Total Resource and Energy Efficiency Management System for Process Industries

Deliverable 4.2

Prototype library of case studies linked to a waste database

Date: 28/02/2017

WP4 Industrial Symbiosis

T4.2 Library of case studies and open source database of waste

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Sustainable Process Industry through Resource and Energy Efficiency

Total Resource and Energy Efficiency Management System for Process Industries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680570

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Executive Summary

The MAESTRI project aims to advance the sustainability of European manufacturing and process industries. This will be done by providing a management system in the form of a flexible and scalable platform and to guide and simplify the implementation of an innovative approach in organizations with the Total Efficiency Framework, which encompasses Efficiency Framework, Management Systems, Industrial Symbiosis and Internet of Things platform.

The overall aim of the Total Efficiency Framework is to encourage a culture of improvement within manufacturing and process industries by assisting the decision-making process, supporting the development of improvement strategies and helping to define the priorities for companies' environmental and economic performance.

The MAESTRI project aims to tackle improvements in the impact of manufacturing activities, considering and addressing barriers and challenges at both company level and system level (i.e. concerning for example the transfer of knowledge among different companies and existing gaps between regulation and practice) in order to achieve significant results. A holistic approach will enable process monitoring and optimization, as well as focus on an integrated and cross-sectorial interaction that can have a greater impact within the process industry. The MAESTRI project encompasses an Industrial Symbiosis (IS) approach, which, within the scope of sustainable manufacturing for process industries, fosters the sharing of resources (energy, water, residues and recycled materials) between different processes of a single company or between multiple companies.

This document presents the prototype library of case studies and the linked waste database that have been developed in task 4.2 ("Library of case studies and open source database of waste"). The first part of the document gives an overview of the importance of creating such tools for supporting and boosting the development of Industrial Symbiosis practices among industrial companies. In addition, existing databases for Industrial Symbiosis are presented and described, as well as their main features and weaknesses. The main purpose of the library and the database are defined, and main challenges for Industrial Symbiosis discussed in D4.1 ("Report on challenges and key success factors and gap analysis for industrial symbiosis") and here tackled are identified. Then, the structure of the library of case studies and of the linked waste database are presented, describing entries and attributes in detail. The use of the library and the database is described, together with potential standard queries created for users. Finally, main results from library and database usability test are presented. These results were obtained applying the standard queries defined to the data (namely, NACE code and EWC codes) provided by MAESTRI industrial partners. The results of this study will constitute the foundation for next tasks in WP4, namely the development of a toolkit that can support companies to embark into the application of IS approach in their manufacturing operations. These results will additionally be considered as a source for the definition of new requirements within WP1 ("Requirements Engineering") activities and as support for the integration of WP2 ("Efficiency Framework"), WP3 ("Management System") and WP4 ("Industrial Symbiosis") into the Total Efficiency Framework.

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Abbreviations

CRISP	Core Resource for Industrial Symbiosis Practitioners
EC	European Commission
EWC	European Waste Catalogue
GIS	Geographical Information System
IE	Industrial Ecology
IS	Industrial Symbiosis
IS DATA	Industrial Symbiosis DATA repository
ISIS	Industrie et Synergies Inter-Sectorielles
MFA	Material Flow Analysis

NACE	Nomenclature générale des Activités économiques dans les Communautés Européennes
NAF	Nomenclature des Activités Françaises
NISP	National Industrial Symbiosis Programme
PVC	PolyVinyl Chloride
ROI	Resource Optimization Initiative
SMILE	Saving Money through Industry Links & Exchanges

Definitions

Explicit knowledge > Knowledge or information that is easily communicated, codified, or centralized using tools such as statistics (GRANT et al., 2010)

Industrial Symbiosis (IS) > Industrial Symbiosis engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products (CHERTOW, 2000)

Knowledge Repository > A Knowledge Repository is a system that systematically captures and continuously analyses the knowledge assets of an organization; it is a collaborative system designed for a two ways communication where people can query and browse both structured and unstructured information in order to retrieve and preserve organizational knowledge assets and facilitate collaborative working (SUMATHY et al., 2013)

Tacit knowledge > Knowledge that resides within individuals or a company and which is difficult to express in written forms, i.e. expertise (LAM, 2000)

Waste > Any substance or object that the holder discards or intends or is required to discard (EC, 2008)

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Waste management > Means to the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker (EC, 2008)

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1 Introduction

Industrial Symbiosis (IS) can be considered as a sub-discipline of Industrial Ecology (IE) that is concerned with resource optimization among collocated companies (JACOBSEN, 2006). In practice, it means that manufacturers can make better use of all inputs to their processes through exchanges of waste, by-products and energy with other companies/sectors (MANUFACTURING COMMISSION, 2015).

