on refining the platform, addressing user feedback, and implementing new features to meet the evolving needs of the industry.

In conclusion, an agreement has been reached that Water Europe (WE) will maintain and continuously curate the WE Marketplace beyond the project's end, ensuring its sustainability. Originally initiated by the European Commission (EC) in 2004 as the European Technology Platform for water, under the name WssTP, WE has gained recognition as the leading advocate and facilitator of water-related innovation and research and technological development (RTD) within Europe.

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List of acronyms

API	Application Programming Interface
CAS	Chemical Abstracts Service
CE	Circular Economy
CO2e	Carbon Dioxide Equivalent
EU	European Union
GPL	GNU General Public License
GPT	Generative Pre-trained Transformer
HMS	Hydraulic Modeling and Simulation
HTTP	Hypertext Transfer Protocol
ISO	International Organization for Standardization
IWMMT	Industrial Wastes Matchmaking Tool
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
KWB	KWB KOMPENTENTZZENTRUM WASSER BERLIN GEMEINNUTZIGE GMBH
KWR	KWR WATER BV
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LLM	Large Language Model
MIT	Massachusetts Institute of Technology
NACE	Nomenclature of Economic Activities
NTUA	National Technical University of Athens
QMRA	Quantitative Microbial Risk Assessment
RTD	Research and Technological Development
SAREF	The Smart Applications REFerence ontology
SCALER	SCALing European Resources with industrial symbiosis
TEB	Technology Evidence Base
TRL	Technology Readiness Level
UK	United Kingdom
ULTIMATE	indUstry water-utiLiTy symbIosis for a sMarter wATer society
WE	Water Europe
WP	Work Package
WSIS	Water Smart Industrial Symbiosis

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1. Introduction

Within the scope of the ULTIMATE project, a WSIS-focused marketplace for Water, Energy, and Materials has been developed in line with Task 5.5 requirements. The Grant Agreement of ULTIMATE specifies that the existing NextGen Marketplace should be leveraged and augmented with advanced functionality to more effectively support Water, Energy, and Materials in a Water Smart Industrial Symbiosis (WSIS) context.

To meet Task 5.5 requirements, the existing Marketplace was updated with new industrial ontology-based matchmaking functionality, developed in T2.1, enabling registered users from various industries to explore potential symbiotic arrangements for reusing water, energy, and materials within their region. Additionally, the Technology Evidence Base from WP1 was integrated into the Marketplace, enriching the platform's information towards industrial symbiosis (technologies, regulations, applications, etc.). The new ULTIMATE tools, including the WP2-developed Key Performance Indicator (KPI) tool specifically designed for WSIS, were added to the existing Marketplace's toolbox. Finally, the basis for enhanced matchmaking functionality has been set, which takes into account not just matching problem owners and solution providers, but also facilitating symbiotic arrangements among multiple stakeholders.

The outcomes of T5.5 are presented in deliverable D5.5, which is the online WSIS-oriented marketplace for Water, Energy, and Materials. This enhanced version of the NextGen Marketplace is now accessible under the name WE Marketplace at the URL https://mp.watereurope.eu. Alongside the website, this document offers a detailed overview of the innovative features and improvements introduced throughout the ULTIMATE project, serving as an in-depth guide for users to better grasp the platform's advancements.

In the following sections, key aspects of WSIS in the WE Marketplace will be addressed. Section 2 discusses the data model for the WE Marketplace, focusing on the ontologies for industrial symbioses, the enhancements of the conceptual data model, and the implementation of the data model in a relational information system. Section 3 focuses on enhancing the Technology Evidence Base, introducing a taxonomy of technologies supporting the Circular Economy and discussing the relationship between products and technologies.

Section 4 delves into the enhancement of the toolbox, providing a short introduction to the NextGen Toolbox, expanding the attributes list of tools, and detailing the product factsheet submission process, including state transition and printable factsheets. Additionally, this section covers populating the Marketplace with

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ULTIMATE tools during the initial phase of the project and discusses other relevant aspects.

Section 5 examines the matchmaking functionality for WSIS, specifying industries and presenting a use case for searching resources. It also addresses the development of an API with the Industrial Waste Matchmaking Tool (IWMMT), describing various API functions. Finally, Section 6 concludes the report by summarizing the key findings and outcomes of the project.

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2. A Data Model for the WE Marketplace supporting WSIS

2.1. Ontologies for the Industrial Symbiosis

The ontologies for the WSIS have been defined in Task 2.1 and documented in D2.1, providing a structured representation of concepts and their relationships within the domain related to industries and their associated processes and technologies. According to these ontologies, an **industry** can have different roles, such as a resource producer, who creates resources, a resource consumer, who utilizes resources, or a solution provider, who offers problem-solving products or services.

These industries consist of various **processes** that contribute to the creation of products. To carry out these processes, industries rely on one or more **technologies**. These technologies are responsible for processing **resources** and generating new resources as needed. Moreover, technologies are not uniform across locations. They can be found in specific regions and locations, and their capabilities for resource recovery and processing may vary. This variability makes technologies a feature of interest within the ontology, indicating that they are an essential aspect to consider when studying or analyzing the domain. Finally, within the SAREF[1] ontological ecosystem, technologies also hold a significant place as features of interest (saref:FeatureOfInterest) (A. Corchero, 2022). Figure 1 showcases the relationships between industries, processes, and technologies, highlighting their roles and interdependencies within the context of resource production, consumption, and solution provision.

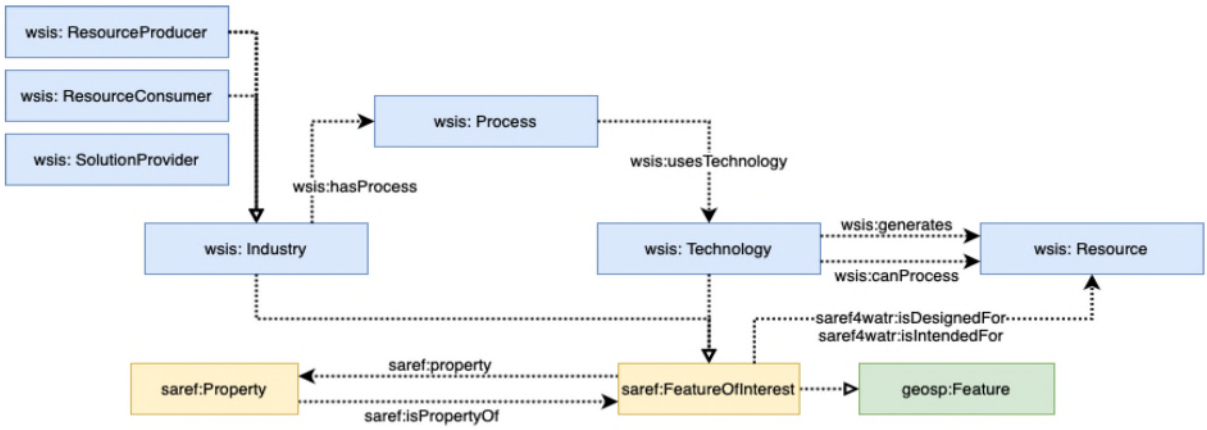

Figure 1: WSIS representation of the industrial symbiosis (source: A. Corchero, 2022)

[1] SAREF: The Smart Applications REFerence ontology

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2.2. Enhancing the Conceptual Data Model of the WE Marketplace

Based on the ontologies for the WSIS, the conceptual data model that has been developed for the relational database of WE Marketplace has been expanded to accommodate **Resource** entity. This entity is related to two technologies in terms of resource or by-product exchange. The first technology is one that produces by-products in a process, which another technology can utilize. More specifically, the Resource class consists of the following fields:

can_process: A foreign key field that establishes a relationship between the Resource class and a Technology class. This field represents the technology that uses the by-products of another technology.

generates: Another foreign key field that establishes a relationship between the Resource model and another Technology class. This field represents the technology that produces by-products that can be used in another technology.

An implemented referential action for handling foreign key constraints when a row is deleted in a related table ensures that related Resource instances will be deleted if the corresponding Technology instance is removed, maintaining the integrity of the data.

usage: A String that can store up to 255 characters representing the usage of a technology. It is optional (i.e., it can be left blank or set to null).

Additionally, the existing data model has been extended by incorporating two new entities: **Industry** and **Process**. Processes are connected to technologies through an optional many-to-many relationship, signifying that a technology can be employed in one or multiple processes, and a process can utilize one or more technologies. Similarly, a many-to-many relationship has been established between industries and processes, meaning that an industry can encompass one or several processes, and a process can be associated with multiple industries.

Figure 2 presents the entity-relationship diagram illustrating the specific portion of the conceptual data model designed to improve the WE Marketplace. This enhancement focuses on addressing challenges related to water-smart industrial symbiosis while maintaining alignment with the established ontologies.

