Business case framework

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Deliverable 4.3

Business Case Framework

WP4 Action plan for Industrial Symbiosis in Europe

T4.3 Business Case Framework

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Executive summary

This deliverable is part of the SCALER WP4 research program. It builds on the previous research activities on innovative business models performed within the scope of EPOS project. It uses all previous works made during SCALER and on other SCALER WP to present two major tangible outcomes:

- A framework to assess the viability of synergies and list/collect all values generated by a synergy creation
- A process to help industrial managers assessing the viability of a synergy

The framework is designed to provide a modular tool to industrial managers who want to initiate and get involved in a synergy creation process. This framework is generic but widely applicable and adaptable to many different contexts and IS projects: type of resource, geographical location, socio-political situation, etc.

The framework will facilitate the choice of the most suitable Business Model and the creation of adapted business cases for each individual partner involved in a synergy creation. by making evident all values created by the establishment of the synergy.

A step-by-step process has also been provided for assessing a synergy in detail, defining the associated business model and setting-up as many Business Cases as necessary for all individual stakeholders.

Step 1 consists in identifying opportunities on-site. The LESTS method (Legal, Economic, Spatial, Technical, Social) developed by the University of Ghent in EPOS is an easy qualitative early assessment that help ideas emerge. The well-established SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) is adapted to screen the positive and negative aspects of each idea. The Value Mapping Tool developed by the University of Cambridge is helping to identify value surplus, absence, missed or destroyed, a useful mean to explore less tangible benefits or impacts. Finally, the Material Flow Cost Analysis is an effective method to quantify costs deposits over the lifecycle of the resource. Selection criteria identified with a survey carried out in SCALER are listed to facilitate decision-making.

Step 2 focuses on identifying synergies, which requires to identify potential partner sectors and spot relevant facilities in these sectors close to the facility originating the synergy. This is a crucial and challenging step in the process of setting up synergies. A list of most applicable synergy identification software tools is provided based on a worldwide study of 100+ tools. Examples of intermediaries who can support and facilitate the process are described. Finally, databases of synergies and knowledge repositories are listed to provide information on already implemented synergies.

Step 3 proposes a method to assess in detail the identified synergies. It lists the information required to initiate the work: qualities of resources, constraints from potential partner, technical aspects related to the treatment and logistics of the resource, the mapping of relevant facilities, the questions to raise with potential partners, the steps to test and confirm their willingness to use the resource, the procurement of logistics services. A simple decision tree synthesises the different steps. The quantification of every economically relevant value is provided, both for monetised aspects (value of heat, fuel and raw materials, taxes, waste management costs, logistic and labour costs) and non-monetised aspects (human health, ecosystem quality, resource productivity, climate change, social and territory values).

Business Model and Business Case examples are provided to illustrate a concrete application of the methodology to the guide user.

This guide will hopefully support practitioners and industrial representatives in creating new, sustainable industrial synergies, and therefore create a positive impact on the European economy, environment and society.

Figures and tables

Abbreviations

BC: Business case

BM: Business model

LCA: Life Cycle Assessment

SEA: Socio-Economic Assessment

IS: Industrial Symbiosis

LESTS: Legal, Economic, Spatial, Technical, Social

MFCA: Material Flow Costs Accounting

SWOT: Strengths Weakness Opportunities Threats

CAPEX: Capital Expenditure

OPEX: Operational Expenditure

SBMC: Sustainable Business Model Canvas

DALY: Disability Adjusted Life years

1. Introduction

1.1 SCALER project

Industrial Symbiosis (IS) aims at optimising the use of resources between industrial companies and communities by exchanging and sharing energy, wastes, effluents, by-products or by mutualising assets and services. IS can increase the competitiveness of industries, generate social and environmental benefits, reduce raw materials consumption, reduce the dependency on suppliers, and create a new local, sustainable activity related to the implementation of synergies.

The SCALER project successfully scaled up the delivery of value embedded in European physical resources (materials, water and energy) through efficient and implementation of industrial symbiosis (IS) across the whole European area. It provides mechanisms to foster a wider implementation of IS in the European process industry by providing action plans and adapted solutions to industrial stakeholders and communities.

1.2 Scope and objective

Industrial symbiosis implementation is a complex and iterative process, requiring effort and cross-sector expertise. Managers and decision-makers usually lack internal resources and methods to identify opportunities and assess them. These industrials may not necessarily know in detail the potential of all values generated by the industrial activity, in particular concerning supply chains and surplus resources generated. They usually identify opportunities on-site but do not know how to address the issues and convert ideas into concrete IS solutions.

The objective of this deliverable is to address this need with a simple guide for industrial managers. Typically, they may be site managers, energy managers, environmental managers, corporate and sustainable responsibility managers, and operational managers. This guide proposes several methods and tools to help them throughout the process of identifying and assessing synergies to build a strong case for deciding whether or not to pursue with the implementation of the synergies. This assessment is consolidated into a 10 module business framework, to support decision-making.

The structure of the framework is intended to be a modular tool to:

- Create an analysis framework for value created and destroyed by a synergy
- Set and follow a coherent process from the beginning to the end of a synergy implementation
- Assess the viability of implementing a synergy (technically, economically, environmentally, etc.)
- Define the business case of a synergy including monetary and non-monetary values
- Identify and implement the most appropriate and relevant business model

This methodology is a key practical outcome of the SCALER project.

1.3 Background & Literature review

This guide builds on several high-quality research results from European projects SCALER, MAESTRI and EPOS related to innovative business models and methods to map and capture value. These methods were proven against real test cases and used to obtain operational guide directly applicable by industrial managers.

SCALER results from other WPs were also used for this guide. WP2 studied pathways to foster resource synergies. several deliverables were specifically used:

- Deliverable D2.1 [1] identified best practices and lessons learnt for scaling up IS based on 85 peer-reviewed papers (among 210 interrogated) addressing IS adoption. Economic, environmental, government and policy related topics are the most commonly aspects that could trigger the interest in implementing IS. Another major trigger is the scarcity of certain material resources. The most prominent enablers are government policies and subsidies, the use of green marketing, changes in regulations, the relationship between government and businesses corporations, the availability of knowledge like databases and other intermediaries' skills, geography and new technology. D2.1 was used for this guide to identify actors involved in the creation of a synergy, benefits and values generated by synergies, common business models, common contractual agreements, acceptance criteria and recommendations for business practices.
- Deliverable D2.2 "Intermediaries and key enabling technologies" [2] provides insight into the role of intermediaries at multiple scales in the process of initiation and implantation of industrial symbiosis. The study exploits the results of an expert enquiry to learn about the role of intermediaries for the creation of a synergy, and lists a set of enabling technologies for IS. Some IS programs were also selected to be recommended to industrials.
- Deliverable D2.4 "Pathways to increase industrial symbiosis implementation" [3] provides a detailed insight into state-of-the-art tools and methods facilitating the implementation a synergy and enable stakeholder pathways towards self-organised industrial symbiosis. This deliverable was used to find adapted tools for two steps of the synergy creation process: the identification of opportunities and the synergy identification.

SCALER WP3 aimed to assess the potential of industrial symbiosis (IS) for major heavy industries in Europe and to support evidence-based policy-making, based on the in-depth analysis of a representative set of 100 synergies. It included several deliverables of interest for this guide.

- D3.1 lists 100 promising synergies (combinations between already implemented and innovative synergies) also presented in the "Synergies Outlook" [4]. This list was used in this report for the synergy identification process to provide synergies ideas to industrials. The list of synergies used a tool developed by Strane Innovation within SCALER for identifying synergies.

- D3.2 [5] describes the technologies required for each of the 100 synergies. The report was used to list technical variables necessary to obtain to proof the technical viability of a synergy, and to highlight its methodology for finding adapted technologies for a given resource.
- D3.3 [6] modelled a life cycle assessment of the 100 synergies. The methodology used to compare baselines scenario with synergies scenario is reported in the environmental assessment module to enable practitioners comparing the solution retained with the initial one. LCA indicators are used here to quantify environmental and human health values generated by a synergy creation. These values are reported in the framework
- D3.4 [7] analysed the socio-economic benefits of the 100 synergies. Socio-economic indicators are used to inform the economic and social aspects of the framework.
- D3.5 consolidated all findings for assessing the IS potential in Europe. It highlights the most impacting synergies and a quantitative evaluation of benefits as well as geographical areas relevant for IS implementation. This information was used to give synergies ideas and context information on IS.

Table 1: Examples of indicators used in the SEA (source: Strane)

Synergy 13	
Waste stream price in Baseline scenario (€/Unit)	-
Waste stream volume (Unit/y)	68127
Substituted material equivalent price (€/Unit)	66,5
Final volume recovered (Unit/y)	68127
Operational costs (€/y)	2207,3148
VA	4 528 238 €
VAT	971 760 €
Labour Share (€/y)	2 082 990 €
Direct jobs (€)	47
Indirect jobs (min)	24
Indirect jobs (max)	143
Investment	
CAPEX	Some companies are already able to treat this flow
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO_2-eq)	-13309202
Human health (DALY)	-27,445159
Ecosystem quality (PDF.m2.y)	-10784602
Use of resources (MJ)	-208030610
€ Climate change	1 064 736 €
€ DALY	2 030 942 €
€ Ecosystem quality	15 098 442 800 €
€ Use of resources	832 122 €
Sum of external economic impacts (€)	15 102 370 600 €
Carbon tax evolution (€/y)	-532 368 080 €
Waste tax	
Waste tax Baseline scenario (€/y)	2 644 690 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-2 644 690 €
Viability distance (100% of the resource price)	380
Viability distance (10% of resource price)	38
Waste treatment costs Baseline scenario (€/y)	3 617 544 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-3 617 544 €

Finally, this report builds on WP4 results. It developed 6 Guidelines for IS [8], including economic, social, human and policy risks related to IS projects [9]. Another guide [10] introduces a process to technically implement new synergies. It was also used to detail the whole technical and non-technical synergy creation process. A section dedicated to support tools for IS opportunities identification and synergy finding was also a source of information.

The SCALER quick guides [11] summarise some benefits (costs savings, avoided pollution and wastes, reduction of transportation and road occupation, increase of the local economy, job creation, etc.), tools, methods, modelling, new 4.0 technologies use for IS, finance triggers and means of actions, the role of intermediaries and networks.

EPOS was a H2020 Collaborative project dedicated to foster IS (GA no. 679386, 2015-2019, budget 4M€). It gathered 13 partners, including prominent industrial companies (Veolia, ArcelorMittal, Cemex, Ineos, Omya). It delivered tools and methodologies dedicated to practitioners. EPOS deliverable D6.3 "Industrial symbiosis guide for conceptualising business relations" provides guidelines to industries, cluster managers or IS facilitators to manage non-technical issues to identify and assess IS opportunities:

- Prioritise synergy opportunities according to their implementation potential;
- Collect relevant data, define analysis scenarios and, create a synergy-focus stakeholder ecosystem;
- Assess an extended range of values (economic, social, environmental, territorial);
- Crystallise these values within a dedicated sustainable business model canvas;
- Create preliminary business cases to trigger interest of each involved organisation's decision-maker.

The EPOS framework was iteratively developed all along the project thanks to synergy analyses in the 5 demonstration clusters of the project. It has been designed to be generic - and widely applicable, in different contexts – and most importantly to be realistically used by stakeholders by trying to limit efforts in terms of spent time and data required. Its final goal is not to make a detailed assessment of the synergy but to make a preliminary opportunity analysis, trigger interest of stakeholders' decision-makers who could then decide to further detail the project analysis.

The MAESTRI project aims to advance the sustainability of European manufacturing and process industries. The project provided a management system to guide and simplify the implementation of an innovative approach, the Total Efficiency Framework. The overall aim of this framework is to encourage a culture of improvement within process industries by assisting the decision-making process, supporting the development of improvement strategies and helping define the priorities to improve the company's environmental and economic performance.