As already detailed in D4.1, the development process for Industrial Symbiosis is described in literature as an iterative sequence of five different phases (GRANT et al., 2010): (i) opportunity identification; (ii) opportunity assessment; (iii) barrier removal; (iv) commercialization and adaptive management; and (v) documentation, review and publication. The first phase in particular, i.e. opportunity identification, can benefit from the creation of knowledge repositories enhancing the mechanism of "relationship mimicking" (GRANT et al., 2010). This mechanism involves mimicking successful relationships employed by similar organisations. Triggering mimicking mechanisms by the means of knowledge repositories is a process that has proven to be positively practical and easy to implement. In fact, this requires enabling information exchange by matching companies from similar industrial sectors, a process that is supported by existing standardised classifications for industry. These classifications, unlike classifications of waste and resources, which still represent a challenge, are already well-known and widely used. A successful linkage can therefore be explicitly designated by two codes, one for each of the industries it connects (GRANT et al., 2010). The creation of such explicit linkages is for example not as easy in "input-output matching" approaches, where available resources have to be defined and associated with one organization, and then complementary resource requirements for another organization have to be identified. These approaches are generally successful in closed systems, where synergies are established among pre-selected industries, basing on their geographical proximity or on their existing relationship and mutual trust (CECELJA et al., 2015); one famous example of a closed system is Kalundborg, Denmark (CHERTOW, 2000). However, nowadays the development of open models enabling unrestricted and wider participation of partners as well as competitive terms in exchanging materials and energy is becoming more and more common, as it is considered to be consistent with the dynamic nature of IS networks (CECELJA et al., 2015). Therefore, "relationship mimicking" approaches and knowledge repositories are becoming key elements for Industrial Symbiosis implementation.

This introductory chapter will briefly present the research process that has been carried out to complete task 4.2 activities, as well as existing databases for Industrial Symbiosis. In the present text, database is intended as an organised collection of data, i.e. the physical structure of a knowledge repository.

1.1 Research process

This deliverable aims at illustrating activities carried on in T4.2 for the development of a library of case studies linked to a waste database. An overview of the research process is given in Figure 1 and explained in the following.

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First, a literature review of existing IS-related databases has been carried out, and the results of such literature review are reported in the following section. Building on what emerged in this first step, and in particular on common features of different databases and on their main weaknesses and limitations, a first structure of the library and database was designed.

A small set of case studies was then selected for a preliminary library and database population. This preliminary population has allowed to test the suitability of the designed structure and of the link between the library and the database, as well as to refine it. After this refining, the structure was shared with other researchers in the Industrial Symbiosis field and with MAESTRI partners for consolidation and first validation.

Then, both the library and the database have been populated with a set of 46 different case studies (and corresponding 426 waste exchanges) from literature.

Eventually, the library and database have been tested together with the four MAESTRI industrial partners to assess their usability.