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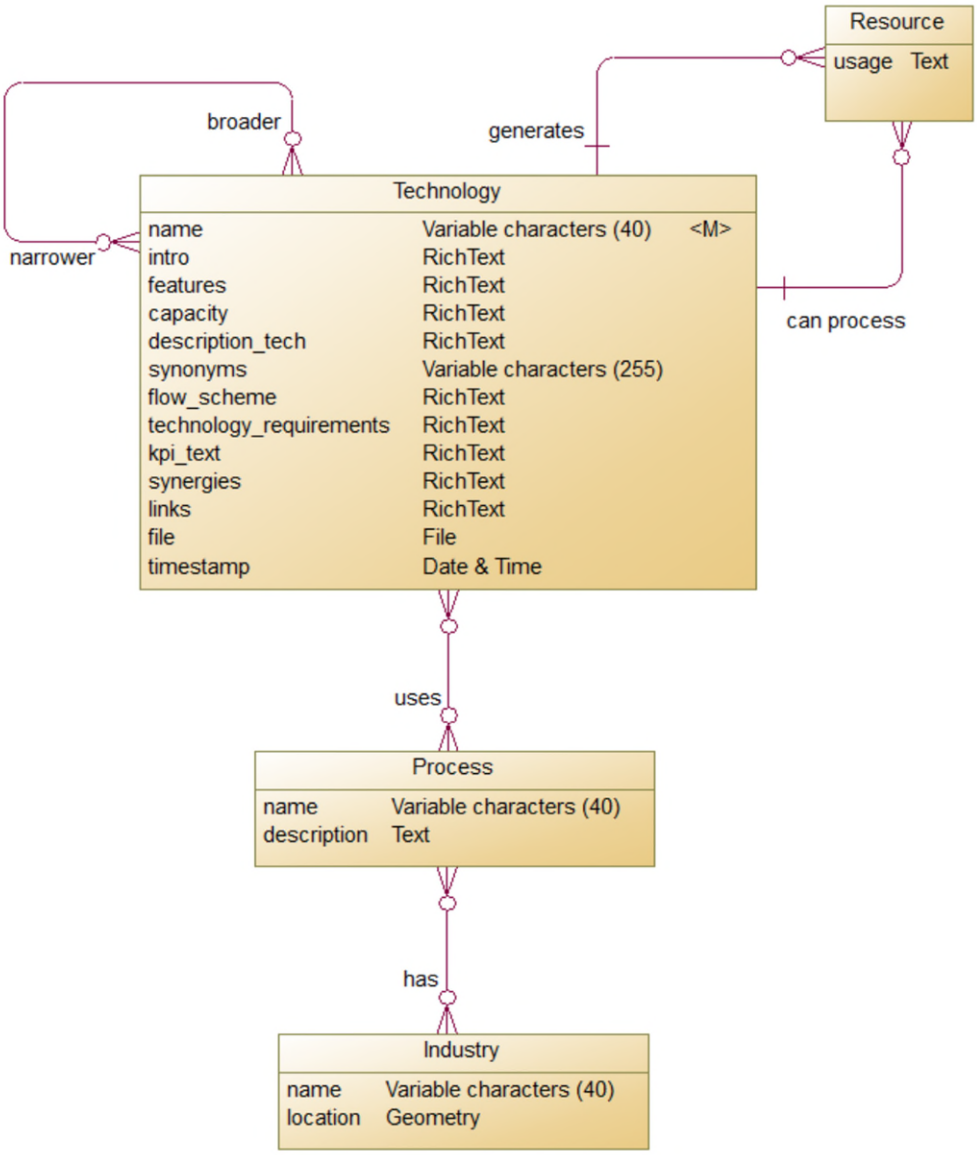

Figure 2: Entity-relationship diagram for the WSIS

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3. Enhancing the Technology Evidence Base

3.1. Fields and technologies supporting the CE and the IS

In the NextGen project, an open access database called Technology Evidence Base (TEB) has been developed (Kleyböcker, et al., 2023), focusing on technologies relevant for the CE, which were related to water management and recovery, material recovery, and energy recovery. In the initial version, the TEB included 24 innovative technologies that have been applied in the framework of the project in 10 case studies in Europe. For each technology, a factsheet was created, including details about its operation, unique selling points, implementation requirements, flow schemes, pictures, and links to relevant case studies. Similarly, factsheets for each case study were prepared, outlining the main results, lessons learned, best practices, and assessment outcomes.

In the ULTIMATE project, technologies have been identified that are particularly useful for the industrial symbiosis. Additional domains and technologies have been documented enhancing the TEB with technologies for the WSIS (see section 3.2). Next to technologies, numerous tools, products, and services utilizing CE technologies have been documented in the Marketplace and linked to technologies specified in the TEB. This has enabled the creation of cross-links between related pages on the platform, personalized product recommendations based on users' preferences and interests, and facilitated searches for products in specific fields of interest. However, many tools applied in case studies of both NextGen and ULTIMATE projects are general-purpose products, not directly related to CE and WSIS technologies. This is particularly true for software tools that can be highly useful in specific processes of the CE and WSIS but cannot be categorized within one of the common CE domains, i.e. water, energy or materials. As a result, there has been a growing need for a new domain of technologies supportive to the CE and to the WSIS, which has been developed in the framework of the ULTIMATE project. Table 1 lists scientific fields and technologies supportive to the CE and to the WSIS. These have been incorporated into the existing taxonomy of technologies, primarily to facilitate interconnections between technologies and other components of the platform. Consequently, these supplementary technologies aren't delineated as thoroughly as the core technologies within the CE's primary domains. Furthermore, unlike those for the main technologies, detailed factsheets for these fields and technologies won't be produced.

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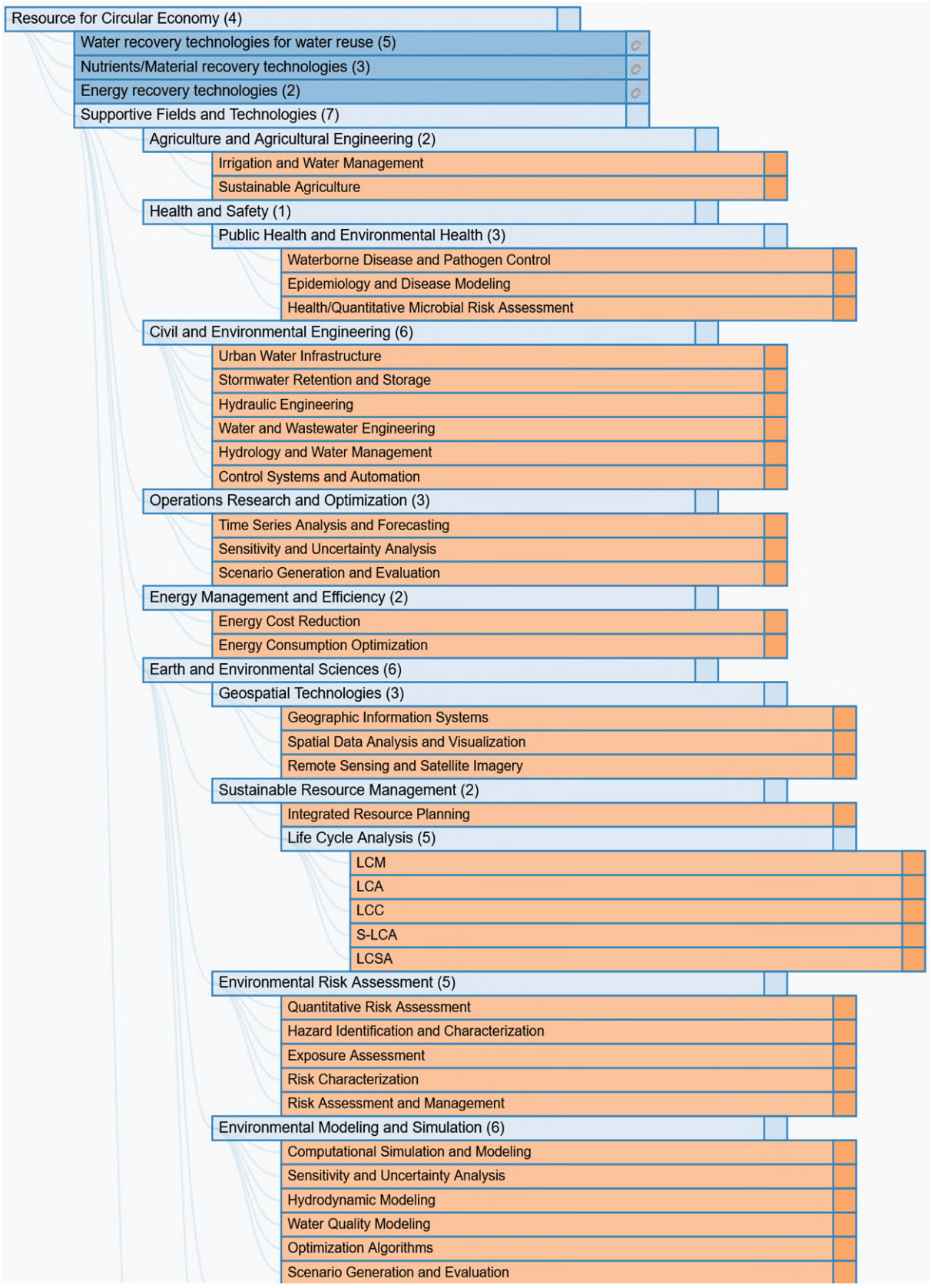
Table 1: Taxonomy of Supportive Fields and Technologies



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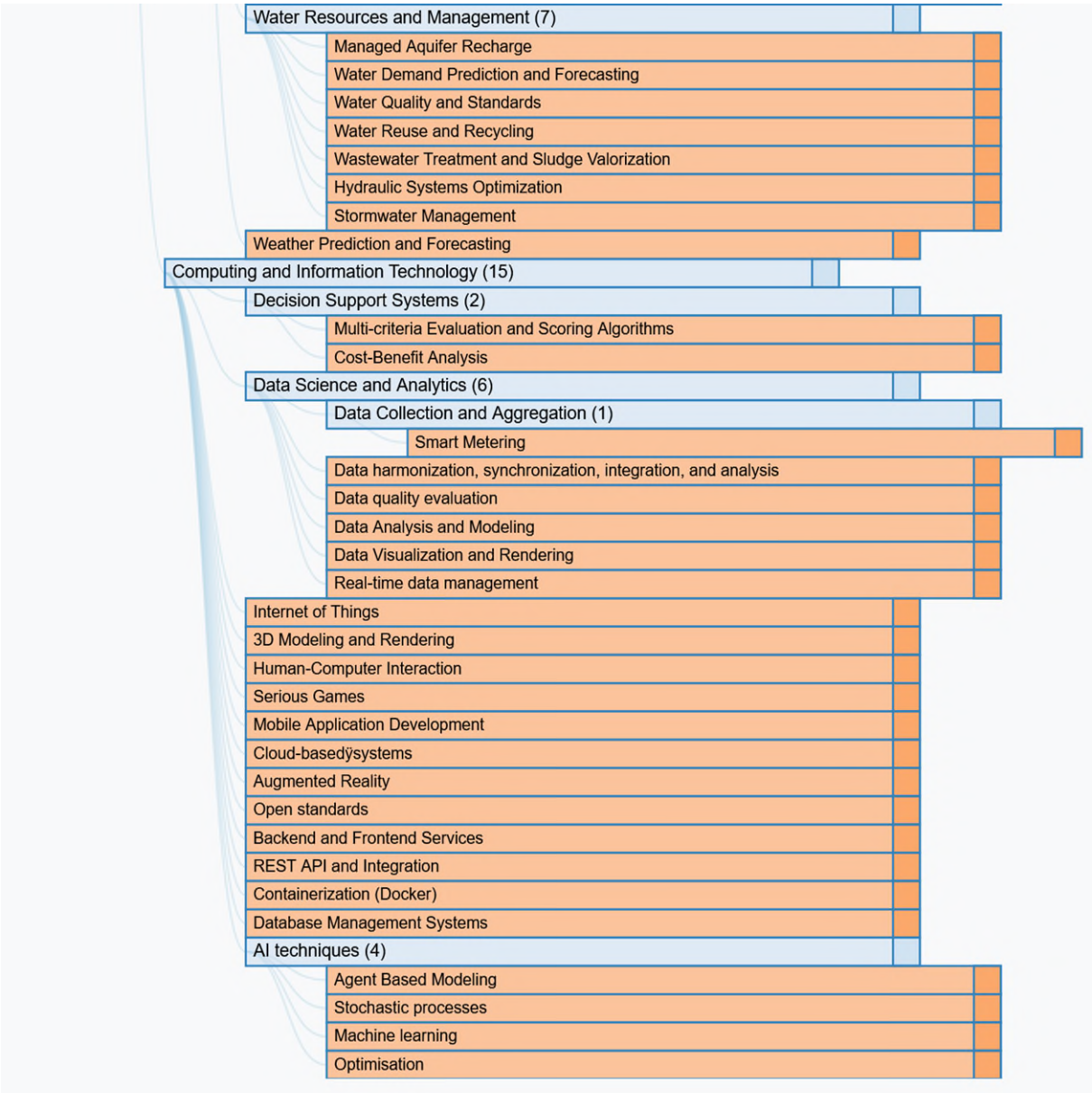