The project developed a Library of Case Studies and linked Exchanges Database [12] to provide potential Industrial Symbiosis improvement ideas and opportunities for new symbiotic exchanges. It is a source of information on existing Industrial Symbiosis implementations worldwide, built using public documents (scientific publications, etc.). Unlike existing matchmaking repositories and tools, where the registered user can identify potential neighbouring partners for specific exchanges, the prototype Library of Case Studies and linked Exchanges Database has been designed as an open access tool, does not require registration, and provides support in identifying new ideas for alternative waste reuse as well as the process to implement them. This library was used in the synergy identification step as a tool for helping industrial managers being inspired by other IS projects and find synergies already implemented in the same core business.

The report also uses the public results of a study for French industrial association RECORD carried out by Strane entitled "Material and energy flow management tools overview for circular economy" was analysed [13] The study mapped all software tools which may be used to initiate new synergies in relation to the concept of Industrial Symbiosis (IS). A first representative sample of 100+ tools was screened in the first part of the project. A multicriteria analysis led to shortlist 12 relevant tools, which were analysed in more details in a second phase, including interviews with tool developers, users, and beneficiaries. This study was used to list the most adapted tools for the identification of opportunities and the research of synergy.

Other sources used in this report include Advisory Board members' recommendations, the field experience gained through SCALER's spin-off Seitiss, SCALER partners experience and methods, in particular Cambridge University expertise on uncaptured value identification and new business models, and ISQ expertise on technologies required for synergies treatment and the technical compliance assessment.

2. Business model framework

2.1 Sustainable Business Model Framework

This section provides an IS business model framework that can consolidate synthetically all information for taking the decision to implement a synergy. The blocks summarise the value propositions of the synergy, and how they are created, delivered and captured by the stakeholders. The framework is depicted in the following figure.

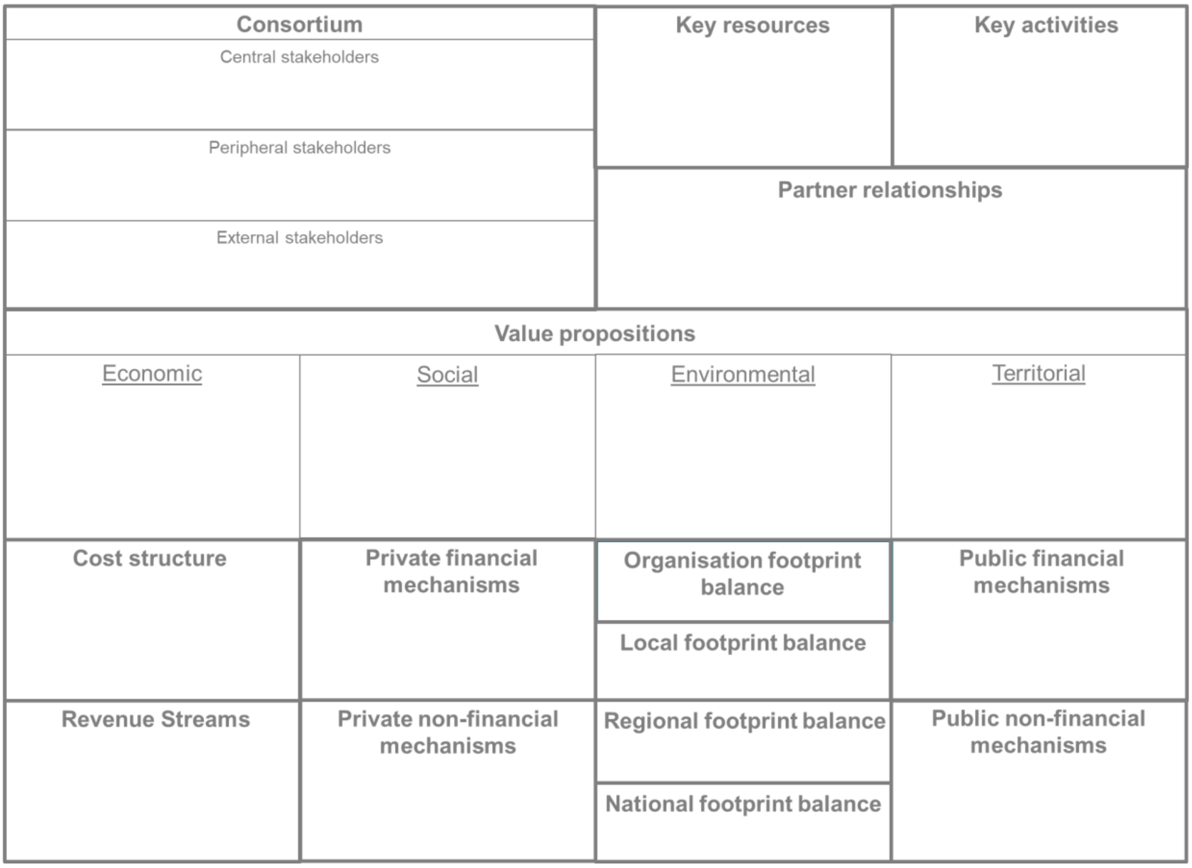


Figure 1: Synergy Sustainable Business Model Canvas (SBMC)

The role of the blocks and how they should be filled is described below:

- **Consortium/Partnership**. These 3 boxes must be filled with the name and role of each central, peripheral and external stakeholder in the synergy (e.g. "Peripheral – Company C – transport the resource from A to B" or « Peripheral – Company D – perform the separation of two fractions of a liquid stream »; "External – Religious community – their consumption of agri-food products from B if processes are fuelled with wastes").
- **Key resources.** The guide user must describe the infrastructure and assets indispensable to set up the synergy (e.g. "tank", "monitoring sensors", "trucks", etc.). If dedicated human resources are necessary to ensure the viability of the synergy, they need to be mentioned and can be separate from other technical means.

- **Key activities**. In this box are summarised the actions, organisational changes, skills, expertise required to set up the synergy (e.g. "distillation", "blending", "train employees", etc.).
- **Partner relationships**. The user must detail the nature of consortium members' relations when running the synergy (e.g. competition, cooperation, coopetition).
- **Value propositions.** In the centre of the canvas four boxes are dedicated to formulate values identified and assessed regarding economic, social, environmental and territorial values. The practitioner must summarise here the values created (positive) and destroyed (negative) and their associated stakeholder (e.g. "Company A - improve material efficiency"; "Biodiversity - lose 7 Biodiversity-Adjusted Hectare Year BAHY")
- **Cost structure & Revenue streams**. In the associated boxes, the user respectively details how the synergy economic propositions are composed in terms of CAPEX, OPEX and/or foregone incomes. All revenues must be associated to the concerned stakeholder (e.g. "Company A – 2,5 M€ CAPEX"; "Company A – 700 k€ raw material savings).
- **Private financial mechanisms & Private non-financial mechanisms**. These two boxes must be filled in with mechanisms traducing how the social values are captured by the stakeholders. The first expresses the monetarisable values (e.g. "Company A – 10k€ for further resource analysis to replicate the synergy with intermediary 1"), while second is dedicated non-commercial mechanisms (e.g. "Company B – label 100% local sourcing").
- **Organisational/Local/regional/National footprint balance**. Based on the analysis of the environmental value proposition, the user need to fill in the boxes depending the scale of the value captured. Value can be captured at individual organisation level (e.g. "Company A – CO_2 emission reduction of 30%"), at local level (e.g. "Local Community – local air quality improvement led to 5 additional QALY"), at regional level (e.g. "Region – reduction by 5% of regional material extraction") or at national or even international level (e.g. "EU – system reduced by 30% its contribution to global warming"). The aggregation into monetary units enable expressing these non-economic values in euros (€) in the perspective of negotiation between industries and public authorities. By creating environmental values and quantifying them economically, industries could expect financial benefits such as tax reduction or subsidies.
- **Public financial mechanisms & Public non-financial mechanisms**. Similar these boxes must be filled in with the mechanisms traducing how territorial values are captured by public stakeholders. The first box is dedicated to financial mechanisms (e.g. "Local municipality – synergy fosters energy security of 50 000 people on long-run, municipality subsidies by 20 M€"), and the second to non-financial (e.g. "National authority – based on the example of the values provided by this synergy, public contracts should only be granted to companies with a circular material rate of 50%).

It is recommended to use this framework to summarise in a visual way all the information collected and analysed during the synergy assessment process. The result can then be submitted to all stakeholders, individually or through a workshop, to validate the content. The goal is to ensure a fair value sharing between stakeholders and maximise the chances for a good synergy implementation and its long-term perpetuation and viability.

The use of this tool may lead to innovative value transfer mechanisms such as public subsidies based on environmental, social and/or territorial expected performance and quantified benefits. In that way, stakeholders will engage themselves to respect their initial goals and monitor real impacts after implementation.

It is also necessary to consider synergy risks and contractual clauses defining stakeholders' engagement, scope and responsibilities. Risk can originate from consortium members (e.g. insufficient resource quality, safety rules not respected, transport, etc.) or external factors (e.g. resource market prices drop or soaring, natural disaster, takeover of a company, etc.). They must be identified, reduced as much as possible with prevention measures and managed with contractual clauses (e.g. which entity is responsible of such type of accident; how the exchanged resource price should evolve with market prices). Other typical contractual clauses are related to investments, goals, functionalities, proper operating conditions, monitoring, maintenance, operation, site locations and accesses, utilities and resource payment, environmental constraints, regulatory constraints, communication aspects, contract duration, update and termination, insurance.

The summary of all the synergy value propositions in an easy-to-use framework can support decision-making. It must clearly detail how values are created, delivered and captured, and their associated stakeholders.

This framework differentiates from existing canvas because: (1) it is dedicated to industrial symbiosis, (2) it includes environmental, social and territorial value propositions, and (3) it proposes an innovative approach focused on the synergy project, rather than a single organisation, more adequate to such collaborative project and value co-creation.

Based on these outcomes, the user can address individually to each stakeholder key elements for its own decision-making through dedicated business cases.

2.2 Business Cases

Based on the business model defined, each individual stakeholder needs a specific business case to support the decision-making. A Business Case details the situation and all parameters to take into account for one individual stakeholder. It is a way to analyse the synergy's implications at their own scale. The project leader must inform and advise decision-makers by providing all arguments to justify, or not, a synergy project. A generic business case framework is provided in Table 2 with typical elements required for an informed decision-making. It is divided in 7 sections: key context elements; stakeholder's needs clarification; business as usual or other projects in competition with the synergy; synergy's values propositions; impacts on the organisation; financing; risks. Key elements are highlighted.

A well-conducted synergy project should build as many as necessary BCs in order to provide each individual stakeholder's decision-maker the elements to position themselves favourably or negatively regarding the synergy project. If positive decision is made, it does not mean the synergy will be directly implemented but it traduces a certain decision-makers' interest and is the trigger for further detailed analysis.

Table 2: Business Case Framework

Sections	Content
General context	- **Political, legal, cultural, regulatory, environmental, economic context of the organisation**, the local territory, the state, the EU - **Risks and trends** associated to organisation's activities - Employees' perception of the organisation - Organisation dynamism (projects, innovation, research) - Current relations with the territory, neighbourhood actors
Need	- Main problem/pains carried by the organisation - **To what extent the organisation needs the synergy creation** - Existing **problems solved by the synergy** - To what extend the synergy **support the organisation's strategy**
Alternatives	- Define the business as usual - Define other considered solutions solving the same problem - **Compare advantages/disadvantages of alternatives**
Synergy values Propositions	- **Project and its boundaries** (resource considered, uses, organisational changes, key activities, etc.?) - Detail **how the synergy satisfies organisation's needs** - Synergy legal issues - Detail **all values created (positive) and destroyed (negative)** for the organisation in comparison with best competitor and how they should be captured
Impacts on the organisation	- Project **partners** and their associated role - Identify whether existing partnership might disappear or evolve - **Logistic, human resource, competence and infrastructure requirements** - **Additional responsibilities and engagements** - **Next steps** in terms of additional studies or implementation and their timeline - Expected synergy duration
Financing	- **Potential investment needs** and if so, potential sources - Detail all **financing schemes**
Risk	- **Project risks** and associated potential impacts - New interdependencies and their impact - How future organisation modification can impact the synergy - Risk management plan

This table helps the guide user to design targeted BCs with necessary information. A BC must ideally be synthetic and concise (10 pages) to have the highest chances to be correctly analysed by decision-makers.