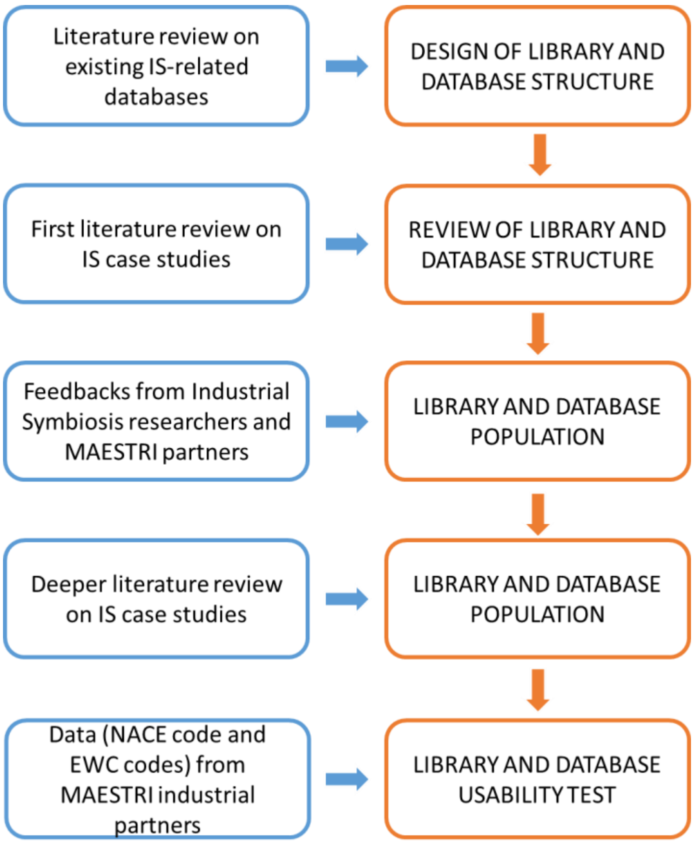

Figure 1 – Overview of the research process

It is important to mention that both scientific and non-scientific literature have been considered for database population. This has allowed taking into account also whitepapers and industrial presentations other than scientific papers, thus including in the knowledge repository also simple but effective forms of Industrial Symbiosis that are usually left out of academic research.

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1.2 Existing databases

There are mainly three different types of databases connected to Industrial Symbiosis implementation or facilitation, and more broadly speaking to waste management practices, that are available in literature: (i) databases containing information related to waste available or resources required in a defined geographical area; (ii) databases containing information related to waste management products and services available in a defined geographical area; (iii) databases containing information regarding existing synergies and Industrial Symbiosis case studies.

The first two types are usually created to support input-output matching approaches, while the third aims to support relationship mimicking. The fundamental difference in comparison to the first two types is that in order to make the third database type effective, it is vital to avoid structuring it as a mere data (and explicit knowledge) repository, and to try to enrich it with tacit knowledge contents. In fact, unlike commodities such as recycled metals, which can be traded solely based on explicit knowledge, waste materials are typically nonstandard or highly variable in composition, thus the process of exchanging them can be more challenging and requires more tacit knowledge flows (CECELJA et al., 2015). This could help avoiding practitioners' biases towards their own expertise (tacit knowledge) or particular industries they wish to serve, informing them about new and unexplored potential synergies as well as required associations, know-how expertise and engineering intuitions. In this perspective, tacit knowledge offers tremendous opportunities to enable IS networks (CHERTOW, 2004; DESROCHERS, 2004).

In Table 1, a brief description of existing databases of all the presented types is given.

Table 1 Existing databases related to IS and waste management implementation

Database	Type	Description
CRISP (GRANT et al., 2010)	i	During the NISP, a national programme on Industrial Symbiosis operating in the UK between 2003 and 2013, a project and contact management suite was created to enable relationship management, synergy management, data collection and reporting, communication and collaboration through a single internet portal. It contains all basic information of companies participating in the programme and of their available or required materials.
RecycleBlu (https://www.recycleblu.com/)	i	RecycleBlu is specifically developed and tailored for the waste and recycling materials market. It offers multiple tools to manage a company's waste inventories and sales processes.
SMILE (http://www.smileexchange.ie/)	i	SMILE is a free service for businesses that encourages the exchanging of resources between its members. Businesses can request or offer reusable materials, by-products or surplus stock that could potentially be a raw material for another business.
US MATERIALS MARKETPLACE (http://materialsmarketplace.org/)	i	The United States Materials Marketplace is a project from the US Business Council for Sustainable Development, World Business Council for Sustainable Development, and Corporate Eco Forum to scale up business-to-business materials reuse across the US. This marketplace facilitates company-to-company industrial reuse opportunities that support the culture shift to a circular, closed-loop economy.
Solid Waste (https://www.solidwaste.com/)	ii	Solid Waste is an online marketplace for waste related products and services, mainly focused on solid waste handling and disposal.