To create the taxonomy, the advanced Large Language Model (LLM) GPT-4 was employed. GPT-4 assisted in particular in the following tasks: a) identifying relevant CE technologies from product factsheet descriptions, and b) developing a hierarchical structure of scientific fields and technologies by categorizing them into broader technological fields and sub-fields.

It is essential to acknowledge that despite significant efforts to expand the TEB and include a broad range of supportive fields and technologies, this new domain, like the other three, remains inherently incomplete. The existing list of supporting technologies and fields is derived from documented tools, products, and services that facilitate the CE and the WSIS in the projects NextGen, B-WaterSmart and ULTIMATE. Nevertheless, other technologies and scientific disciplines may prove valuable to the CE and to the WSIS. Therefore the TEB's design has been made

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intentionally flexible and adaptable. A method for integrating additional technologies into the TEB has been developed and documented in Kleyböcker et al., 2022.

3.2. Integration of ULTIMATE technologies

During the ULTIMATE project, numerous CE technologies are being implemented across various case studies and recorded in the TEB. Some of these technologies may have previously been utilized and documented in the NextGen or B-WaterSmart projects, while others are being introduced for the first time within this project. In total, the ULTIMATE project aims to explore and document 20 distinct technologies and treatment trains in the TEB by the project's conclusion (Kleyböcker et al., 2022).

Table 2 provides a comprehensive overview of all the technologies that will be implemented in the ULTIMATE case studies and documented in the final deliverable of the TEB upon the project's completion. As of now, information of only a portion of these technologies can be found in the WE Marketplace platform.

Table 2: Technologies to be applied in the ULTIMATE case studies

Technologies	Case studies	Main CE Domains
Adsorption using renewable GAC	Rosignano, Italy	Water, Material
Ammonium adsorption with zeolites	Camp de Tarragona, Spain	Water
Ammonium sulphate production (air stripping & scrubbing)	Tain, UK	Material
Anaerobic membrane bioreactor (AnMBR)	Lleida, Spain, Tain, UK	Water, Energy
Aquifer thermal energy storage	Westland, Netherlands	Energy
Coagulation and adsorption with bentonite	Rosignano, Italy	Water
Early warning and control system for high chloride concentrations	Rosignano, Italy	Water
Early warning system for membrane fouling	Lleida, Spain	Water, Energy
Electrodialysis	Westland, Netherlands	Water, Material

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Electrostimulated anaerobic reactor	Lleida, Spain	Water, Energy
High added value products adsorption and subcritical water extraction	Nafplio, Greece, Karmiel and Shafdan, Israel	Water, Material, Energy
Immobilized anaerobic high rate anaerobic system	Karmiel and Shafdan, Israel	Water, Energy
Joint control system for an industrial and municipal WWTP	Kalundborg, Denmark	Water, Energy
Low grade heat recovery from wastewater	Tain, UK	Energy
Membrane distillation	Camp de Tarragona, Spain	Water
Novel tight ultrafiltration membrane	Lleida, Spain, Kalundborg, Denmark	Water
Reverse osmosis	Camp de Tarragona, Spain, Tain, UK	Water
Small bioreactor platform	Nafplio, Greece	Water
Solid oxide fuel cell	Lleida, Spain	Energy
Sulphur recovery	Chemical Platform Rousillon (FR)	Material

3.3. Relating products to technologies

It is important to relate products uploaded by registered users with technologies of the circular economy and industrial symbiosis for several reasons. Enhanced cross-linking can be achieved by relating products to specific technologies, enabling users to easily navigate between products and associated technologies. This increases the visibility of both products and technologies and promotes a better understanding of their interconnectedness. By proposing recommended products to users with an interest in specific technologies, the platform can provide personalized and tailored suggestions that cater to their preferences. Additionally, linking products to established technologies makes them more easily discoverable, as users can search and filter products based on the technologies they are interested in. Furthermore, by showcasing how products are connected to circular economy and industrial symbiosis technologies, the platform can raise awareness about the benefits of

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adopting sustainable practices and drive the adoption of these technologies across various industries.

The list of domains and technologies can be extensive, and users may inadvertently overlook critical technologies that their products are utilizing. To address this challenge, implementing machine learning techniques can assist product owners in accurately identifying the technologies their product employs. By analyzing product descriptions, features, and other relevant information, machine learning algorithms can intelligently recognize patterns and associations, ultimately suggesting appropriate technologies for each product. This not only streamlines the process for product owners but also helps ensure that all relevant technologies are accounted for, thus enhancing the platform's overall user experience and promoting the discovery of related technologies.

The WE Marketplace development team has explored the cutting-edge technology of LLMs, specifically ChatGPT, to enhance user experiences in identifying product-technology connections. The team has assessed various engines available via the LLM API, yielding diverse outcomes. The most advanced, widely available engine, gpt-3.5-turbo, delivers satisfactory results but falls short in identifying all potential associations. A higher degree of accuracy is achieved with the GPT-4 version of the LLM (as illustrated in Figure 3), however, this version is currently accessible through the API only to early adopters and developers. Additionally, a fee is charged for the use of the API. The WE Marketplace team is committed to investigating how this improved version can be made available to all registered users of the WE Marketplace once it is released to the general public.

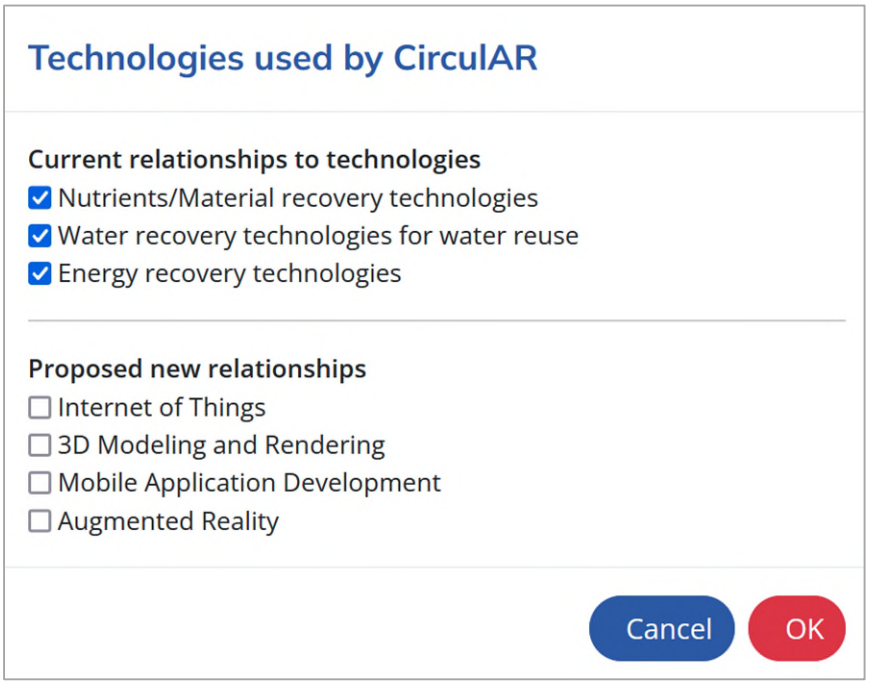

Figure 3: Example of a proposed association between a product and its related technology.

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3.4. Making ULTIMATE technologies findable

One method for identifying technologies used in the ULTIMATE project and documented in the WE Marketplace is to perform a full-text search for the term "ULTIMATE." To accomplish this, users don't need to register or have a valid account, as this functionality is openly accessible to all website visitors. Users can utilize the search bar at the top of the page, enter the keyword "ULTIMATE," and select "Technologies" from the data type list. After initiating the search, users will be presented with a list of technologies associated with the ULTIMATE project. By clicking on relevant entries, they will be directed to the technology factsheets containing detailed information.

Nonetheless, a search using the keyword "ULTIMATE" will only retrieve technologies with that term in their description. A more efficient approach to finding technologies applied in ULTIMATE case studies involves using a project filter. This method is essential for several reasons. First, it simplifies the search process, enabling users to swiftly pinpoint and access technologies linked to specific projects that meet their requirements and interests. Second, it enhances the visibility of state-of-the-art innovations by highlighting project-based advancements. It is important to note, however, that only those technologies documented on the platform and applied in documented case studies will be filtered. Many case studies have not yet been documented in the WE Marketplace, and their factsheets will be uploaded by the project's end. As a result, not all ULTIMATE technologies listed in Table 2, will appear when using this filter. Figure 4 illustrates the "By Project" filter located on the Technologies Overview page in the WE Marketplace.