3. Process of a synergy creation

Creating an industrial synergy is a complex process starting with the identification of opportunities on-site and ending with a successful setup and operation. A synergy finds value in industrial opportunities mainly based on increase of waste stream intrinsic value by diverting it from landfill, incineration or realising in the nature.

Based on the research background detailed in the previous section 1.3 and field experience, the following synergy creation process applies in most cases.

Each step is described in the following sections, together with recommended tools and methods, with a focus on steps 1 to 3 which enable to identify synergies and assess the synergy in detail to fill business models canvas and business cases for each stakeholder.

- Identifying opportunities in-site (Step 1)
- Searching for resources synergies and adequate industrial partners (Step 2)
- Then, the business case framework is defined to assess in detail the synergy (Step 3)

Step 4 and 5 concern the operational implementation of a synergy and management of a synergy. These steps are complex and can take various form depending on the synergy. They are not analysed in this document.

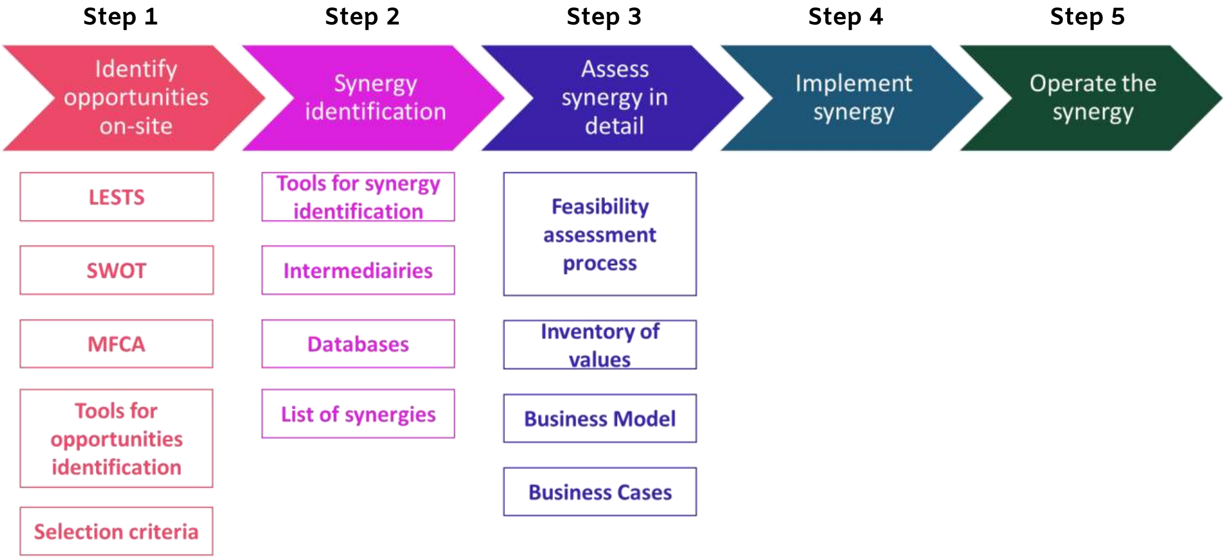


Figure 2: Tools and methods for IS (Source: Strane)

3.1 Step 1 – Identify opportunities on site

Before starting to consider a synergy, it is recommended to identify opportunities on-site that may already optimise resource management. The purpose is to find, investigate and confirm existing opportunities that could lead to a synergy creation and provide tools to help this identification step.

The objective of this step is to identify uncaptured values leading to IS project. The section presents how to search and identify interesting values uncaptured for an industrial synergy. Several methodologies are exposed to pinpoint key parameters indicating good opportunities to exploit. Tools introduced can be used to

- Identify synergetic opportunities (LETS)
- Characterise opportunities (SWOT)
- Catch uncaptured values (Value mapping tool and value uncaptured for sustainable business model innovation)
- Analyse costs related to resources management (MFCA)
- Enable the selection of relevant topic

3.1.1 Tool 1 - Synergetic opportunities overview: LESTS

The first stage of an IS project is the identification of resources that can lead to a synergy creation [14]. For this purpose, the LESTS methodology [15] is suggested. Its objective is to characterise the companies' relationships within an industrial cluster and identify opportunities. The LESTS framework is detailed in Figure 3.

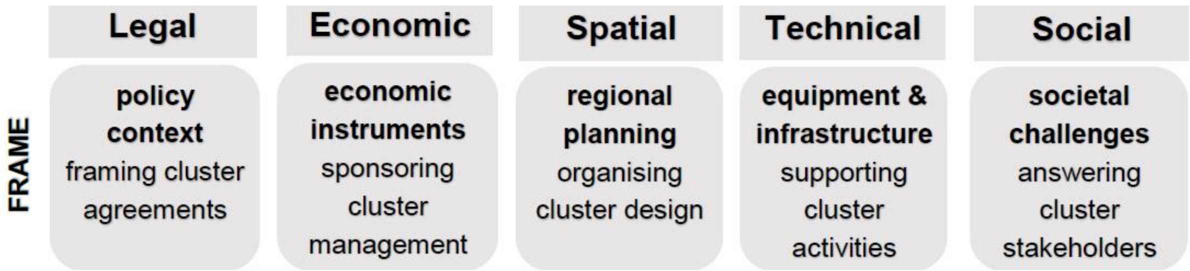


Figure 3: LESTS Framework (source : [15])

A LESTS analysis at a cluster level use [16]:

- The analysis of Information publicly available about the company according to the 5 LESTS factors perspective
- Send LESTS questionnaire to keys actors
- Make complementary literature review to identify opportunities. The objective here is to find similar industrial context or cases to replicate. As an example, the MAESTRI's library of case study can be used to find synergies corresponding to the situation of the seeker [12].

A categorisation of synergies at a cluster/territorial scale is synthesised in the following figure [16].

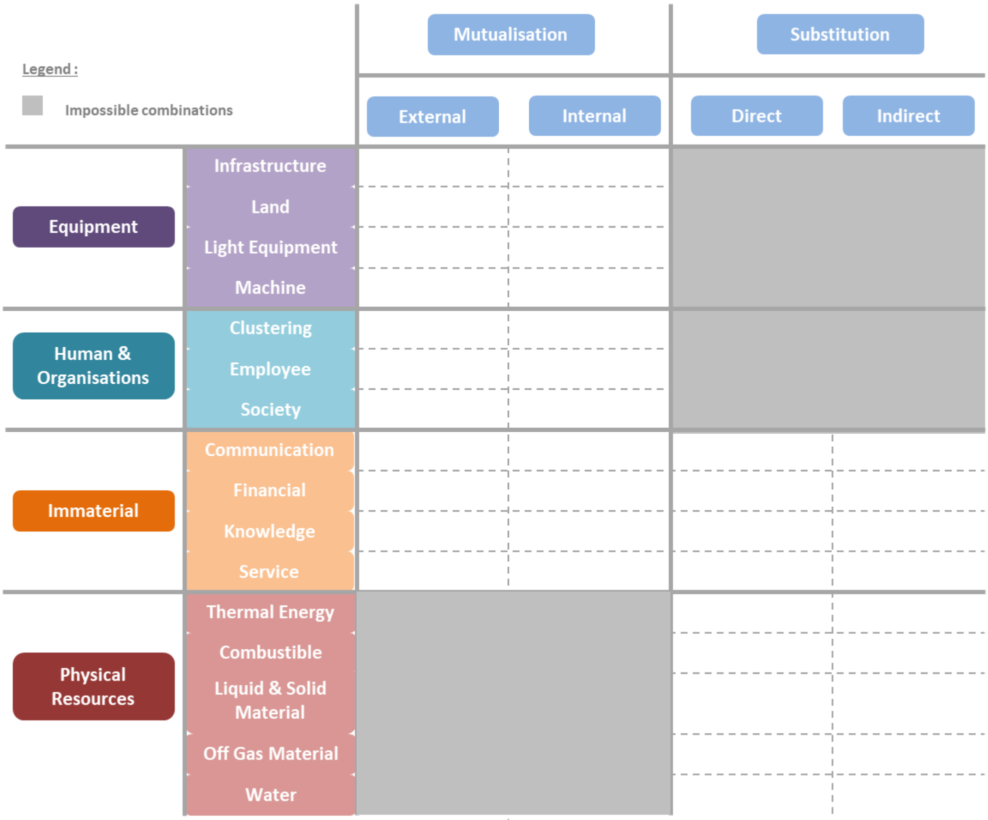


Figure 4: Synergy classification (source: EPOS Project [16])

Synergies can be divided into two main type of categories

- The type of synergies is split into 2 main categories: mutualisation (external or internal), and substitution (direct or indirect). They respectively refer to shared resources between several stakeholders requiring a third-party or owned by one of the industries, and resources substituting traditional raw material with or without intermediary treatment.
- The nature of the resources valorised are divided into four main categories: equipment (infrastructure, land, light equipment, machine), human & organisation (clustering, employee, society), immaterial (communication, financial, knowledge, service) and physical resources (thermal energy, combustible, liquid & solid material, off gas material, water) [16].

The potential of each synergetic opportunity identified must be roughly assessed through specific LESTS scores. A list of 15 items, 3 points for each LESTS dimension, corresponds to IS success factors as described in the EPOS project [17]. The 3 points per LETSTS dimension are allocated to three different scales:

- Strategy level (top-policy level)
- Readiness level at a company or a cluster level
- Resource level

The user must qualitatively assess the "barrier level" for each of the 15 items. He has to score items on a Likert scale from 1 to 5 (1: Extreme barrier to IS / 5: No barriers identified). The final LESTS score refers to barriers for the exploitation of an opportunity. In two situations, all individual scores higher than 2 and the total average score above 3, the opportunity assessed is considered as promising because of the absence of strong barriers. It provides finally the readiness level toward IS [16].

readiness level towards IS

extreme barrier to IS 1 2 3 4 5 no barrier / no relevance to IS

LEGAL	L Q1	Policy/regulation	3	3,0
	L Q2	Readiness to close deal	3	
	L Q3	Permit requirements	3	
ECONOMIC	E Q1	Public funds	3	3,0
	E Q2	Readiness to invest	3	
	E Q3	Payback requirements	3	
SPATIAL	S_p Q1	Regional planning	3	3,0
	S_p Q2	Readiness of land	3	
	S_p Q3	Transport requirements	3	
TECHNICAL	T Q1	Existing infrastructure	3	3,0
	T Q2	Readiness of technology	3	
	T Q3	Expertise requirements	3	
SOCIAL	S_o Q1	Community acceptance	3	3,0
	S_o Q2	Readiness to collaborate	3	
	S_o Q3	HSE/CSR impact	3	

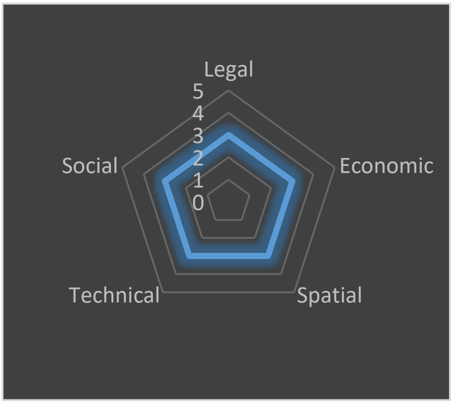


Figure 5 : Example of LESTS score at resource level without major barrier identified (source: [16])

At resource level, LESTS score enables prioritising valorisation opportunities. The most relevant ones can be deeper investigated.

3.1.2 Tool 2 - Opportunities characterisation: SWOT analysis

Although opportunities characterisation can be searched without previous results, the most relevant LESTS information can be assessed with the well-known SWOT framework (Strengths, Weaknesses, Opportunities, Threats) [18]. It is also possible to apply the SWOT framework without LETES results.

A SWOT analysis provides a qualitative assessment of each specific synergy identified with the LESTS analysis and main expected issues. It highlights the positive and negative aspects for each synergy whether they are internal (strengths and weaknesses) or external (opportunities and threats).

An example of SWOT analysis at a synergy level is presented in the table below.