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Waste360 (http://marketplace.waste360.com/)	ii	Waste 360 is an online marketplace for waste related products and services. It mainly contains information related to the United States waste market, but its aim is to become a worldwide repository.
Waste Industry Marketplace (http://wasteindustrymarketplace.com/)	ii	Waste Industry Marketplace is an online marketplace for waste related products and services, mainly focused on the United Kingdom market.
IS DATA (http://isdata.org/)	iii	IS DATA is an open platform for collecting and supplying structured information on industrial symbiosis. It provides a source of best practice activities in the form of a downloadable spreadsheet, containing links to case studies. Each case is identified by the NACE code of companies involved and the EWC code of waste exchanged.
NISP Media Centre (http://www.nispnetwork.com/media-centre/case-studies)	iii	The NISP website has a dedicated area where users can find a list of successful case studies of the NISP project. It also contain a synopsis of each case, highlighting the challenges addressed by industrial companies with the help of NISP facilitators.
Presteo (GRANT et al., 2010)	iii	Presteo is a tool used in some French and Swiss industrial areas. It is derived from the ISIS database that was created to store industry flow information identified from bibliographic sources. The industries are identifiable by the NAF code.
ROI (http://www.roionline.org/case_study.php)	iii	The ROI website contains a section where a number of case studies from different parts of the world are available and maintained in a "digital library". Synopses of these cases can be seen on the webpage.
eSymbiosis (http://esymbiosis.clmsuk.com/Home; CECELJA et al., 2015)	i ; iii	eSymbiosis is a LIFE+ Environmental Policy and Governance Project co-funded by the European Commission. The project's aim is to develop a knowledge-based service that will promote, demonstrate and advance Industrial Symbiosis in Europe. eSymbiosis has created a web-based platform which enables users to participate in Industrial Symbiosis activities by documenting their resources and also reviewing success stories.
MarketplaceHUB (http://marketplacehub.org/)	i ; iii	The MarketplaceHUB is a tool for businesses and policymakers to establish a network of circular economy practitioners. It allows users to find a marketplace according to one's location or by material category. The Hub also aims at facilitating knowledge exchange through case studies and encourages users to contribute to the website by submitting new marketplaces, best practices and other insights.
Materials Innovation Exchange (http://www.materialsinnovationexchange.com/)	i ; iii	The Materials Innovation Exchange is a website and an active industrial materials exchange where companies can buy, sell, donate and trade materials, as well as share innovative stories, best practices, ideas and tools.
SymbioGIS (GRANT et al., 2010)	i ; iii	SymbioGIS stores and utilizes data from input-output analysis and literature review to document and detect potential exchanges and service sharing in a given region. A GIS interface allows the visualization of potential exchanges and facilitates technical and geographical feasibility assessment. SymbioGIS supports the detection of new potential partners within the manufacturing activities and the identification of the optimal location for new facilities based on material flow.

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SymbioSys (ALVAREZ and RUIZ-PUENTE, 2016)	i ; iii	The database which is part of the SymbioSyS tool has been designed to store dynamic information from participating companies and the Industial Symbiosis knowledge database. The dynamic information includes name, location, geographical coordinates, industrial area, and number of workers, while the knowledge base of IS consists of tacit knowledge based on partnerships, know-how of IS experts and case studies from the scientific literature.

As it can be seen in Table 1, over the last years there have been several efforts by different kinds of entities (public, private, research institutes or consultants) in order to create databases that could somehow support Industrial Symbiosis implementation.

Focusing on databases of the third type is particularly interesting for MAESTRI activities and for the broader research community (as highlighted in previous section). Existing databases of this type currently have two main limitations: they are generally lacking tacit knowledge content and they often only include synergies created within a specific project or in a specific geographical area, losing general validity.

2 Purpose

The main aim of both the library and the database is to represent a repository of potential improvement ideas and opportunities for new symbiotic exchanges. Companies can use the library and the database to identify case studies and symbiotic exchanges involving other companies, either within their own sector or from different sectors. This enhances cross-sectorial learning and mimicking opportunities.

The database of waste can support companies to see their wastes, providing examples of wastes identified by other companies in the same sector and to understand which valuing and exploiting processes other companies used, providing examples of already feasible exchanges.

The library of case studies, instead, allows companies to find out how industrial symbiosis can help them facing some of their operational challenges, whether they are directly or indirectly related to waste management. In addition, it can help them understanding the effort (additional analysis, projects or investments) needed to effectively implement industrial symbiosis and how and when third-party facilitators can help.

The library and the linked database here presented can help addressing two of the main challenges for IS implementation pinpointed in D4.1, as explained in the followings.

In the previous WP4 task (T4.1, "Challenges and success factors for industrial symbiosis"), in fact, the need for further research on tools and methods that can support companies to identify and evaluate, at early stages of ideation, the different possibilities for both their waste streams and for enlarging their procurement activities by looking for symbiotic exchanges with other companies has clearly emerged. The waste database can contribute to address this need, helping companies identifying and valuing their wastes and triggering the mimicking mechanism.