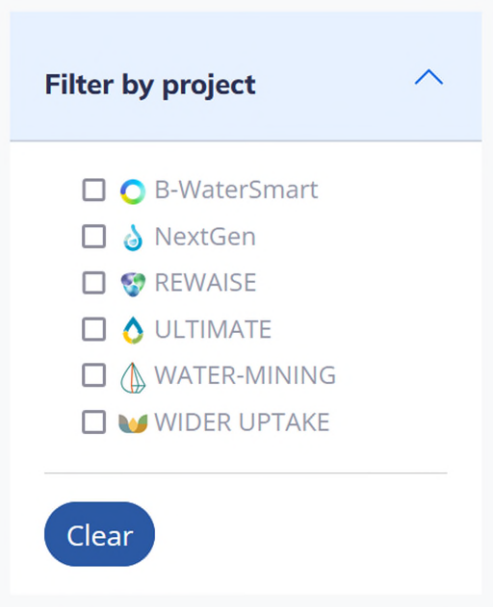

Figure 4: Filtering technologies by project

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4. Enhancing the Toolbox

4.1. Short introduction to the NextGen Toolbox

The Toolbox has been initially developed as part of the NextGen Interactive Platform (also known as the NextGen Marketplace) in the framework of the NextGen project (T. Katika et.al., 2021). The Toolbox's users include problem owners, solution providers, and investors, along with representatives of regulatory bodies, state administration, NGOs, academics and other stakeholders. It is designed to serve also as the primary toolbox for other EU-funded projects related to the circular economy.

Products, tools, and services within the Toolbox have specific attributes that provide their main characteristics. Contact details of the person associated with the tool are also required, typically a person affiliated with the organization that created or developed it, and is related to one or several CE technologies. These fields are mandatory and can be modified through a custom form. Tools also have a set of tags used in the matchmaking/recommendation process and can be associated with case studies and images.

4.2. Expanding the attributes list of Tools

As part of the ULTIMATE project, the NextGen Toolbox has been updated with additional features to serve as a Marketplace for the WSIS. To ensure the Toolbox was suitable for the WSIS, experts from various fields were consulted during the adjustment process. A robust procedure has been established for uploading tool information to the Marketplace. While tool owners are responsible for maintaining the uploaded information, the system administrators have been provided with functionality to review and evaluate tool factsheets, and approve them before publishing. Additional tool attributes have been introduced to support this process, including the submission status of the factsheet. An expiration date has also been implemented to ensure that the published information is always up-to-date. Section 4.3 provides a detailed explanation of the submission and approval process.

The final list of tool attributes for the Toolbox used in the ULTIMATE project is provided in Table 3.

Table 3: Attributes characterizing a tool in the WE Marketplace

Name	The item's unique name, which should be descriptive and specific.

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Abbreviation	Optional short form or abbreviation of the product's name, if available.
Description	A comprehensive and detailed description of the item, highlighting its features and functions
URL	Optional related URL that directs users to further information about the item.
Image	Visual representation of the tool in a web browser-supported format (e.g., png, jpeg, gif), which will be used as the reference illustration of the tool.
Illustrations	Additional illustrations can be used to represent the Tool, Product or Service.
Actors	Details about the actors involved in the item's context (e.g., water utilities, industries, technology providers, end-users), their roles, and interactions.
Is software	Boolean flag indicating whether the item is a software tool that supports the Circular Economy.
Is hardware	Boolean flag indicating whether the item is a hardware product or technology device related to the Circular Economy.
Is service	Boolean flag indicating whether the item is a service offered by a service provider as part of a Circular Economy enabling portfolio.
Is methodology	Boolean flag indicating whether the item is a methodology or process related to the Circular Economy.
USP	Description of the unique selling points, added value, and innovative elements of the tool, product, or service.
Target audience	A description of the intended user profile, highlighting who would find the product useful or is qualified to use it.
Environment	One or more environments can be linked to the Tool-Product-Service, indicating the operating environments in which the tool or application runs.
Technical requirements	List of technical requirements necessary to obtain, install, or run the tool, product, or service.
Initial release	The year the item was initially released.
Version	Information about the current stable version number or code for the product.
Version timestamp	Automatically generated date and time of the most recent update to the version information.

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License	A description of the license associated with the item (e.g., GPL 3 or MIT) and the conditions for purchasing the product, obtaining a license, or providing the service.
License Type	The Tool-Product-Service may have a specific License type.
License timestamp	Automatically generated date and time of the most recent update to the license information.
Costs	A description of the costs, pricing structure, and conditions for purchasing the product, obtaining a license, or providing the service.
Costs timestamp	Automatically generated date and time of the most recent update to the cost information.
Publications	List of publications related to the item, such as software, hardware, service, or process.
TRL	Technology Readiness Level indicating the maturity of the tool.
TRL timestamp	Automatically generated date and time of the most recent update to the TRL (Technology Readiness Level) information.
Ownership	One or several organisations which own the tool.
Publications	Tool, Product or Service, can be related to multiple publications.
Case Studies	One or multiple case Studies can feature the application of a Tool, Product or Service, which can be applied in multiple applications.
Tags	Tags can be associated with the Tool-Product-Service to help categorize and find them easily.
Interest	A Tool-Product-Service can be the subject of expressed interest by users.
Technologies	A Tool-Product-Service can apply one or several technologies.
Contact	Contact information for the person responsible for the item, including their name and other relevant details.
User Update	A User is responsible for the last update of the product data.
Manager	User who is responsible for the data management of this record.
State	The current status of the application for publishing the tool's factsheet.

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Expiration date	If set, the product is no longer visible for other users beyond this date.
Active notes	Administrator's notes on the status of this product.
Timestamp	Automatically generated date and time when the record was last updated.

Descriptive information is provided by the user, using an advanced text editor that enhances the user's ability to create and edit content with rich formatting options.

4.3. Tool factsheet submission

The NextGen Marketplace permitted any registered user to upload information about products, tools, and services related to the CE. The publishing procedure was very simple, product owners were responsible for the content of the factsheets, and the Marketplace provided a platform for their promotion. In the ULTIMATE project, the existing procedure for uploading tool factsheets supporting the CE and WSIS to the Marketplace has been revised to ensure a high standard of quality and compliance with legal requirements. By introducing a more stringent and supervised approval and publishing process, the platform can better safeguard against the dissemination of misleading, offensive, or unlawful content. Furthermore, this revised approach helps to guarantee that the tools published on the Marketplace align with the principles of CE and WSIS. Requiring the involvement of an administrator to validate and approve new submissions, rather than allowing registered users to freely upload factsheets, creates an additional layer of oversight. This added scrutiny also enables the platform to request evidence from applicants demonstrating the relevance of their tools to the WSIS, thereby maintaining the integrity and purpose of the Marketplace. The procedure also allows for the possibility of imposing a nominal subscription fee, although this fee will be waived during the initial operational period of the Marketplace.

4.3.1. State transition of tool factsheets

The procedure for publishing tool and product factsheets involves a series of steps that must be completed by both the user and the administrator of the Marketplace. To begin, any registered user can upload product information using an online form, which will be subject to typical data validation checks by the Marketplace (Katika et al. 2021). This ensures that mandatory fields are completed and the expected data types are correct. Before submission, users need to review and consent to the legally binding document containing the terms and conditions. The full text of the terms and conditions for publishing product information on the WE Marketplace is documented

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in Annex A. During the approval process, the owner can view and amend the uploaded information as needed.

Upon receiving a new product submission, the Administrator will be notified via email. The system will highlight the applications that require the Administrator's approval, allowing them to review the product factsheets thoroughly. At this stage, the Administrator can either approve or reject the application, or request changes from the owner before resubmission. If the application is approved, the product factsheet will be immediately published and become visible to all users of the platform, both registered and unregistered. It is crucial to keep the product information up to date to maintain the accuracy and relevance of the published factsheets.

Figure 5 displays a state transition diagram for a tool factsheet, consisting of five states: drafting, submitted, approved, hidden, and rejected. The diagram illustrates the potential transitions between these states, with arrows indicating the direction of the change. The drafting state serves as the starting point, and the product moves through different states along the available paths. Arrows in the diagram signify actions or events prompting a transition, such as finishing the drafting phase, approving the factsheet, or removing it from the platform. Administrators initiate actions denoted by red arrows, while green arrows indicate actions initiated by the tool owner. The diagram offers a visual representation of the factsheet's life cycle, with the states defined as follows:

drafting This initial state allows the creator to add, edit, and refine information before finalizing and submitting the document for review or publication. During this stage, the factsheet is visible only to the tool owner and system administrators.

submitted Upon completion, the user can submit the factsheet for approval. It remains in this state until an administrator reviews and approves it. The user can still view and modify the factsheet, while the administrator may request amendments or reject it if it doesn't comply with the terms and conditions for publishing product information on the WE Marketplace.

approved Once approved and provided that the subscription has not expired, the factsheet is published and visible to all users, including registered and non-registered visitors of the WE Marketplace.

hidden The tool owner can temporarily hide the product information from public view. After making necessary modifications, the factsheet can be republished.

rejected If a tool is irrelevant to the circular economy or the WSIS, or if it does not conform to the terms and conditions (Annex A), system administrators can reject the factsheet. While still in the system, it is removed from public view until the case outcome is clarified.