Table 3: SWOT analysis at synergy level (source: [4])

Strength	Weakness
- The IS project is compatible with the core processes of both partners - The material is easy to transport via truck - Investment costs may prove minimal	- The resource volume is not significant compared to the production of the receiving industry - Emissions caused by transport of material could reduce the environmental benefits of the IS
Opportunities	**Threats**
- Economically beneficial for both parties - Can pave way for further collaboration	- It may take time to obtain permits for resource transportation by trucks

	- The emergence of a parallel market could divert the flow and end the synergy operation

A SWOT analysis gives a first screening of the synergy feasibility and its warning points. It can help the user and the decision maker to select the most promising synergies. At this stage, collected information is still rough but it gives clear pathways for further analysis in the synergy implementation process.

3.1.3 Tool 3 – Identify uncaptured values: Cambridge value mapping tool

Cambridge University developed methodologies and tools to identify all capture and uncaptured values [19]. These methods can be used in workshops, for research activities.

The framework uses the concept of value uncaptured as a new perspective for sustainable business model innovation. The logic behind the framework is that sustainable business model innovation can be more easily achieved by identifying the value uncaptured in current business models, and then turning this new understanding of the current business into value opportunities that can lead to new business models with higher sustainable value.

Before developing new business models, it is important for actors to understand their current business model. In this framework, the current business model is represented by the current value proposition, value creation and delivery, and value capture, i.e. what and how a firm creates and delivers value to its stakeholders, and how the firm captures value from it. This understanding extends the widely accepted business model framework proposed by Richardson (2008) [19] to a wider scope. Firstly, the value is not only for customers and the firms, but for all stakeholders, such as end users, suppliers, shareholders, government and partners. Secondly, the value covers not only monetary value, but also wider value for the environment and for society. For example, improved energy efficiency, zero carbon emissions and cleaner production are regarded as value created and delivered for the environment.

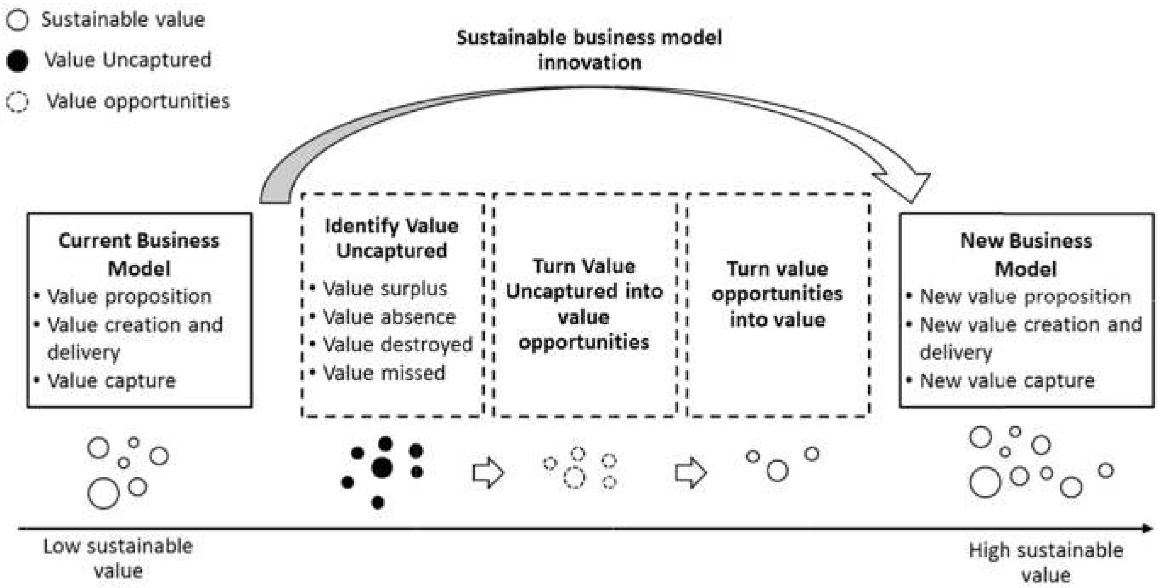


Figure 6: Framework of using value uncaptured for sustainable business model innovation(Source: [20])

Value uncaptured: the potential value that could be captured but has not been captured.

- ***Value surplus*** - value which exists, but is not required.
- ***Value absence*** - value which is required, but does not exist.
- ***Value missed*** - value which exists and is required, but is not exploited.
- ***Value destroyed*** - value with negative consequences.

The types of values are the following

- **Value surplus (VS)** is value which exists, but is not required. These are things or activities that are more than needed. They are redundant and unnecessary. They can be regarded as waste in a company or unnecessary value delivered to stakeholders. The concept of VS is similar to waste but embodies a broader meaning. It includes not only tangible waste but also intangible waste, such as underutilisation of human resource. It offers higher potential to be turned into value. It exposes avoidable resource consumption and cost. Examples could be wasted heat, waste energy, over production, underutilisation of resources, and unnecessary, repeated work.

- **Value absence (VA)** is value which is required, but does not exist. There are things or activities that are needed but have not been provided. It can be regarded as needs that could have been met but have not yet been met; or as a lack of resource that is needed by the company or its stakeholders. For example, this could be a temporary lack of labour, the need for recycling service, the need for experts in certain fields, or the need for a platform. A specific example could be that there is a temporary need for additional warehouse space and workers due to increased production, but the company may not be inclined to buy extra warehouse space or to hire new employees just for this short busy period. In this case, the need for additional warehousing and labour can be regarded as a value absence.

- **Value missed (VM)** is value which exists and is required, but is not exploited. It could create more value but it does not. It is currently squandered or inadequately captured by the current business model. It can be regarded as waste with high potential to be used. It does not bring about negative outcomes but it reduces value that could be created. Examples are underutilisation of by-products and co-products, underutilised assets and resources, and inefficient use of human resources.

- **Value destroyed (VD)** is value with negative outcomes. It causes negative effects for the company or other stakeholders, and is the negative outcome of the current business model. It can be seen as damage to the planet, people and profits. In the context of sustainability, value destroyed refers particularly to damage to the environment and to society. Examples include depletion of non-renewables, pollution, poor product and service quality, bad working conditions and health and safety problems.

The main sources of values captured at the beginning of life are listed in annex 7.2, Table 25. This can help the users of this guide to identify values [20]. For example, excess design, quality problems and excess heat generated or used can lead to a waste of resource. Once identified, these topics are fully relevant to develop IS projects.

3.1.4 Tool 4 - Quantify costs deposit: Material flow cost Accounting (MFCA)

Material Flow Cost Accounting (MFCA) is a methodology that allows for a thorough quantification of material stocks and flows as well as all associated costs. This methodology analyses all flow, including those not directly related to the final product manufacturing but involve elsewhere in the company. The MFCA provides a full view of costs related to the production but also links between products and wastes costs. The information gathered in this analysis allows comprehensive learning of these relationships. In consequence, by applying MFCA, organisations can identify otherwise hidden or invisible production problems and underused resources. MFCA aims at obtaining information to optimize the environmental footprint and cost savings, mainly by implementing waste reduction strategies.

MFCA can be adapted and applied to any type of industry, including service industries.

The application of the MFCA is made for every production step by allocating costs between products and waste generated. This makes possible to quantify economically waste of resources. All costs generated by material or energy use must be quantified and assigned to a specific flow quantified itself by flow rate in physical units such as mass or volume.

All materials going into any process are traced and categorised as products or non-products, so counted as a material loss. All output materials of a process, including products sales, waste generated and other emissions like atmospheric emissions or residual waters, are classified as positive or negative products, depending on its status as sale, waste or loss.

Cost inspected during the MFCA application at each production step: materials, energy and water consumption and system costs. System costs involve: labour, waste management, equipment maintenance, transportation, and also takes into account depreciation. In the process not only the consumption of energy is accounted for, but its use is specified and tracked.

Figure 7 introduces the basic concept of MFCA [21].

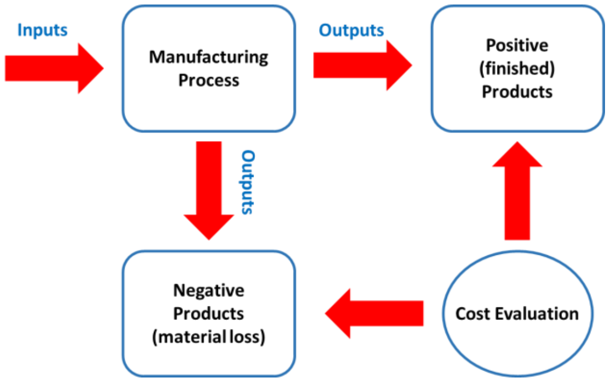


Figure 7: Basic concept of MFCA (Source: ADEME [21])

The methodology is designed to account for internal factors and does not take into account externalities. The ISO 14051 norm [22] describes the MFCA process in ten steps:

1. Definition of the participation and role of the management. It is important for the leadership of the organisation to cover the following concerning the application of the MFCA: correct implementation, role assignment to the team that will conduct the MFCA, ensuring the availability of all resources required, progress follow up and results review.
2. Assignment and mobilisation of the expertise needed
3. Definition of the schedule and scope of the MFCA
4. Definition of cost sources
5. Identification of all inputs and outputs per cost source
6. Quantification of material flows in physical units for each cost source
7. Quantification of all material flows in the previous step in monetised units
8. Synthesis and interpretation of MFCA resulting data
9. Communication of results to stakeholders
10. Identification and assessment of opportunities for improvement

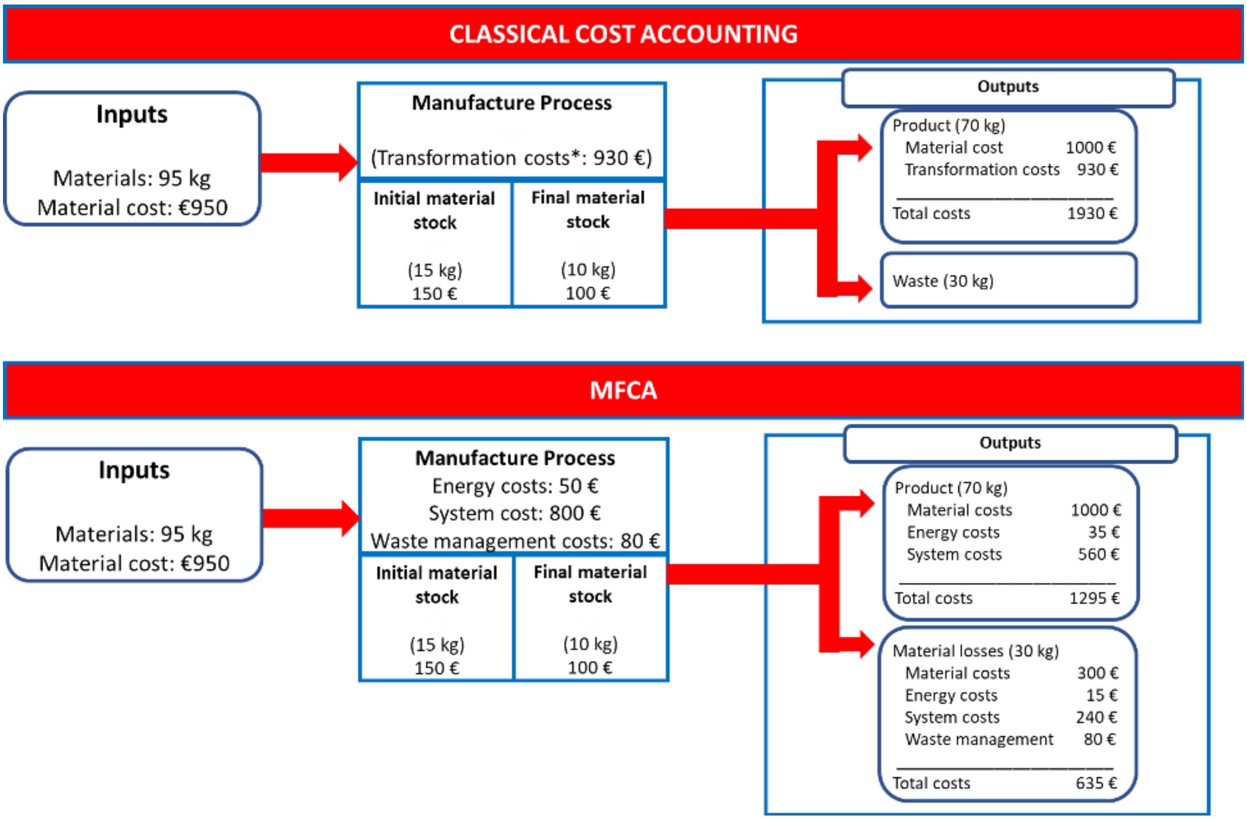


Figure 8: Comparison between classical cost accounting and MFCA (Source: ADEME

A paper [23] presents how to use MFCA method on waste reduction in a company with dedicated calculation sheets. The guide user can use this paper and its associated tables to apply the MFAC to its industrial context.