In addition, during the first task of WP4, it had been pointed out that it is not clear whether companies fully understand the activities necessary to deliver progress towards the vision.

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A consideration for the design and implementation of tools associated with industrial symbiosis is therefore that the instruments should focus on the activities (e.g. identify waste), the means (e.g. MFA, environmental assessment), the aims (in particular the benefits, e.g. competitive advantage, environmental responsibility) from a business point of view rather than utilising the academic vernacular. The library of case studies can contribute to fill this gap, providing companies with the description of the discovery processes other companies had to undergo in order to set up successful synergies.

3 Structure of the prototype library of case studies and of the linked waste database

The library of case studies is a collection of cards containing relevant information (mainly related to the tacit knowledge content) about different case studies available in literature.

The structure of the cards constituting the library of case studies is illustrated in Figure 2.

CASE IDENTIFICATION				
Case Identifier*			**Case Title**	
#			...	
SOURCE DETAILS				
Source Identifier*	**Source Typology**		**Source Link**	**Year (publication/last updated)**
#'	❑Paper ❑Scientific conference presentation ❑Whitepaper ❑Website ❑Industrial presentation		...	XXXX
CASE DESCRIPTION				
Country	**Benefits quantification**			**Level of completion***
...	❑Economic ❑Environmental ❑Social ❑Not Available			❑C: Completed, every identified exchange is implemented ❑TBC: To Be Completed, some of the identified exchanges are not yet implemented ❑FS: The whole project is still under feasibility study
TACIT KNOWLEDGE CONTENT				
Main challenge (triggering factor)	**Main barriers**	**Approach**	**Discovery process**	**Preconditions**
...	...	...	...	...

Figure 2 – Structure of the cards constituting the library of case studies

Each card is divided into four different sections, highlighted with different colours in Figure 2.

The first section is the "case identification". It contains the case title and a numeric identifier, which will constitute the main link between the library and the waste database. In fact, the numerical identifier of each waste exchange in the database will contain the case identifier of the case study it belongs.

The second section is the "source details". It gives several information regarding the original source of the case. Its aim is twofold: on the one hand it allows to acknowledge the work made by other researchers in collecting information and describing the case study, while on the other hand it gives the users the possibility to easily find the original source. This second feature is particularly needed in order to make users able to refer to the original

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source in case they need more information on a specific case. All of the sources are identified with a numerical identifier, also included in the identifier of waste exchanges in the database. That was necessary for clarity as one case can be described by more than one source and one single source can contain different cases.

The third section contains a general description of the case: the country where it is set, the typology of benefits quantified in the source (economic, environmental or social benefits) and the level of completion of the case. The level of completion is "Completed" when all the exchanges in the case (described in detail in the waste database) are already implemented, "To Be Completed" when some of the exchanges in the case are planned, but not yet implemented, and "under feasibility study" when the source describes a preliminary study.

The fourth section is the one containing the main tacit knowledge content, extrapolated from each case. The main reason for the company to pursue the synergy implementation is described. This challenge represents the triggering factor, i.e. the contextual factor that caused the starting of the synergy. In addition, main barriers to IS implementation are listed, as well as the approach used in order to overcome them. Then, the discovery process is illustrated, highlighting all the main steps and efforts made by the involved companies (or facilitators) to make the synergy feasible (namely, the process of identifying – characterising – valuing – exploiting wastes). Eventually, the preconditions, or antecedents, that made the synergy feasible in the specific context are described (antecedents are here intended with the same meaning as illustrated in BOONS et al., 2011, i.e. inputs to understand and analyse the dynamics of industrial symbiosis).

The explicit knowledge content is instead mainly contained in the linked waste database.

The waste database is a spreadsheet in which each row corresponds to an exchange occurring between two different companies. These exchanges are the ones described in the cases of the library of case studies. The exchanges are linked to the corresponding cases through their numerical identifier, which is composed as follows:

$$\#, \#', \#'' = \mathit{case\ identifier}, \mathit{source\ identifier}, \mathit{sequential\ number\ of\ exchanges\ belonging\ to\ the\ same\ case}$$

The structure of the waste database is illustrated in Figure 3.