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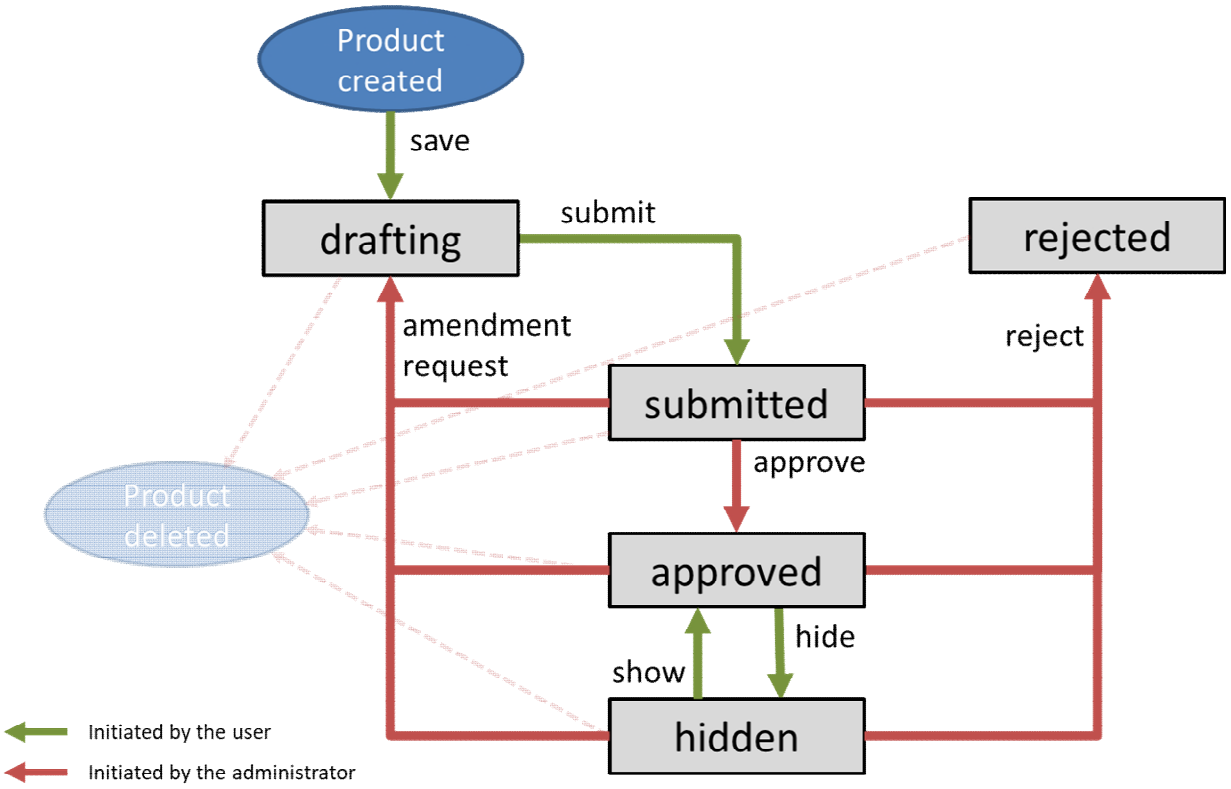

Figure 5: State transition diagram of product factsheets

Users can make modifications to the factsheet at any stage of its life cycle. Both the tool owner and the administrator have the authority to remove a factsheet from the platform if deemed necessary.

4.3.2. User interface for product administration

Administrators can manage all products through the Administrators' products list page, as depicted in Figure 6. This page displays a table containing essential product details, including the name, product manager, owning organization, product status, potential expiration date, and the most recent update of the product factsheet.

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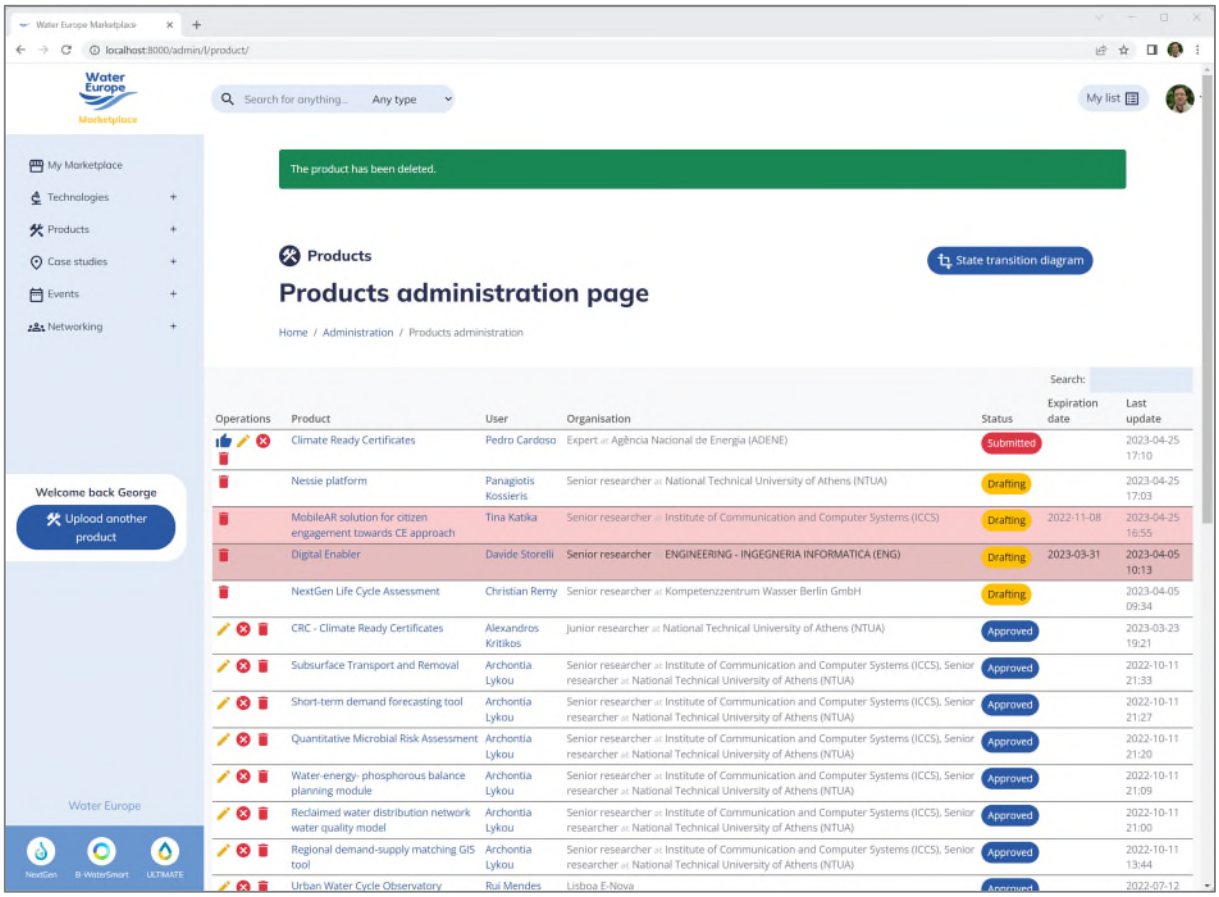

Figure 6: Products Administration page

When users click on the product name, they are directed to the product factsheet, which offers a comprehensive description of the product. From the factsheet page administrators can access the edit page to modify the product's status. Alternatively, the status can be updated directly from the Products Administration page by clicking on the corresponding icons located adjacent to the product names as follows:

	approve	The project factsheet is currently in the "submitted" state, and the Administrator can approve it by clicking the "Approve" icon.
	amendment request	Clicking this icon sends the submitted product factsheet back to the product manager with a request for amendments.
	reject	Clicking this icon rejects the application to publish the product factsheet.
	delete	Clicking this icon deletes the product factsheet.

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4.4. Populating the Toolbox with ULTIMATE tools - Phase 1

Work Package 2 (WP2) encompasses five key tools, which aim to facilitate the exploration, assessment, and optimization of water-based industrial symbiosis schemes. Deliverable 2.1 (D2.1) introduces an online tool that leverages ontologies to help industries discover and evaluate potential symbiotic opportunities in industry-water processes. This deliverable results in the development of a WSIS ontology and a data exploration tool. Deliverable 2.2 (D2.2) reports on Life Cycle Assessment (LCA), Life Cycle Cost (LCC), and risk assessment outcomes, including Quantitative Microbial and Chemical Risk Assessment (QMRA & QCRA) for WSIS, ensuring adequate risk management and highlighting potential benefits. Deliverable 2.3 (D2.3) offers best practice guidelines for using hydraulic modeling and simulation (HMS) to investigate WSIS scenarios, considering technological, socio-economic, and environmental factors. Deliverable 2.4 (D2.4) provides an interactive online tool for visualizing HMS analysis results, facilitating decision co-creation among multiple interest groups. Lastly, Deliverable 2.5 (D2.5) presents an online KPI tool to assess the performance of alternative WSIS schemes, supporting evaluation during both simulation and post-implementation phases.

The complete suite of ULTIMATE tools will be catalogued in the WE Marketplace Toolbox. While the majority of these tools are scheduled for delivery by the project's conclusion and have not yet been added to the Toolbox, a select few are currently documented. These tools are included either because they have been employed in prior projects or because their development is complete or significantly progressed.

The subsequent sub-sections provide concise descriptions of the tools currently documented in the Toolbox, which are either under development or being applied within the scope of the ULTIMATE project.