3.1.5 Criteria for prioritising opportunities

After the identification of opportunities, it is necessary to prioritise IS projects to develop and study. A criteria list was established on D2.1 expert enquiry result. The purpose was to select criteria according industrialists' feedbacks on industrial symbiosis.

Table 4: SCALER D2.1 survey results and associated selection criteria retained

SCALER D2.1 expert enquiry result	Opportunities prioritising (selection criteria)
A sound business case with clearly outlined economic benefits.	- Waste management costs - A large volume of waste or by-product - A high stream economic value (rare earth metals, critical raw material, etc.): large volumes or high economic values
Impact on and alignment to organisational goals.	Topics fitting with the current organisation and goals
Environmental criteria — generation of environmental benefits.	- Large volumes of waste or by-product - High impact resources
Legal compliance — compliance with environmental protection policies.	Topics fitting with the current legacy
Operational feasibility considering waste composition and volumes.	- Waste composition - Waste accessibility

	- Waste volumes
Reduction of costs of raw materials.	- Annual demand and site demand - Raw material price
Reduction of dependency on virgin material.	Identification of several by-products and waste sources alternatives
Creation of new products.	Synergies leading to new commercial opportunities or the creation of new products
Reduction of gas consumption.	Fuel alternatives identification
Favourable results of proof vs. opportunity analysis.	
Sharing of resources and costs.	Mutualisation and massification synergies

Based on the SCALER WP3 activities and the synergy prioritisation performed in the T3.2 a full list of criteria was defined to choose most promising synergies.

- State of matter easy to handle and transport
- Energy, water and material streams
- Quantity
- Economic value of the resource on the European market
- Avoid resource which can be internally reused
- Non-hazardous resources are more convenient to handle and transport
- Interest from a potential partner already proven
- Supply issues
- High number and diversity of potential pre-identified partners
- Opportunities not involving air emissions

This list of criteria can also be useful for industrial managers to choose key IS projects to support after the identification of opportunities

3.2 Step 2 - Synergy identification step

The objective of this step is to identify the synergy corresponding to an opportunity found previously, do a preliminary assessment of its technical feasibility and look for possible partners for the synergy implementation. Several tools and method can support the practitioner to succeed in this step like digital tools and platforms, the support of intermediaries and the consultation of synergies databases and knowledge repository.

3.2.1 Synergies identification tools

This section is based on the RECORD study of 100+ software tools worldwide carried out by Strane. The research was carried out worldwide, but most tools were found to come from Europe and France in particular [13].

- **Tools dedicated to IS**: ACTIF, BE CIRCLE, BizBizShare, CERES, EasyBulkPlace, Community Energy Explorer, economiecirculaire.org, ELIPSE, EPOS toolbox, eSymbiosis, Excedentterre.fr, FaST, France Barter, Industrial Ecology Planning Tool, iNex Circular, ISDATA, Munirent, PHOENIX, Pro spare, RECYTER, Sharebox, Soldating, SymbioGIS, SymbioSys, SYNERGie, United States Materials Marketplace, UpCycléa, Warp it, Co-Recyclage, Presteo;

- **Other alternative tools (in red boxes)**: Aménagement 3D, ArcGIS, CARMEN, Eclipse Sirius, e-sankey, E-PRTR, Finéo, For City, GABI, Google fusion table, NOVA, NOVA Light, Open LCA, Prediwaste, ProSimPlus, SILOG GPAO, SimaPro, Superpro Designer, SysML Architect, Umberto

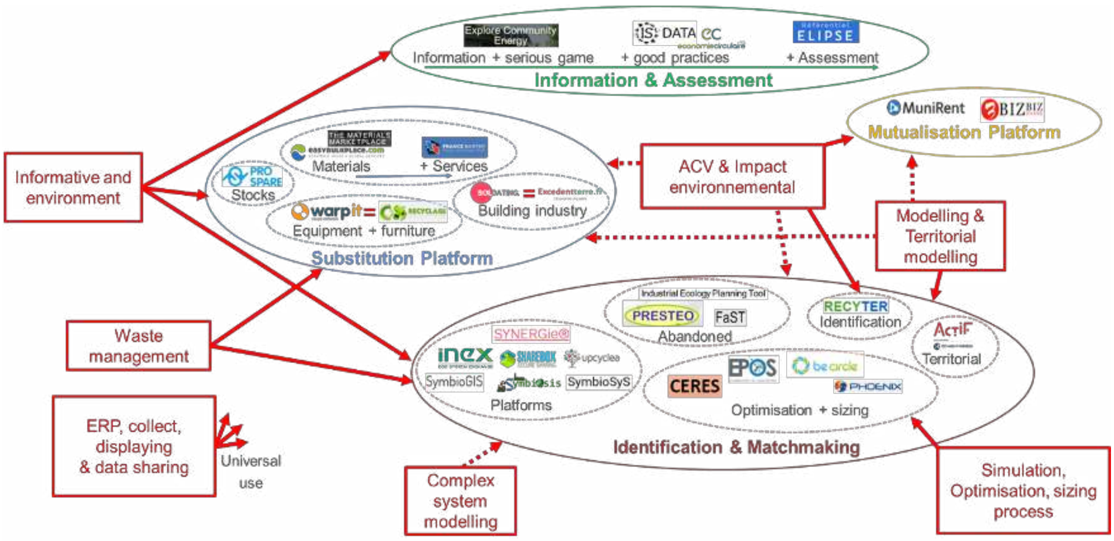


Figure 9: Overview of the software tools (Source: Strane)

As depicted in Figure 9, four groups can be identified for tools dedicated to IS:

- Platforms to mutualise equipment (ex: BizBizShare);
- Platforms to substitute resources (materials, services, sectorial, stocks or furniture);

- Tools to identify synergies (with collaborative platforms, territory approach or process optimisation);
- Information and assessment portals

All tools in development take more advanced approaches for identifying synergies. New tools will therefore emerge and likely boost the creation of IS initiatives.

Generic tools non-specific to IS can usefully complement IS tools. A variety of tools was selected for the sample. 90% of these tools address the feasibility study phase, which is critical to make the investment decision for the implementation of synergies. 50% can support the identification of synergies. Several kinds of tools can be noticed: LCA tools, Public information portal, waste management tools, process optimisation tools, tools for data collection/visualisation/sharing/analysis. Most of non-IS tools are generic as regards the addressed phases, the resources and application scales. Their added value and their applications must be assessed in detail on a case-by-case basis.

Several IS and non-IS tools were shortlisted for a detailed assessment.

1°) IS TOOLS

ACTIF is used by public actors (chambers of commerce and industry or local authorities). Thanks to its naming convention and a system to mutualise real data, this tool supports facilitators in coordinating themselves and in implementing synergies on their territory. In its current version, the tool enables to map companies, to detail their administrative information and provide information about their input and output flows (materials, services, equipment and facilities, human resources). Simplified search engines enable to map resources and already implemented synergies on territories.

BE CIRCLE is the outcome of a European collaborative project, in which participates ENGIE. This tool should be operational early 2019. It enables to model the infrastructures required for synergies at the level of territories and industrial parks according to their real environment. Furthermore, it simulates industrial optimisation scenarios and assesses their economic and environmental performance. These pre-feasibility studies are useful to raise the interest of decision-makers. The tool can work without extra data input thanks to its internal database.

EPOS Toolbox is a software in development to simulate and optimise industrial systems (intrasite and intersite) regarding resources, materials and energy management. This tool models in details industrial processes. EPOS Toolbox uses generic facility profiles for individual industrial sector, which can be refined with real data. The tool solves technical and non-technical optimisation using the expertise of the 12 project partners. The target users are industrial companies, but its interface could be used by intermediaries.

INex Circular supports the service offered by the iNex team. The tool can assist IS facilitators. It identifies actors and resources on a territory to identify synergies of material substitution and service mutualisation. The tool can be used on all economic sectors, but it is not intended to be used for complex flows. The software is based on comprehensive databases, knowledge about links between wastes and resources, and theoric sectorial profiles of input and output for companies with no real data available.

PHOENIX, developed by EDF R&D, enables to optimally design the material and energetic valorisation network between industrial facilities. It reduces the cost involved in the implementation of exchanges while considering technical, technological, economic and spatial constraints. The tool can be applied at the levels of an industrial facility or a territory.

RECYTER, developed by EDF R&D as well, complements PHOENIX at the previous stage of the synergy identification. Using a generic database of flows for individual sectors, the tool identifies input and output flows mutualisation and substitution potential for materials and energies. The tool enables to identify synergies at the levels of industrial facilities and industrial parks, to be studied in detail in a later stage.

Sharebox is based on the tool SYNERGie of International Synergies Ltd. Sharebox is currently in development in a European project. The tool contains significant databases of resources and synergies, and will be a platform for industrial companies and IS facilitators. It has a machine learning feature and a modular architecture to add new features according to needs.

Upcyclea is a collaborative platform that aims to gather all stakeholders of a synergy. Based on the experience in IS of the company founders, the tool uses databases of synergies and resources profiles with a fine-tuned naming convention, and a machine-learning feature for continuous improvement. Once synergies are decided, Upcyclea can effectively support actors in the exploitation of the synergy.

2°) Non-IS tools

Eclipse Sirius is an open source tool to support the customized and generic model graphic creation for repetitive complex subjects (supplier – flow- receiver – treatment). It enables to treat systems as a whole, as well as flows according to a terminology and the method specific to a domain.

ForCity simulates a territory on the mid- and long-term. Collectivities and companies can visualise scenarios of possible evolutions. The current modules of the tool help to solve potential problems related to the network of heat, water treatment and mobility in the urban area. ForCity company develops applications on-demand.

PREDIX is a full big data solution, composed of universal acquisition units for real-time data of sites, massive advanced calculation facilities and a big data application creation platform. Applications are mainly in the industry. PREDIX could be used in the exploitation phase for inter-sites synergies management

ProSimPlus is a simulation and optimisation software tool for industrial processes, which aims to improve their performance. It is based on thermodynamic calculations and algorithms that enable to generate complex simulations. The software has open interfaces to import data, calculations or personalised unitary operations. This tool is useful in IS for making detailed technical feasibility studies.

IS software tools fall into 2 main groups. The first group (e.g. BE CIRCLE, EPOS, RECYTER, PHOENIX) focus on industrial processes and find complex synergies based on a technical assessment. These are mostly complex software tools enabling to model processes, and with complex matching algorithms based on thermodynamic and mass balance equations. The second group (e.g. ACTIF, iNex, Upcyclea) address almost any resource in a generic way. These software tools are mostly platforms open to expert intermediaries and in some cases to the end-users. The tool facilitates the collection of data and suggests potential matching. No tool is able to provide matchings automatically and a human analysis is required. These tools allow to identify direct synergies and less frequently indirect synergies. The outputs of these tools are limited to passive or lightly assisted matchmaking features. The required input data are simpler than in the first group. Collecting data can be assisted by the tool but also through workshops. Upcyclea offers a simple solution of operational and collaborative monitoring of synergies with several users

The analysis of existing alternatives made very clear the importance of tacit knowledge in identifying and assessing in detail potential synergies. Explicit knowledge (that can be included in a software) is fairly limited to quantifiable parameters for which a data is available. These metrics represent however partially the reality. And many criteria cannot be translated into a software, especially as regards the context of the synergies.