EXCHANGE IDENTIFICATION	INVOLVED COMPANIES						SYNERGY DESCRIPTION							SYNERGY DETAILS			
	Donor Company			Receiver company			Flow		Treatment								
Exchange Identifier*	Company name	Main Business	Sector (NACE)	Company name	Main Business	Sector (NACE)	Brief description	EWC code/general classification	Actor	Brief description	Company (if owner is a third-party)	Business (if owner is a third-party)	Sector (NACE) (if owner is a third-party)	Use	Quantities avilable in the source	Payment	Level of completion*
#,#',#''	…	…	xx,xx	…	…	xx,xx	…	xx xx xx / …	Donor/Receiver/Third party	…	…	…	xx,xx	…	Yes/No	By the donor/By the receiver/NA	C/TBC/FS

Figure 3 – Structure of the waste database

If the same flow is described in more than one source, the most updated one is taken as a reference, so that the same flow is not entered several times in the database.

Each row of the database is divided into three different sections.

The first section gives details regarding companies involved in the exchange. For both the donor and the receiver company, the name of the company (where available) and a

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description of the main business of the company are given. In addition, basing on the information given in the original source, four-digits NACE codes have been associated to each company.

The second section is the "synergy description". In this section, details regarding exchanged flows and potentially needed treatments are given. As regards the flow, apart from providing a brief description of the material/energy exchanged, an EWC code has been associated (where possible) to each flow, in order to give a material taxonomy as standardised as possible. The EWC code has been chosen for this attempt for its wide diffusion among companies of different sectors and also because it has proven to be suitable for this purpose in previous studies (CECELJA et al., 2015; AID et al., 2015). Where it was not possible to match a EWC code to the flow, particularly when non-material wastes were involved, a general classification has been added (mainly: water, steam, heat, industrial gas, electricity, fuel) in order to enable an easier search. As regards the treatment, if needed, it is first of all defined who is the owner of the treating process. It could be the donor company, the receiver company or a third party. If it is a third party, the name of the company (where available), the description of its main business and a NACE code are given. In addition, the treatment itself is briefly described.

The third section adds some more details regarding the synergy. Specifically, the use that the receiver company makes of the flow, information regarding the quantities exchanged (if this is available in the original source), information regarding the payment (if a payment is due by the donor or by the receiver), and the level of completion of the exchange. The level of completion is "Completed" when the exchange is already implemented, "To Be Completed" when the exchange is planned, but not yet implemented, and "Under Feasibility Study" when the source describes a preliminary study.

4 How to use the library of case studies and the database?

Results can be extracted from the library and the linked database in different ways.

As regards the library of case studies, it is possible to make keywords searches related to each of the different attributes detailed for each case. For example, it is possible to search for cases set in specific countries, or addressing specific challenges and facing specific barriers. It is also possible to scroll down the list of short titles given to each case, to select the ones that might be of interest and, only for these, to retrieve additional information.

As regards the waste database it is possible to make keyword searches related to some of the attributes (such as the description of the flow, of the treatment or the use) or more specific queries for coded fields (namely, the NACE and EWC codes). Once entered the database with the NACE code, users will be shown different exchanges where companies with the same NACE code have been involved (as donors, receivers or taking part to the treatment process). Once entered the database with the EWC code, they will be shown different exchanges of waste with the same code, as well as if any treatment is needed to make the exchange feasible. When the database records corresponding to searching criteria have been found, it is possible, thanks to the numerical exchange identifier, to identify the related case studies in the library, and to get additional information regarding

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the tacit knowledge content (main challenges and barriers faced in industrial symbiosis implementation, approach adopted, discovery process and preconditions).

Two different types of standard queries and results extraction processes are illustrated in the following figure:

- Standard query type A, looking for similar companies (same NACE code);
- Standard query type B, looking for exchanges of similar waste materials (same EWC code).

As shown in Figure 4, the last two steps of the two standard queries are identical, as they are referred to the identification of the case studies within the library that corresponds to the exchanges in the waste database.

Keyword searches are not considered as standard queries due to their intrinsic variability and higher degree of customisation. They will, however, follow a similar logic as query type A and B. Thus, these two searches by coded attributes are here illustrated to describe how the library and the database are interconnected, independent of the type of the query that is used to access the information.