4.4.1. Circular Economy Performance Auditor

Tool URL: https://mp.watereurope.eu/d/Product/68

The Circular Economy Performance Auditor is a KPI Tool, developed in WP2 that is used to measure and improve on the performance of circular eco-innovations in terms of technological, environmental and socio-economic domains. It can offer an estimation across these areas of circularity, eco-efficiency, reliability and profitability. A combined online tool and ontology tool powered by FIWARE has been developed

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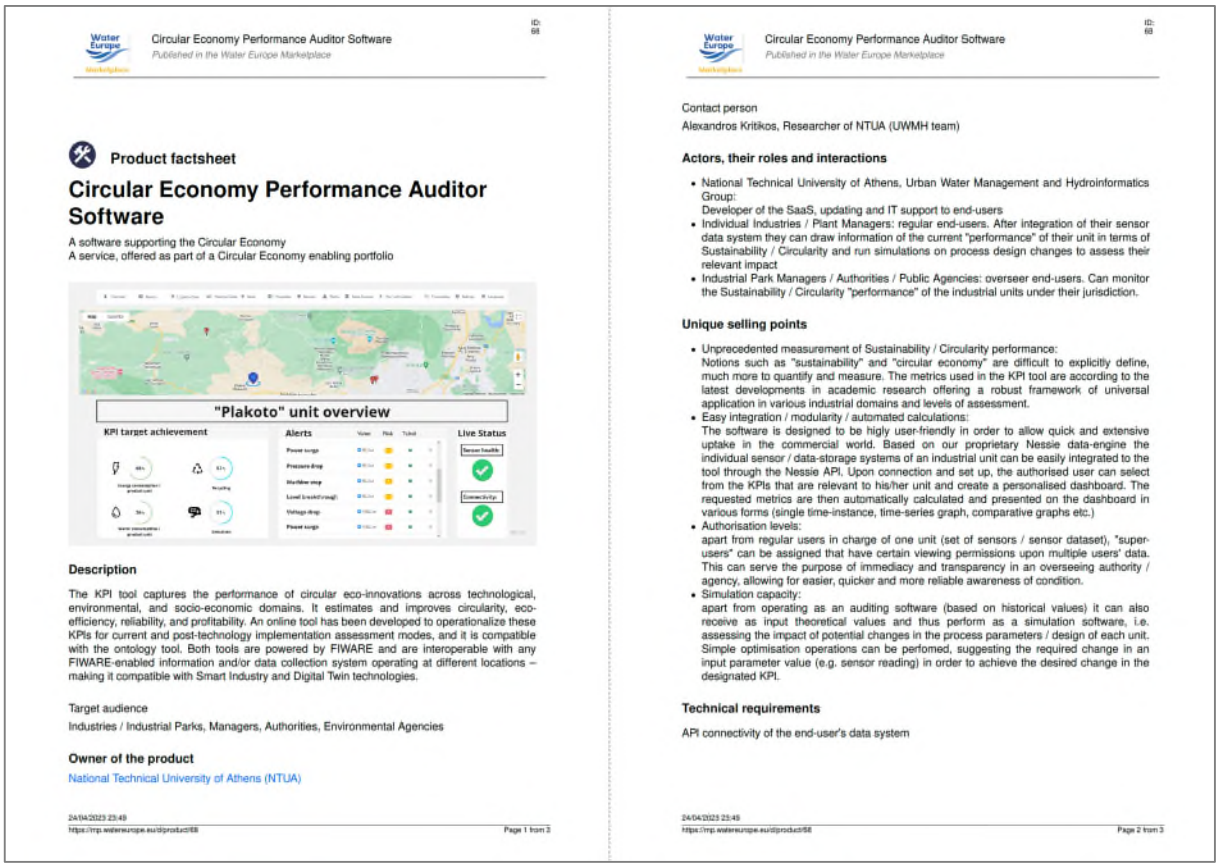
to operationalise this, being interoperable with any FIWARE-enabled systems and technologies such as Smart Industry and Digital Twins.

The unique selling points of the KPI tool includes the unprecedented measurement of sustainability and circularity performance, easy integration, modularity and automated calculations. It is also user-friendly to ensure quick and extensive uptake in the commercial world. It also offers different authorisation levels, so that the authorised user is able to create a personalised dashboard and select relevant KPIs. The tool also offers simulation capacity, so that it can be used as an auditing software or assess the impact of potential changes in specific parameters.

The tool has been designed for use by industry, managers and agencies, as well as environmental authorities. It can be used to create transparency and awareness of industrial activities and to enable quick, reliable optimisation of any KPI. Figure 7 illustrates the printable version of the KPI tool.

Figure 7 shows the printable version of the tool factsheet.



Circular Economy Performance Auditor Software
Published in the Water Europe Marketplace

ID: 68

Product factsheet

Circular Economy Performance Auditor Software

A software supporting the Circular Economy
A service, offered as part of a Circular Economy enabling portfolio

"Plakoto" unit overview

KPI target achievement | Alerts | Live Status

Description

The KPI tool captures the performance of circular eco-innovations across technological, environmental, and socio-economic domains. It estimates and improves circularity, eco-efficiency, reliability, and profitability. An online tool has been developed to operationalize these KPIs for current and post-technology implementation assessment modes, and it is compatible with the ontology tool. Both tools are powered by FIWARE and are interoperable with any FIWARE-enabled information and/or data collection system operating at different locations – making it compatible with Smart Industry and Digital Twin technologies.

Target audience
Industries / Industrial Parks, Managers, Authorities, Environmental Agencies

Owner of the product
National Technical University of Athens (NTUA)

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Circular Economy Performance Auditor Software
Published in the Water Europe Marketplace
ID: 68

Contact person
Alexandros Kritikos, Researcher of NTUA (UWMH team)

Actors, their roles and interactions

- National Technical University of Athens, Urban Water Management and Hydroinformatics Group:
  Developer of the SaaS, updating and IT support to end-users
- Individual Industries / Plant Managers: regular end-users. After integration of their sensor data system they can draw information of the current "performance" of their unit in terms of Sustainability / Circularity and run simulations on process design changes to assess their relevant impact
- Industrial Park Managers / Authorities / Public Agencies: overseer end-users. Can monitor the Sustainability / Circularity "performance" of the industrial units under their jurisdiction.

Unique selling points

- Unprecedented measurement of Sustainability / Circularity performance:
  Notions such as "sustainability" and "circular economy" are difficult to explicitly define, much more to quantify and measure. The metrics used in the KPI tool are according to the latest developments in academic research offering a robust framework of universal application in various industrial domains and levels of assessment.
- Easy integration / modularity / automated calculations:
  The software is designed to be higly user-friendly in order to allow quick and extensive uptake in the commercial world. Based on our proprietary Nessie data-engine the individual sensor / data-storage systems of an industrial unit can be easily integrated to the tool through the Nessie API. Upon connection and set up, the authorised user can select from the KPIs that are relevant to his/her unit and create a personalised dashboard. The requested metrics are then automatically calculated and presented on the dashboard in various forms (single time-instance, time-series graph, comparative graphs etc.)
- Authorisation levels:
  apart from regular users in charge of one unit (set of sensors / sensor dataset), "super-users" can be assigned that have certain viewing permissions upon multiple users' data. This can serve the purpose of immediacy and transparency in an overseeing authority / agency, allowing for easier, quicker and more reliable awareness of condition.
- Simulation capacity:
  apart from operating as an auditing software (based on historical values) it can also receive as input theoretical values and thus perform as a simulation software, i.e. assessing the impact of potential changes in the process parameters / design of each unit. Simple optimisation operations can be perfomed, suggesting the required change in an input parameter value (e.g. sensor reading) in order to achieve the desired change in the designated KPI.

Technical requirements

API connectivity of the end-user's data system

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Figure 7: Printable version of the Circular Economy Performance Auditor factsheet

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4.4.2. NEXTGEN Life Cycle Assessment

Tool URL: https://mp.watereurope.eu/d/Product/24

The NEXTGEN Life Cycle Assessment tool has been developed and first used in the NextGen project. Life Cycle Assessment is a standardized framework (ISO 14040) for assessing the potential environmental impacts of a product or service over its entire life cycle, including all relevant upstream and downstream processes. It quantifies impacts based on a thorough data inventory, calculating cumulative potential environmental impacts with scientifically derived LCA indicators, such as greenhouse gas emissions, resource depletion, water and air quality, and toxicity. In the frame of circular economy, LCA helps to explore the environmental benefits and potential drawbacks of CE schemes in comparison to conventional "linear" production systems or services. This approach provides valuable information for decision makers and process developers to promote and improve CE products and services.

LCA models have been developed for nutrient and energy recovery from sludge or centrate, water recovery with membranes or natural systems, and energy recovery via biogas. These models are based on the current state-of-the art and take into account local boundary conditions. Key benefits from this service include science-based information on Carbon Dioxide Equivalent (CO_2e) footprint, water quality, and other environmental benefits of CE, as well as the identification of hot-spots and trade-offs for selecting the most suitable scheme at an individual site.

The target audience for this service is broad and includes decision makers, plant operators, process developers, politicians, engineers, researchers, and other CE professionals.

4.4.3. AquaNES QMRA tool for water reuse scenarios

Tool URL: https://mp.watereurope.eu/d/Product/26

Water quality assessment and risk assessment are necessary for the evaluation of water treatment and, in some cases, cannot be suitably monitored with traditional techniques due to labour intensity, detection limits, or variations in source water quality. To account for these difficulties, scenario studies must be conducted to evaluate the treatment processes. The AquaNES QMRA tool enables planners, scientists, and operators of water reuse systems to undertake these assessments and identify whether a set treatment process will reach the microbial safety quality

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criteria. QMRA facilitates the assessment of microbial safety within the treatment process, including the use of default values or own process data.

4.4.4. RIOTER - Online Tool for Semantic-Driven WSIS

Tool URL: https://mp.watereurope.eu/d/Product/69

This online tool allows users to explore semantic enriched datasets about industrial symbiosis and develop strategies for implementing such symbiosis in their own companies. With this tool, users have a unique opportunity to determine industrial symbiosis and aid their businesses.

This tool is specifically aimed at businesses that wish to better understand and put into practice industrial symbiosis for a competitive edge.

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5. Matchmaking functionality for the WSIS

This section delves into the matchmaking functionality for WSIS by identifying relevant industries, and highlighting the importance of key sectors with significant potential for improvement and innovation in the context of CE and WSIS. Results from the SCALER[2] project, an EU-funded research initiative, are utilized, as it has identified potential synergies to increase industrial resource sharing among various sectors. The section also introduces the Industrial Wastes Matchmaking Tool (IWMMT) developed by the National Technical University of Athens (NTUA), a digital platform designed to promote the exchange, reutilization, and recycling of industrial wastes, with a particular emphasis on wastewater streams, across various industries.

Furthermore, an API is specified, which facilitates seamless communication between the WE Marketplace and the IWMMT. The API allows users to access up-to-date information on materials, find suitable matches for their industry requirements, and submit and manage offers or demands for industrial materials. The section also explains how authorized clients can enhance the IWMMT database by submitting offers or demands of materials with certain characteristics using the API.

Additional API endpoints are provided to enable clients to select the industrial sector and processes from a closed list known to the IWMMT, ensuring data consistency and error prevention. Finally, the section presents a use case for manufacturing companies, where a company requires a material for its production process and utilizes the IWMMT API to efficiently locate the best available offers based on material, quantity, unit, and industry location.