The taxonomy and ontology are core to all IS software tools. Their analysis demonstrates that finding the optimal taxonomy to name correctly the resources is particularly difficult. Complex taxonomies are difficult to manage. Simple taxonomies will not enable to find all synergies.

The two groups do not overlap. Synergies among process industries require a high level of technical expertise to avoid fake positives, study resources and the required technical setups. The only relevant way to work out these synergies is to model technically the production systems, as done by the first group of tools. The generic platforms mainly deal with the other resources, with simpler technical setups. Some tools in development (as Sharebox) have an intermediate positioning but this may be a double-edge sword.

The territorial aspect is addressed at different levels in IS tools. Territorial approaches require geographical methods, and therefore geolocated data and cartographic analyses. However, most tools do not target local authorities. Some developers offer services to them, such as territorial forecast studies, identification of high potential land areas or assistance in workshop IS facilitation. But these features are still new or in development.

In theory, IS digital tools and methods should support decision-making for a detailed assessment of the synergies and their implementation. However, IS tools generate few and insufficient indicators, compared to the numerous parameters considered by decision-makers. IS tools produce no or very few indicators of economic and social context. They do not produce complex indicators such as the impact on workers' health, and do not capture the probabilistic nature of indicators, as required for risk analyses.

For this guide, a list of recommendation depending the user profile and its function within the company is made in Table 5. The practitioner can find adapted tools to reach the purpose of its entity.

Table 5: Tools recommendation by user profile

Local authorities	➢ To facilitate inter-territorial exchanges, ACTIF is relevant. ➢ On defined territory scopes and for generic resources, iNex Circular (and maybe Upcyclea) enables to identify networks of potential synergies. ➢ For a highly industrialized territory, BE CIRCLE (still in development) might be used to find optimal matches of industrial

	activities, in particular by identifying the most interesting additional profiles. RECYTER, which is already operational, has similar features for energy resources or materials. Sharebox (in development) positions also in this segment and might be suggesting modules to facilitate data collection by industrial facilities. ➢ To simulate IS strategies, a web application developed with a software like ForCity could be particularly relevant in order to assess the impact of the synergy networks creation for the property, infrastructures or the logistic / mobility.
Industrial park managers	➢ Today, RECYTER and PHOENIX are effective to identify and study potential synergies for energy and materials on industrial parks. PHOENIX can solve global site optimisations, using pinch analyses. ➢ BE CIRCLE is developed to help industrial park managers. BE CIRCLE addresses all industrial resources, with specific features like land optimisation and resources use analyses.
Waste managers	➢ Upcyclea targets waste managers to integrate them to stakeholders' ecosystems and provide operational services in waste management.
Process industries	➢ PHOENIX has particularly strong assets for energy and material optimisation and is currently operational. ➢ EPOS Toolbox, currently in development, could provide global and multi-resources optimisations (energy, material, etc.), multi-objectives (depending on different indicators), and preparatory economic and environmental studies. This tool is limited to 5 sectors. ➢ BE CIRCLE, still in development, could identify and simulate new synergies, on a wider scope of industrial sectors. ➢ Sharebox, also in development, is not specific to process industries but is made on a database of synergies including some synergies for those sectors. Its use seems less relevant for identifying new synergies.
Other types of companies	➢ There is no operational tool for those stakeholders. iNex Circular develops a tool but very few information is available for the moment. Sharebox and Upcyclea still currently development.

3.2.2 Intermediaries

Intermediaries, also known as "knowledge brokers" or "coordinating bodies", can provide managerial, financial and regulatory support to firms. As neutral players, they facilitate the communication and cooperation among parties, and provide methods and processes.

They can help advance industrial symbiosis networks and enhance eco-efficiency through reviews, opportunity and implementation assessments, or provide workshops for ideation and matchmaking.

The National Industrial Symbiosis Programme (NISP) is an exemplary illustration. NISP is the world's first national industrial symbiosis initiative, has been fundamental to catalysing the development of new industrial symbiosis systems in the UK and ensuring their effective operations. Their primary role was to identify, connect and coordinate firms and stakeholders within the Humber region Industrial Symbiosis Programme (HISP), with the scientific support of researchers from the University of Lund, Sweden

Intermediaries can also provide informational support to identify synergy feasibilities and help negotiate the terms of engagement to enable the setup of a synergy, which is especially useful when multiple firms are setting up a network. They can facilitate communication between various stakeholders, both private and public, and allow for more efficient exchanges and collaboration.

The Italian National Agency for New Technologies, Energy and the Environment is one example of an intermediary, establishing a programme between various leather & agro producers and research institutes

In summary, intermediaries can support by:

- Disseminating information in a clear/open format to appropriate firms and stakeholders
- Setting up and running awareness raising programmes, such as formal lunches or awareness building workshops
- Helping negotiate formal agreements to realise synergies (and develop confidence)
- Coordinating the agreement of timings between stakeholders
- Monitoring and feeding back information to guide initiatives and/or develop further synergies

Intermediaries can also provide an expert, technical support to setting up synergies. For example, SCALER's spinoff Seitiss developed by partner Strane Innovation can identify resource matchings across industries and research the closest possible partners. Its software tools are based on the models of all input and output flows of 160 industrial processes from 20 industries, matching algorithms to identify valorisation options and database of 33 000 geolocated industrial facilities database in order to find efficiently partners for the synergy's implementation.

Depending on their role in the synergy identification and implementation process, intermediaries are included in the BM framework as peripheral stakeholder or external stakeholder. The description of the relationship with intermediaries should be described in the partner relationship section.

3.2.3 Databases and list of synergies

Databases and knowledge repositories of industrial synergies disseminate information on implemented synergies, case studies and best practices, which can trigger direct replication or inspire new synergies elsewhere. The information described in such databases help the practitioner finding all data he has to gather to fill the BM framework and build its business case.

In SCALER, 100 synergies were assessed and thoroughly described, and a database was developed with their technical, economic and environmental data. The 38 most impactful synergies in Europe are listed in the GUIDELINES FOR INDUSTRIAL SYMBIOSIS – SECTORIAL OUTLOOK [24]. This list enables industrial managers of process industries to identify synergies ideas. The full list of SCALER 's 100 synergies is visually presented in the

“Synergy Outlook”[4] and the final EU potential assessment [25]. It gives an overview of a wide variety of potential synergies applicable for process industries.

The circulator [26] is a self-service tool and open platform for knowledge sharing that allows users to select cases based on key aspects around circular business models and industrial symbiosis.

MAESTRI offers a library of industrial symbiosis case studies and linked exchanges that contains information related to existing cases. One section presents the description of the case studies, while the exchanges database describes all the exchange resources used [12].

The industrial symbiosis DATA repository is an open platform for collecting and supplying structured information on industrial symbiosis, containing existing cases of symbiotic implementations. IS DATA Toolbox [27]

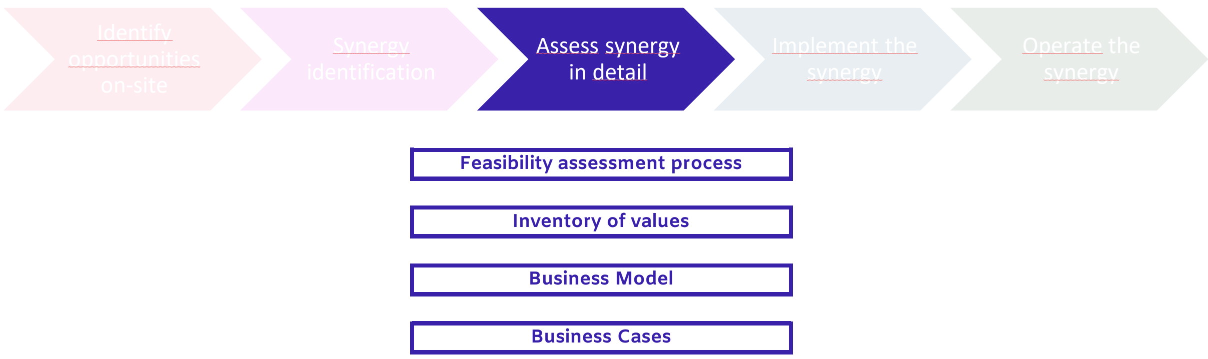
Existing databases and feedbacks from IS case studies are also a good starting point to identify synergies for waste resources: Kalundborg case list of synergies [28], Bussi Case list of synergies [29] and Taranto case [30].

The consultation of academic papers related to IS cases is also a source to identify synergies for the user (Cf. Annex 7.1; Table 24)

3.3 Step 3 – Assess the synergy in detail

The objective of this step is to analyse the synergy project in-depth and collect all values and parameters required to assess the synergy. This step is necessary to evaluate the relevancy of the project then build the business model and all business cases for individual stakeholders.

Step 3 follows Step 2 which identified potential synergetic partner sectors for a given resource and specific industrial facilities have been listed. Step 3 consists then in analysing the synergies in more detail in technical (required intermediary treatments and services, packaging, transportation, etc.), economic and regulatory terms.



3.3.1 Feasibility assessment process

This section details a step-by-step approach to support a practitioner in assessing the feasibility of a synergy. The process is composed of a general description of the different stages, a summary table and a risks decision tree. The synergy feasibility assessment process is introduced in Figure 10 then detailed in the following sections.

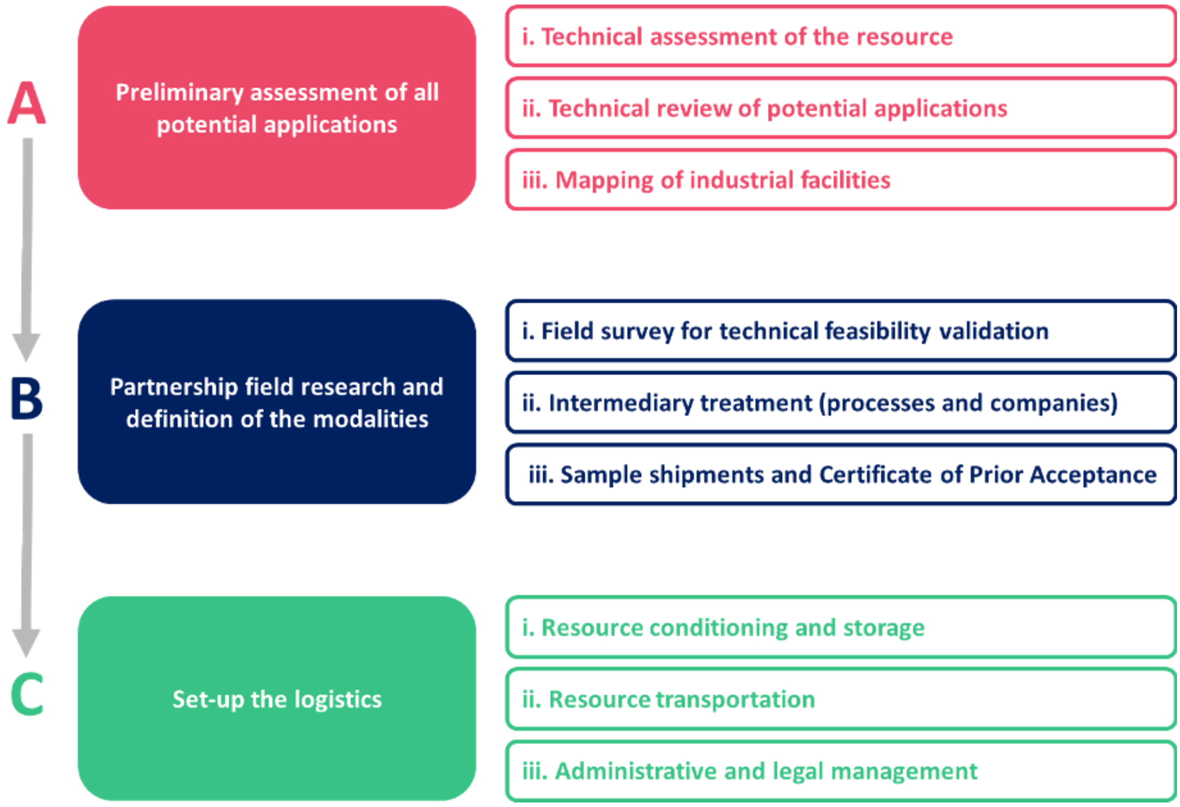


Figure 10: Feasibility assessment process (Source: Strane)

A decision tree is presented at the end of the section to avoid spending too much time on the analysis of low success rate synergies.