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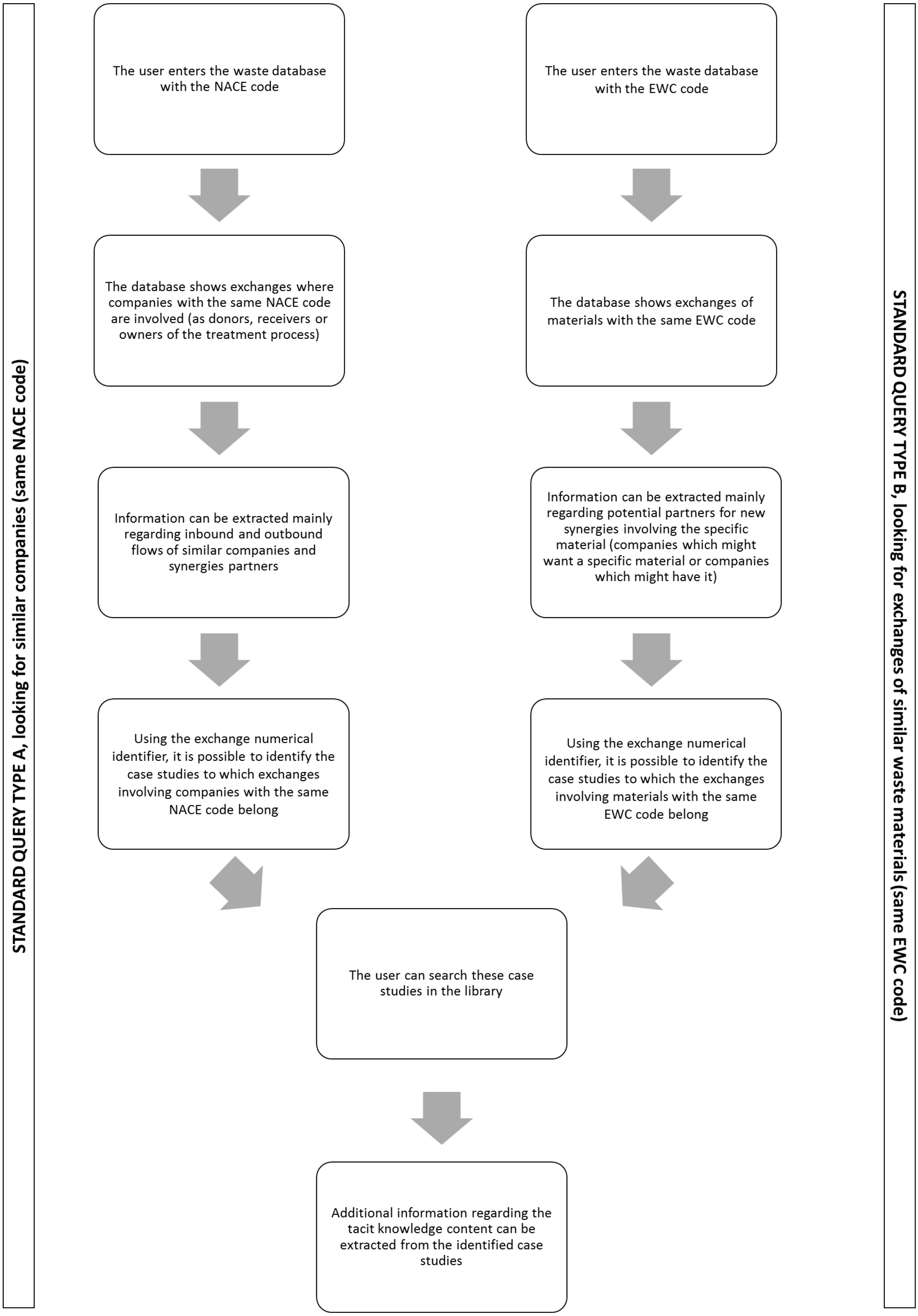

Figure 4 – Standard query type A and type B

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5 Findings related to MAESTRI industrial cases

The two standard queries (type A and type B) described in Figures 4 and 5 have been applied using NACE and EWC codes provided by MAESTRI industrial partners.

In the following, the main findings from these queries are illustrated. Please note that confidential data have been removed from the text. Complete reports containing all relevant results have been provided to the industrial partners and circulated within the consortium.

Table 2 Summary of findings using data from MAESTRI industrial partners

	Type of code used to enter the database	
	NACE	**EWC**
Number of identified flows	18	20
Number of identified cases	9	10
Number of identified sources	8	8

The database provided examples of flows corresponding to the search criteria for 20% of the analysed codes. Multiple examples of flows have been found for single codes in several cases.