5.1. Specification of industry sectors

To better comprehend the possible collaborations between industries in the context of the CE and the WSIS, it is important to examine key sectors that have significant potential for improvement and innovation. Potential synergies to increase industrial resource sharing have been examined and analysed in the SCALER project. The SCALER project (Scaling European Resources with Industrial Symbiosis) is a research initiative funded by the European Union's Horizon 2020 program. Its primary goal is to facilitate the development and implementation of industrial symbiosis in the European process industry.

[2] SCALER: SCALing European Resources with industrial symbiosis

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Table 4 presents the primary emitting and receiving sectors as identified by the list of synergies in the SCALER project (L. Nolan, 2020). The table also correlates these sectors with their respective NACE[3] classification codes up to the second level. This association facilitates the understanding and analysis of the economic activities involved in the synergies, utilizing the standardized NACE classification system.

Table 4: Main sectors generating and receiving resources in an industrial symbiosis according to L. Nolan, 2020.

Emitting or Receiving Sectors	Corresponding NACE sector	
	Sector name	NACE code[1]
AGRO-INDUSTRIAL PRODUCTION	AGRICULTURE, FORESTRY AND FISHING or Manufacture of food products	A C.10
CEMENT	Manufacture of other non-metallic mineral products	C.23
CERAMIC	Manufacture of other non-metallic mineral products	C.23
COMBUSTION PLANT	Electricity, gas, steam and air conditioning supply	D.35
FERTILISERS	Manufacture of chemicals and chemical products	C.20
FOOD DRINK AND MILK INDUSTRIES	Manufacture of food products	C.10
GLASS	Manufacture of other non-metallic mineral products	C.23
INORGANIC CHEMICALS	Manufacture of chemicals and chemical products	C.20
IRON AND STEEL	Manufacture of basic metals	C.24

[3] NACE: Nomenclature of Economic Activities

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LIME	Manufacture of other non-metallic mineral products	C.23
MINERALS	Manufacture of other non-metallic mineral products	C.23
NON FERROUS METALS INDUSTRIES	Manufacture of basic metals	C.24
ORGANIC CHEMICALS	Manufacture of chemicals and chemical products	C.20
PHARMACEUTICAL	Manufacture of basic pharmaceutical products and pharmaceutical preparations	C.21
PRODUCTION OF PULP PAPER AND BOARD	Manufacture of paper and paper products	C.17
REFINING MINERAL OIL AND GAS	Manufacture of coke and refined petroleum products	C.19
SLAUGHTERHOUSES AND ANIMAL BYPRODUCT INDUSTRIES	Manufacture of food products	C.10
STEEL	Manufacture of basic metals	C.24
TEXTILE	Manufacture of textiles	C.13
WASTE INCINERATION	Waste collection, treatment and disposal activities; materials recovery	E.38
WASTE TREATMENT INDUSTRIES	Waste collection, treatment and disposal activities; materials recovery	E.38
WASTE WATER TREATMENT INDUSTRIES	Sewerage	E.37

[1] Up to level 2.

The names of key elements of interest according to the most promising synergy types documented in the Synergies environmental impact assessment of the SCALER project are listed in Table 5.

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Table 5: Key elements of interest for industrial symbiosis, based on Lindsay Lessard, Jérôme Laffely (2019).

ANTIMONY	GAS OIL	RHODIUM
ASHES	GYPSUM	SALT
BARK	HEAT	SAND
BASIC OXYGEN FURNACE GAS	HYDROCHLORIC ACID (HCl)	SAWDUST
BENZENE	HYDROGEN	SILICA
BITUMEN	IRON	SILICIUM
BLAST FURNACE GAS	LIME	SLAG
BLAST FURNACE SLAG	LIMESTONE FINES	SLUDGE
CALCIUM	MAGNESIUM	SPENT_SOLVENTS
CARCASE	METHANOL	STEAM
CHROMIUM	NICKEL	SULFURIC ACID (H2SO4)
COBALT	NITROGEN	SULPHUR
COKE	NON-FERROUS METALS	SULPHURIC ACID
COKE OVEN GAS	NUTRIENTS	TAR
COOLING WATER	OIL	WASTE PLASTICS (AMP)
DIETHYL ETHER	PALLADIUM	WOOD
ETHYL ACETATE	PHOSPHORUS	WOOD WASTE
ETHYL PROPIONATE	PLATINUM	YEAST
EXTRACELLULAR ENZYMES	POTASSIUM	ZINC
FERROUS-METALS	REFRACTORY PRODUCTS	Zn

5.2. The Industrial Wastes Matchmaking Tool

The National Technical University of Athens has developed the Industrial Wastes Matchmaking Tool, a digital platform designed to facilitate the exchange, reuse, and recycling of industrial by-products among industries, with emphasis on wastewater streams. The primary objective of this tool is to promote circular economy principles, reduce waste, and minimize the environmental impact of industrial processes, focusing on those industrial sectors, in which, as per the SCALER project, the potential for synergies is significantly maximized. Although the platform is still in the development phase, it will serve the following goals:

- Information gathering: Industries can register on the platform and provide details about the waste materials they produce, along with their quantities, availability, location and relevant properties.
- Matching: The platform uses algorithms to match waste generators with potential users. The matchmaking process is based on a combination of criteria, such as material compatibility, distance between the parties, and cost-effectiveness applying the Sherwood plot cost analysis (Karakatsanis, G., Makropoulos, C, 2023).

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- Interaction: The platform will allow registered users to connect and share information.

Registered users can access the initial version of the IWMMT through the URL: https://iwmmt.uwmh.eu/

5.3. Specification of the IWMMT API

For the purpose of the ULTIMATE project, an API has been designed to facilitate seamless communication between the WE Marketplace and the IWMMT. This API empowers Marketplace users to access up-to-date information on materials, whether they are currently offered or in demand on the IWMMT, and discover the most suitable matches tailored to their specific industry requirements. Moreover, the API can be utilized to grant authorized clients the ability to submit and manage offers or demands for industrial materials on the IWMMT platform.

5.3.1. List of materials

This API provides a list of all materials currently on offer or in demand in JSON format. The user can specify the type of request (offer or demand) in the query parameters. If omitted, the IWMMT returns a list of all recorded resources/materials for the user to select for demand or offer.

Endpoint: /materials

Method: GET

Query Parameters:

- type (string, optional): Type of request, either "offer" or "demand".

Response

A JSON object containing a list of materials with their name, chemical formula (optional), and CAS[4] number.

Example API call:

GET /materials?type=offer

5.3.2. Search for materials

This operation is designed to allow users to search for materials on offer or in demand in the IWMMT based on specific criteria. The user must specify the type of

[4] CAS: Chemical Abstracts Service

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search (offer or demand). Additionally, the API accepts input parameters such as material, quantity, and location coordinates of the requesting industry. In response, the API provides a JSON-formatted list of industries ordered by the best match for the requested material, including details like the producing industry, price, and location.

Endpoint: /search_material

Method: GET

Query Parameters

- type (string, required): Type of search, either "offer" or "demand".
- material_name (optional): The name of the material being searched.
- cas_number (optional): The CAS number of the material being searched.
- quantity (real, required): The quantity of the material being searched.
- unit (string, required): The unit of the material quantity being searched (e.g., kg, lbs, tons, etc.).
- coordinates (string, required): The location of the industry in coordinates (latitude,longitude).

Note: At least one of the material_name or cas_number parameters must be provided.

Response

The API returns a JSON object that includes the requested material information and a list of industries ranked by the best match for the requested material. The sorting order is either descending or ascending, depending on the type of request, whether it's a demand or an offer.

The `requested_material` field contains the query parameters. The `results` field contains a list of industries, with each entry including the following data:

- industry (object): An object containing information about the industry offering or requesting material.
  - name (string): The name of the industry.
  - location (string): The location of the industry in coordinates (latitude, longitude).
  - additional_data (string): Additional data about the industry, such as industry size, contact information, etc.

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- price (float): The price of the material offered or in demand by the industry.

Example API call

GET / search_material?type=offer&material_name=copper&quantity=1000&unit=kg&coordinates=40.7128,-74.0060

5.3.3. Submit an offer or demand for material

Selected clients will be authorized to enhance the database of the IWMMT by submitting offers or demands of materials having certain characteristics. This API allows authorized clients to enhance the IWMMT database by submitting offers or demands of materials providing the necessary information for each submission. Clients must be authenticated using an API key provided by IWMMT. The API key should be included in the request header as Authorization: Bearer {API_KEY}.

Endpoint: /search_material

Method: POST

Request Payload

The JSON payload represents the data sent by the client to the IWMMT server when submitting a material offer or demand. It contains the following key-value pairs that describe the material and its associated information:

- type: (string) The type of submission, either "offer" or "demand".
- material_name: (string) The name of the material.
- cas_number: (string) The CAS number of the material.
- quantity: (number) The amount of the material being offered or demanded.
- unit: (string) The unit of measurement for the quantity of the material (e.g., kg, tons, litres).
- expiration_date: (date) The date when the submitted record expires, formatted as YYYY-MM-DD.
- industry_name: (string) The name of the industry that is producing or consuming the material.
- industry_location: (string) The location of the industry producing or consuming the material.
- industrial_sector: (string) The industrial sector to which the industry belongs, selected from a closed reference list (see Section 5.3.4).

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- process: (string, optional) The process from which the by-product has been produced, if applicable, selected from a closed reference list (see Section 5.3.5).

Example

```
{
  "type": "offer",
  "material_name": "Aluminum",
  "cas_number": "7429-90-5",
  "quantity": "5000",
  "unit": "kg",
  "expiration_date": "2023-12-31",
  "industry_name": "ElecroParts",
  "industry_location": "52.0452,7.1023",
  "industrial_sector": "Electronics manufacturing and recycling",
  "process": "
}
```

This JSON payload is used to transmit the necessary information for creating a material submission record in the IWMMT database. When a client sends a POST request to the /material endpoint with this payload, the server will process the data and create a new record in the database, provided that the submitted data is valid and the client is authorized.

Response

In case of success, the API will return a 201 HTTP status code and a JSON object containing an appropriate message and unique identifier of the submission:

```
{
  "message": "Material submission created successfully.",
  "submission_id": "unique identifier"
}
```

In case of errors, the API will return an appropriate HTTP status code and a JSON object containing an error description.