Stage A – Preliminary assessment of all potential applications

i. Technical assessment of the resource

A complete and comprehensive knowledge of the resource that is being wasted or needed is crucial for moving forward in the process. Lack of information could guide to the wrong conclusion on to which synergies options are actually likely to be feasible for the resource. This include becoming familiar with the industrial processes that generate or use the resource, its material, chemical composition, physical state, volume, quality, moisture. Additional testing could be required in case the entity generating the resource does not have all need information. The compliance with the different revalorisation options must be also assessed. This information can include supplier's raw material datasheets, manufacture methods, etc. If the information is not available, the practitioners can contact raw material suppliers to obtain it.

ii. Technical review of potential applications

A first assessment can be based on preliminary information from the literature. When information is scarce or not easily adapted to the resource or industrial processes involved, contact with key industrial parties or associations will be needed to obtain their preliminary advice and a first point of view on the possible future partners to involve in the process. This first step helps to start identifying if there is a need for intermediate processing of the material to make the valorisation possible.

Potential receiving industries input specifications need to be searched and collected to have a preliminary opinion on the opportunities feasibility.

Some tools previously analysed can help practitioners identifying promising applications, for example: BE CIRCLE, RECYTER, Sharebox, iNex Circular and EPOS toolbox (Ongoing development).

iii. Mapping of industrial facilities

To map potential receiving industrial sites, the practitioner can use IS tools dedicated to find partners (e.g. iNex Circular, RECYTER which use NACE code in France and Germany, ACTIF in France), and in some cases European/National activities databases to search and find nearby potential partners in industrial sectors identified in the previous step. The time and effort required to complete this step depends on the type of resource. This step is key to optimise the transport of materials and minimise economic and environmental impacts of the synergy.

The ideal solution is to use geolocated data in order to map all industrial sites likely to recover the resource. The use the SCALER process industries map enables to find adapted partners across Europe (Figure 11). The map of potential industrial partners will make it possible to visualise and select the nearest to be contacted for a field survey step. If distances between emitting and receiving sites are too large and the value of the resource is not intrinsically sufficient enough, other solution or IS project should be considered (mutualisation, etc.).

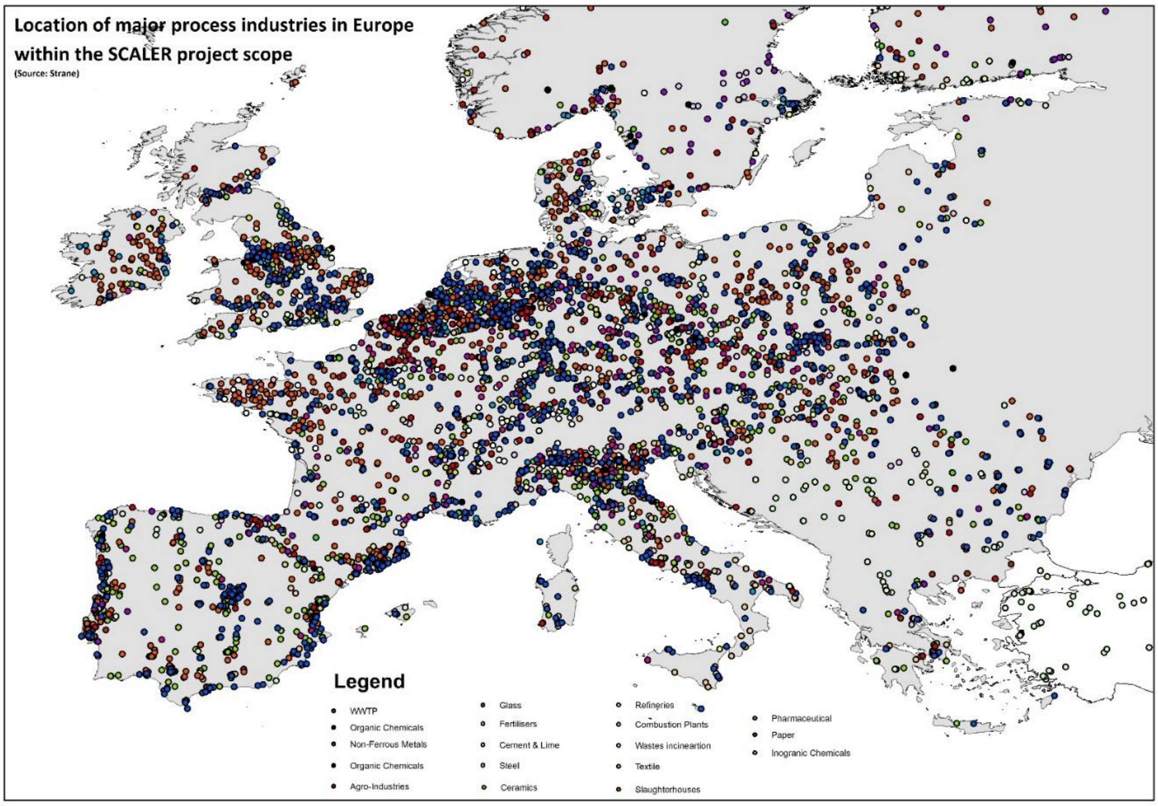


Figure 11 : Location of major process industries in Europe within the SCALER project scope *(Source: Strane)*

Stage B – Partnership field research and definition of the modalities

i. Field survey for technical feasibility validation

After identifying all the industrial sites likely to take in the resource exchange, a field investigation has to be launched. The IS Project leader need to contact the sites to validate their interest in being involved in the resource exchange and check for compatibility with its industrial process. The IS project leader can be assisted by intermediaries to perform this time-consuming step.

The field survey will be conducted to identify and validate:

- Their capacity to reuse the resource internally or emit the resource of interest.
- Their technical capability to process the waste in its form, composition, resource status and hazardousness.
- The preliminary treatment(s) required in case of a multi-fractions resource and/or any other conditions that could prevent them from take part in the resource exchange.
- The reception capacity (material quantity) and supply means.
- The recovery methods, which can potentially impact the budget and will be taken into account in the final business case.

The IS project leader will know which industrial facility is able to take part to the resource exchange and under what economic and technical conditions. Among the potential receivers that would confirm the feasibility, the closest ones may be selected in order to facilitate logistics, reduce transport costs and environmental impact (short circuit).

A major challenge to address is to confirm the technical feasibility and the interest from the receiving industry perspective. The receiving industry ‘contact points can find in the following check list (Table 6) materials to guide them collecting required information for their decision-making. It aims a potential resource receiver at gathering relevant information to sustain or not a future synergy implementation. This list presents all technical/non-technical considerations to take into account from a receiver perspective about three main pillars: Law, Material and Logistics

Table 6: Receiver technical check list (source ISQ & Strane)

Domain	Question to address	Technical Objective
LAW	By product status	Define by product status requirement: Residue, Waste, By product
	Hazardousness	Define hazardous properties of the resource
	**Documentation required	Define all legal documents required to accept or not the concerned resources: doc. name/ doc. Reference code/ doc. template
	Environmental constraints	Define any existing environmental constraint regarding the by product acceptance
	CO2 taxes	Define who will be in charge of pay associated CO_2 taxes
	Type of exchange contract	Define the conditions of the contract: Fixed, variable
MATERIAL	State of matter	Define the desired state of matter of the by product: S,L,G
	Delivery mode/format	Define the specificities on by product delivery format and mode (means of transportation and storage) Ex: Briquetized, compacted powder, …
	Delivery frequency	Define the delivery frequency depending on storage capacities and demand
	Recover interest	Define the interest on: Full by product or element of interest
	Quality (physical/chemical - PC)*	Define the PC analysis variables/thresholds to be presented by sender/intermediary
	Availability/need (qtt/time)	Define how much should be provided per period of time
	Technical compliance (receiver process / material requirements)	Define the quality requirements for by product, element of interest as well as all elements/characteristics of by product that should be avoided (independent from the FQ quality)
	Pre-treatment requirements	Define the associated mechanical/ chemical pre-treatments to assure the technical compliance of by product
	Pre-treatment responsible	Who is the responsible for the pre-treatment: Receiver Company, sender company, external/intermediary stakeholder
LOGISTICS	Conditioning	Define conditioning mean handable
	Means of Transport	Define if some specific mean of transport should be avoided. Ex (truck, railway, pipeline …) and/or define the preferable means of transport
	Transport specificities	Define some compulsory considerations regarding transportation. Ex. Restrictions to enter the facilities (truck size, tires, electrostatic regulations …), access road specificities (max weight, height, …)
	Transport precautions	Define handling and safety characteristics for the transportation of the material during storage, movement for control and protection of the material. Ex: type of containers, packaging, conditioning, worker safety (use of protection equipment). Take into account the hazardous resource transportation authorisation.
	Transport responsibility considerations	Define who is responsible for transportation and associated costs

	International Trans bordering *	Define the constraints in case of international transportation.

By following this checklist, the receiving industry would have all necessary information to secure its own interest and ensure adapted partnership conditions. It will ensure the compliance f the potential synergies with legal declaration and constraints,

For certain types of resource, only indirect synergies involving procedures (pre-treatment and/or treatment and/or post-treatment) are possible. In case of a required intermediate treatment, the next step will support the guide user finding adequate equipment and companies/providers to carry out these intermediate operations.

ii. Intermediary treatment (processes and companies)

With the results of the surveys, the IS project leader will be in position to search for available treatments, and the actors likely to provide equipment or associated services. A field survey with nearby technology/services providers need to be undertaken to confirm the possibility to treat the flows and ensure the after-treatment quality compliance with the receiving industry technical requirements and specifications. Treatment needed can be separation, cleaning, sorting, mechanical treatment, chemical treatment, etc.

iii. Sample shipments and Certificate of Prior Acceptance

Representative samples of the resource (mainly for material and liquid streams resources) must be shipped to the potential receivers to confirm the technical feasibility of the synergy. The emitting company need to request a Prior Acceptance Certificate (PAC) or at least an agreement-in-principle from the industrial partner. Upon receipt of this document, the technical feasibility will be considered as agreed. During this stage, samples will also be shipped to technologies/services providers to pre-treat the waste if needed. Their validation will confirm the technical feasibility of the value chain.

Stage C - Set-up the logistics

The objective of this task is to compare and select the most relevant equipment/services providers to set-up the value chain. It requires to collect quotes and all economic conditions of the participants considered relevant for setting-up the value chain.

i. Resource conditioning and storage

The IS project leader need to search for valuable storage methods and equipment (when and where necessary). The solution needs to be optimised according to on-site available areas, the type and quantity of packaging means required.

Depending on the synergy creation project's preliminary results, it would potentially require to modify storage areas in the stakeholder's facilities in order to optimise it accordingly with the rest of the shipment process.

3-5 quotes should be collected for the procurement. Examples of conditioning solutions are presented in Figure 12.

Figure 12: Examples of conditioning solutions (pallet, Intermediate Bulk Container, storage tank, skip)

ii. Resource transportation

Based on the data from both emitting and receiving sites, the consortium needs to calculate the pick-up delivery frequency and the volume to be stored during each period.

To find the adequate transport provider, a survey with several transport companies is necessary to verify:

- Compatibility with the transport of each type of resource (in particular regarding its hazardousness) and its packaging.
- Ability to follow administrative procedures for the transport of waste in France and/or abroad.

Figure 13: Examples of transportation modes

In case of a major project involving liquid and gas streams with pipeline transportation, a dedicated feasibility study (technical and economic) has to be performed and will engage other stakeholders like consultancies and public authorities.

iii. Administrative and legal management

The IS project leader need to have an overview of all administrative and legal procedures and constraints for the resource exchange at a national level and in Europe if the other partner is abroad, in particular:

- Resource transfer declaration
- Local authorisation
- Regional authorisation
- National authorisation
- Local and national declaration to perform

Assessment process - Decision tree

Based on the synergy assessment process, a decision tree is presented in Figure 14 for a smart management of the project, in particular to avoid a time-consuming creation process for synergy with a low success rate. This decision tree aims at guiding the practitioner in the synergy assessment process.