The standard query type A (looking for similar companies) provided examples of exchanges where companies having the same 4 digits NACE code are involved (note that a generic 2 digits NACE code would find more than 150 flows, here omitted for the sake of brevity).

Some examples of identified flows are the followings:

- Plastic packaging from agro industries, paints and pigments producers, food and fish processing companies reused as raw materials by manufacturers of plastic products;
- A sheet metal parts producer receiving scrap wood to be used as fuel for room heating;
- A galvanic treatment process receiving chemical by-products from a manufacturer of inorganic basic chemicals and using them as input materials;
- Acetone disposed from a gem manufacturer, reused by a manufacturer of plastics in primary forms;
- A paints manufacturer receiving off-spec solvents from a pharmaceutical company, after a treatment performed by a waste management company.

The standard query type B (looking for exchanges of similar materials) provided different examples of exchanges involving different materials, belonging to different case studies. 26 potential types of partners for synergies based on those materials have been identified (e.g. metallurgical plants, insulation materials producers, pulp and paper plants, plastic products producers, food companies, food packaging processes, interior decorations producers, manufacturers of bespoke products for the boating, banner and trailer markets, blast media producers, PVC sewer pipes producers, etc.). Waste treatments needed have also been identified where described in the original source.

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6 Concluding remarks

The identification of Industrial Symbiosis opportunities can benefit from the creation of knowledge repositories facilitating the mechanism of “relationship mimicking” (GRANT et al., 2010). This mechanism involves mimicking successful relationships employed by similar organisations. Triggering the mimicking mechanism by the means of knowledge repositories is a process that has proven to be positively practical and easy to implement. However, existing databases are usually just data and links repositories, neither adding useful information nor extrapolating tacit knowledge content from original sources, or they are limited to synergies created in a specific project or in a specific geographical area. This of course limits the potential of this type of database, failing in both providing a global vision in latest advances in Industrial Symbiosis implementation and supporting companies with meaningful contents.

In addition, nowadays the adoption of open Industrial Symbiosis development models, i.e. not framed in specific projects or locations, and enabling unrestricted and wider participation of partners as well as competitive terms in exchanging materials and energy, is becoming more and more common, as it is considered to be consistent with the dynamic nature of Industrial Symbiosis networks (CECELJA et al., 2015). Therefore, “relationship mimicking” approaches and knowledge repositories are becoming key elements for Industrial Symbiosis implementation.

Therefore, a prototype of a library of case studies and a linked waste database were developed, containing both tacit and explicit knowledge contents and answering the need to create support tools for companies to identify and evaluate, at early stages of ideation, new synergies opportunities. The developed prototype, which is described in this document, aims at overcoming main limitations of existing knowledge repositories for Industrial Symbiosis, already discussed in previous paragraphs: the lack of tacit knowledge content and of general validity.

The impact of the use of such tools in companies willing to implement Industrial Symbiosis is estimated to be considerable, as these limitations are also listed in literature among the most relevant barriers to Industrial Symbiosis implementation (GRANT et al., 2010), as already highlighted in D4.1. The library of case studies and the linked waste database will allow companies to gather ideas regarding new potential exchanges to be implemented, as well as possible ways to value and exploit their wastes. The library of case studies in particular is also a powerful means to increase companies’ awareness on the potentiality of Industrial Symbiosis and on the discovery process needed to successfully implement it.

The cards developed for the library of case studies will be used as a starting point for the development of MAESTRI guidelines in task 4.4, thus building on this valuable information.

The usability of the prototype library of case studies as well as of the linked waste database has been tested. Two different standard queries have been defined and applied to data (namely, NACE and EWC codes) provided by MAESTRI industrial partners. This test has allowed to identify several existing synergies in other companies. Further steps would look at the feasibility of similar synergies, according to the MAESTRI partners’ specific context.

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The usability test gave good results for standard queries type B especially for waste packaging materials. That might be due to the fact that packaging materials are often the same for companies belonging to different industrial sectors, thus the probability to find matching results in the library and database is higher. In addition, packaging materials are also easier to associate to a EWC code. In order to improve the results also for general waste materials, the description of the flows given in the database could be modified to enable more precise keyword searches, so that companies will be able to look for very generic materials' definitions (such as "plastics") and more specific ones (such as "PVC") without missing any information. A more extensive use of the database will be required to find out the keywords that are most used by companies, in order to build a robust keywords sample to support searches.

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