Status: 400 Bad Request

```
{
  "error": "Invalid or missing data in the request payload."
}
```

Status: 401 Unauthorized

```
{
  "error": "Unauthorized. Invalid API key."
}
```

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5.3.4. List of industrial sectors

To enable the client to select the industrial_sector from a closed list known to the IWMMT, the API provides an additional endpoint that allows the client to fetch the list of available industrial sectors. The client application can then use this list to populate a drop-down menu or a similar user interface element, ensuring that users can only choose from the predefined sectors. This approach ensures that the client is using the same set of predefined industrial sectors as the IWMMT, thus maintaining data consistency and avoiding errors in the material submission process.

Endpoint: /industrial_sectors

Method: GET

Example response:

```
 [
  {
    "id": "integer",
    "name": "string"
  },
  ...
]
```

5.3.5. List of processes

Similarly to the list of industrial sectors (Section 5.3.4), to allow the client to select the process from a closed list known to the IWMMT, the API provides an additional endpoint that allows the client to fetch the list of available processes. The client application can then use this list to populate a drop-down menu or a similar user interface element, ensuring that users can only choose from the predefined processes.

Endpoint: /processes

Method: GET

Example response:

```
 [
  {
    "id": "integer",
    "name": "string"
  },
  ...
]
```

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5.3.6. HTTP Status Codes

The API responses of the specified requests can have different status codes depending on the outcome of the request. These status codes help users understand the result of their API calls. The most common ones are the following:

- **200 OK**: This status code indicates that the request was successful, and the API has responded as requested. The response will include the relevant data in the desired format.
- **400 Bad Request**: This status code signifies that there was an issue with the request, such as invalid or missing parameters. In this case, the user should review their request and make sure all required parameters are provided and properly formatted.
- **500 Internal Server Error**: This status code indicates that there was a problem on the server side while processing the request. It is not related to the user's input but rather an issue with the server itself. In this situation, users may need to contact the API provider for assistance or try their request again later.

5.4. Optimizing aluminium procurement: A use case for manufacturing companies

Scenario: A manufacturing company, XYZ Corp., requires 5000 kg of aluminum for their production process. They would like to find the best available offers in the IWMMT based on the material's name or CAS number, the required quantity, unit, and their industry location. An employee of XYZ Corp. uses a client application (e.g. the WE Marketplace) that leverages the IWMMT API to efficiently locate the desired information.

Steps:

1. XYZ Corp. identifies the required raw material, its quantity, unit, and their industry location. For example, they need 5.000 kg of aluminum for their manufacturing process, and their industry is located at coordinates 47.0522, 5.2437.
2. In the XYZ Corp. the user of the client application, selects “Aluminum” from a pull-down list that lists all materials that are currently in offer on the IWMMT platform. The list appears ordered with data that is retrieved on demand and in real time through the **materials** API as follows:
    - The API sends a request, specifying the type of request (offer).

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Example Request:
`GET https://iwmmt.uwmh.eu/api/materials?type=offer`

- The API returns a JSON object containing a list of materials currently in offer, such as in the following example:

```
{
  "type": "offer",
  "materials": [
    {
      "name": "Aluminum",
      "chemical_formula": "Al",
      "cas_number": "7429-90-5"
    },
    {
      "name": "Ethylene",
      "chemical_formula": "C2H4",
      "cas_number": "74-85-1"
    },
    {
      "name": "Methanol",
      "chemical_formula": "CH3OH",
      "cas_number": "67-56-1"
    },
     . . . . .
  ]
}
```

- The application's user interface at XYZ Corp. retrieves the names of all materials and populates a widget that displays them as a drop-down list, making it easy for the user to make a selection.

3. The user of the client application selects "Aluminum" from the drop-down list and provides all other necessary information for the request by filling in other fields of the request form. This includes specifying the type of search (offer), material name or CAS number, quantity, unit, and industry location.

4. A search request for the best offers available in the market is sent to the IWMMT using the **search_material** API.

   Example Request:
   `GET https://iwmmt.uwmh.eu/api/search_material?type=offer&material_name=aluminum&quantity=5000&unit=kg&coordinates=47.0522,5.2437`

5. The API returns a JSON object containing the requested material information and a list of industries ordered by the best match for the requested material.

   Example Response:

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```
{
  "requested_material": {
    "material_name": "aluminum",
    "cas_number": "7429-90-5",
    "quantity": 5000,
    "unit": "kg",
    "requesting_industry_location": "47.0522,18.2437"
  },
  "results": [
    {
      "producing_industry": {
        "name": "Industry A",
        "location": "53.6846,10.8265",
        "additional_data": "..."
      },
      "price": 10000
    },
    {
      "producing_industry": {
        "name": "Industry B",
        "location": "44.0522,12.2437",
        "additional_data": "..."
      },
      "price": 10500
    },
    {
      "producing_industry": {
        "name": "Industry C",
        "location": "57.7749,12.4194",
        "additional_data": "..."
      },
      "price": 11000
    }
  ]
}
```


6. The employee at XYZ Corp. reviews the search results and identifies the best offer based on criteria, such as price, location, and any additional data provided by the producing industries.

7. XYZ Corp. contacts the producing industry with the best offer and proceeds to negotiate and finalize the deal for the raw material acquisition.

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6. Conclusions

In the ULTIMATE project, the NextGen Marketplace (now evolved to WE Marketplace) has been enhanced with the new industrial ontology-based matchmaking functionality developed in T2.1, allowing registered users (industries) to explore the potential for symbiotic arrangements for the reuse of water, energy, and materials in their area/region.

As far as it was available at this stage of the project, the WE Marketplace has integrated information related to technologies developed or applied in the ULTIMATE project from WP1 into the Technology Evidence Base. Further details on case studies from the ULTIMATE project, as well as tools supporting the CE and WSIS, have also been documented in the Marketplace.

The foundation for improved matchmaking between multiple problem owners and solution providers in the context of symbiotic arrangements has been established by specifying the API between the WE Marketplace and the Industrial Wastes Matchmaking Tool, developed by NTUA. Once the API defined in this document is implemented, this tool will further contribute to the effectiveness of the WE Marketplace, enabling users to efficiently find the best possible matches for the demand and offer of by-products and industrial wastes.

As the platform evolves and expands in multiple directions, the WE Marketplace is set to become an increasingly valuable resource for users. With ULTIMATE project partners completing and uploading new tools, technologies, and case study factsheets, the marketplace will continually grow richer in content. Other projects have been invited and are expected to contribute with additional content relevant to the CE and the WSIS.

In addition, the matchmaking capabilities of the platform will be improved with the integration of the newest version of the AI technology GPT-4. This advanced language model has the potential for more accurate identification of technologies that are being applied in the documented tools.

To further enhance the user experience, the administration of uploaded tools and products can be improved with smart notification functionality. This will allow users and administrators to promptly receive notifications when an action is required in the factsheet publication process, such as an amendment request or an approval of a submitted factsheet, ensuring a smooth and efficient workflow.

Lastly, as the project enters its final phase, the implementation of a nominal fee for subscribed users is planned. This will enable users to publish and promote their tools through the WE Marketplace, while also ensuring the platform's sustainability and growth.

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Overall, more improvements to WE Marketplace are scheduled for the last phase of the ULTIMATE project. These will ensure that the platform remains a cutting-edge resource for CE professionals, fostering innovation and collaboration within the industry.

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Annex A: Terms and conditions for publishing product information on the WE Marketplace

The following are the terms and conditions that registered users must adhere to in order to share information about their products on the Water Europe Marketplace.

Subscription fee

By paying the annual subscription fee, users are granted the right to upload and publish information regarding a product, service, or tool (hereafter called “product”) on the Water Europe Marketplace (hereafter called “Marketplace”), in accordance with the remaining articles of these terms and conditions. The subscription fee is an annual charge, and it shall be assessed on a per-product basis. The fee covers solely the costs related to the uploading and publication of product information on the Marketplace. It is explicitly stated that the subscription fee does not include any costs associated with the maintenance or upkeep of the uploaded information.

Notwithstanding other provisions, the uploading of product information is exempt from fees until December 31st, 2023.

Product eligibility

The product must be directly related to one of the three pillars of the Circular Economy (CE), namely Water, Energy or Materials/Nutrients or indirectly related as a product that supports the CE (e.g. a software product). Applicants may be requested to provide evidence for this relation.

Subscription period

The subscription period is for 12 months from the date of payment of the fee. After the subscription period has ended, the product information will no longer be visible to the public. Visibility can be resumed after the payment of the fee. All information related to the product can be deleted by the Administrator of the Marketplace if the subscription is not renewed 6 months after it has ended.

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Ownership and responsibility

The fee refers to a single product and not to the entity (user or organization/company) registered to the Marketplace. The user who uploads and maintains the information to the Marketplace or the organization or company with which the user is affiliated and represents (hereafter referred to as the "owner") must own the product. The owner of the product is obliged to keep the published information up-to-date for as long as it is visible to the public through the Marketplace.

Liability and offending material

The uploaded information is the sole legal responsibility of the person or organization/company that uploads it. Water Europe is not responsible for any errors or omissions, or for the results obtained from the use of the information uploaded, which is provided "as is", with no guarantee by Water Europe of completeness, accuracy, timeliness, or of the results obtained from the use of this information. The uploaded information must not contain any offending material or material and violate the law. The administrator of the Marketplace reserves the right to remove information from the Marketplace if it does not comply with the terms and conditions.

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Water Europe reserves the right to make changes to the Marketplace site, policies, service terms, and these conditions of use at any time. If any of these conditions shall be deemed invalid, void, or for any reason unenforceable, that condition shall be deemed severable and shall not affect the validity and enforceability of any remaining condition. It is the responsibility of product owners to review these terms and conditions of use periodically. The continued use of the site and services of the Marketplace after any modifications to the terms and conditions of use will be considered as an acceptance of those modifications.

Acceptance

By uploading a product, the product owner agrees to accept all the terms and conditions of the Marketplace and understands that Water Europe is relying upon the user's stated acceptance of such terms and conditions.

Disputes

Any dispute or claim relating in any way to your use of any Water Europe Marketplace services will be adjudicated in the courts of Brussels, Belgium, and you consent to exclusive jurisdiction and venue in these courts.

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