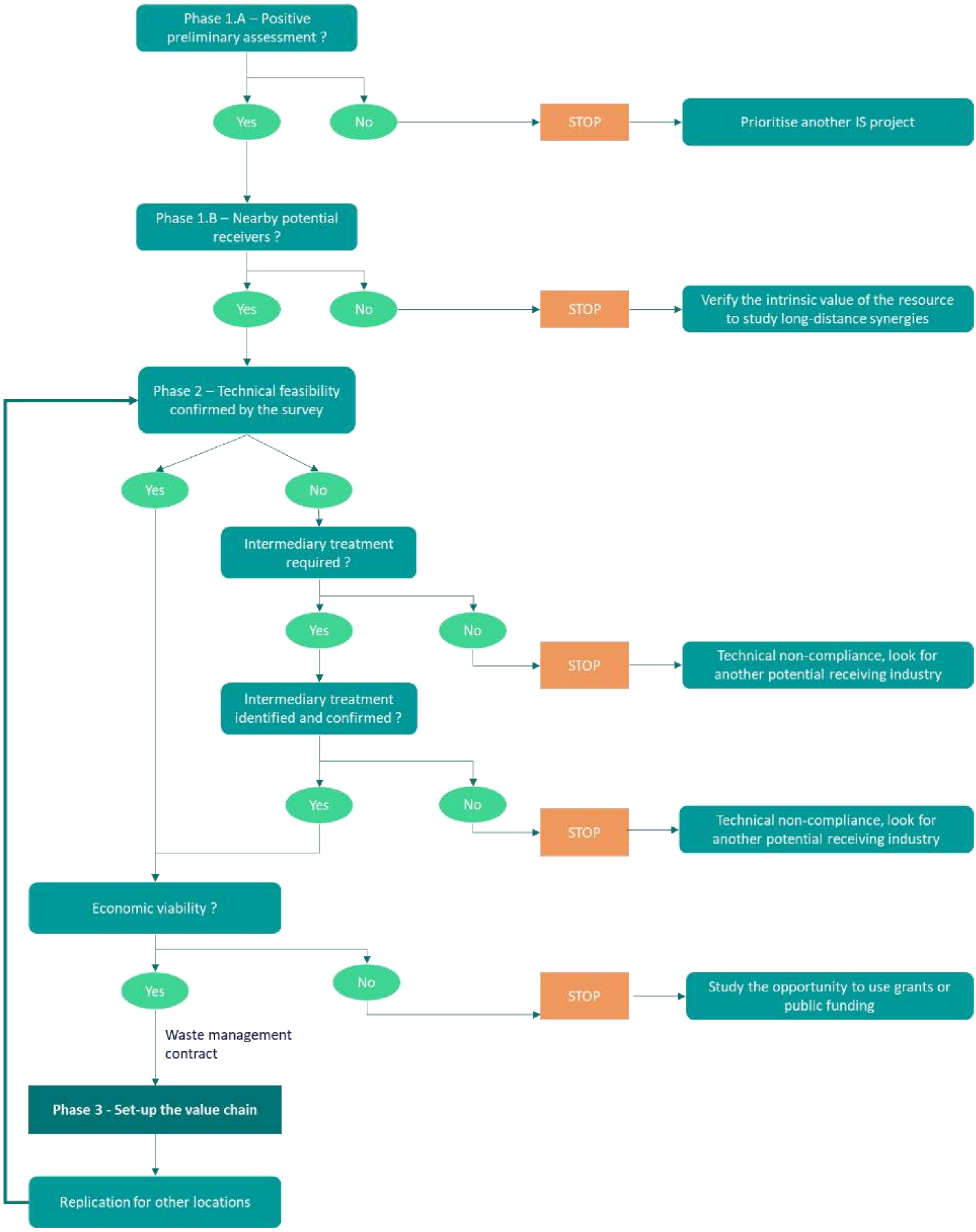


Figure 14: Feasibility assessment process - Decision tree (Source: Strane)

By following this decision tree, the practitioner could avoid spending time on low intrinsic value resources, non-feasible and non-economically viable synergies.

If it arises, depending the situation, the user should act as follow:

- Negative preliminary assessment of potential applications: the practitioner should prioritise other IS project

- <u>No possible partner nearby:</u> the practitioner should assess deeper the intrinsic value of the resource to estimate the relevancy of a long-distance synergy.
- <u>Technical non-compliance:</u> look for another potential receiving industry
- <u>Economic viability not ensured:</u> study the opportunity to use rants or public funding

In any case, following this synergy assessment process would enable the user to identify and collect all values that could be generated by the synergy's creation. The inventory of value need to be done during this synergy assessment process for having sufficient data to support the decision-making.

3.3.2 Inventory of values

For the purpose of filling completely the SBMC and defining the most suitable Business Model and Business Cases for each individual stakeholder, it is necessary to make the inventory of values generated by a synergy. Values can either be positive (creation) or negative (destruction). As the intrinsic nature of IS is complex, specific analyses involving a wide range of actors are required to assess all value forms (economic, environmental, social, territorial), and more importantly the ones generally not considered [31]. The guide methodology is inspired from Bocken et al. who proposed a value mapping tool [32] and then adapted to IS conditions. It mobilises the synergy stakeholders' ecosystem to explore and assess value propositions. It is not necessary to directly imply each individual stakeholder, but it is recommended to consider created/destroyed values for all of them to develop an accurate value analysis and consider the global viability of the synergy.

Based on field experience and literature review, the guide proposes some assessment guidelines for several value typologies.

A. Economic values

This sub-section focuses only on pure economic values created or destroyed by a synergy project. Several typologies of economic values must be considered: **new revenues, costs avoided, costs created, and revenues avoided.**

New revenues are generated by being aware that underutilised resources might have hidden economic values. They are highly important for the economic assessment. In this purpose, the IS project manager must define how the resource would be used in the synergy (1. Heat, 2. Combustible, 3; Material) and its main attributes. Resource economic value depends on its uses and more precisely the type of substituted resource. For example, coke can be used as a combustible in several energy intensive industry and as a raw material for its intrinsic properties in the steel sector. For the former, its value will be indexed on other solid fuels depending on its quality (e.g. coal, biomass, tyres, etc.) while for the latter, the value will be based on coke market prices or production costs. These economic values can significantly change. Some assessment details are provided below for the three uses:

- **<u>Heat valorisation</u>**. If the resource is used as a heat source, its value is estimated from 26 €/MWh to 44 €/MWh depending on its temperature (Table 7). These values represent the cost to produce 1 MWh of steam in Europe, at different temperature level, with a boiler fed with natural gas (with early 2019 natural gas prices).

Table 7: Heat equivalent prices by temperature level (Source: EPOS [16])

T (°C)	100	200	300	400	500	600	700	800	900	1000

€/MWh	26,3	27,6	29,9	30,4	32,1	34,0	36,0	38,4	41,1	44,2

- **Combustible valorisation**. For resources used as combustible, they must be compared to alternative fuels with the same state of matter (solid, liquid, gaseous and electricity) and for the same amount of energy produced by combustion (based on LHV). It must be noted that boiler efficiency might decrease with alternative fuels and should be considered when calculating the equivalent substituted energy amount. Some equivalent fuels of reference are provided in Table 8 (with early 2019 prices).

Table 8: Alternative reference fuel prices and LHV

Fuel of reference	Coal	Heavy fuel	Natural Gas	Electricity
Price (€/t)	70[1]	580[2]	18,1 (€/MWh)[3]	0,11 (€/kWh)[4]
PCI (GJ/t) [5]	27-32	39-40	39	

- **Material valorisation**. Resource economic value is defined by comparing with prices of available resources on the market. In cases where flows are mixed, the total value of the flow is the sum of individual elements value from the mix. It is assumed here that technical solutions exist to treat any mixed flow and split it into individual fractions. Table 6 provides some market prices of material examples.

Raw material	Industrial water	Sulphur crystal	Tar	Coke breeze	Scrap

[1] https://commoprices.com/fr/c/Energie/Houille/Charbon/WRB-COAL_COL?currency=EUR (consulted the 2019/03/21)

[2] http://www.prix-carburants.developpement-durable.gouv.fr/petrole/se_resul_fr.php (consulted the 2019/03/21)

[3] https://commoprices.com/fr/c/Energie/Gaz/Gaz-naturel/WRB-NGAS_EUR?currency=EUR&unit=20 (consulted the 2019/03/21)

[4] https://commoprices.com/fr/c/Indices-Macro%C3%A9conomiques/Energie/Prix-de-l_%C3%A9lectricit%C3%A9/ELEC-FR#CP (consulted the 2018/08/30)

[5] https://www.picbleu.fr/page/tableau-comparatif-pouvoir-calorique-inferieur-pci-des-energies (consulted the 2019/03/21)

Market prices (€/t)	0,5[6]	123[7]	210[8]	131[9]	200[10]

It is important to note that this methodology leads to assess the maximal value recoverable in the resources. Fairer values might be defined by the practitioner or through co-assessment discussions between involved actors, considering quality and availability among other criteria. Decreased rates might be applied (from a few percent up to 80%) and in some cases resources might finally have negative economic values (i.e. provider pays to send its resource).

Costs avoided can emerge from different sources. Business as usual costs might be related to:

- **Public bodies** (e.g. EU-ETS with a CO_2 ton cost of about 21,4 €/t[11] in March 2019, while it was about 5€/t between 2013 and mid-2017);
- **Private entities** for several types of disposal or depollution treatments (e.g. landfill taxes in EU vary from a few euros to more than 150 €/t depending on the region)
- **Internal costs** if part of the waste management is done by the organisation.

These costs are highly dependent on the business, context and resource nature. By implementing synergies, these avoided costs generate positive values for organisations.

Treatment procedures and associated technologies might be required for the synergy implementation. These costs can be externalised, through subcontracting services (OPEX), or internalised with infrastructures investments and day-to-day operation (CAPEX and OPEX). Available data was gathered during the T3.3 in the technology database.

Additional costs are automatically generated with a synergy creation and **must be (roughly) assessed** by the user guide. Depending on the case, they can be insignificant or require significant investments. These costs are:

- Inherent and related to:
  - transport. They vary depending on transport type (e.g. freight, river, truck, pipeline transport) and resource nature (e.g. state of matter, corrosiveness, hazardousness, etc.). As an example, truck transport of non-hazardous solid

[6] Industrial partner

[7] https://minerals.usgs.gov/minerals/pubs/commodity/sulfur/mcs-2016-sulfu.pdf (consulted the 2019/03/21)

[8] http://www.crugroup.com/about-cru/cruinsight/The_changing_coal_tar_supply_demand_dynamics (consulted in 03/2017)

[9] http://www.eia.gov/coal/production/quarterly/pdf/t25p01p1.pdf (consulted the 2019/03/21)

[10] http://www.eurofer.org/Facts%26Figures/Scrap%20price%20index.fhtml (consulted the 2019/03/21)

[11] https://sandbag.org.uk/carbon-price-viewer/ (consulted the 2019/03/21)

waste can be estimated to 20 €/t/100km OPEX[12], while pipelines require around 1 M€/km CAPEX and 40 k€/km/y OPEX[13];
    - organisational changes and must be assessed by organisations themselves;
    - transaction costs, i.e. efforts spent in thinking, designing, implementing the synergy.
- **Conditional** and appear whether new infrastructures, additional treatment or decommissioning of existing equipment are required for the synergy creation. These costs can be externalised, through subcontracting services (OPEX), or internalised with infrastructures investments and day-to-day operation (CAPEX and OPEX). They can be split in engineering, manufacturing, installation, financial, insurance, operation, and maintenance sections. The study does not aim to be exhaustive, but serves as a reference, giving accurate ideas of costs magnitudes for similar equipment. Values are split into fixed costs (i.e. investment for the system, installation and decommissioning) that usually depend on equipment sizes and variable costs (i.e. operating costs including utilities costs and maintenance). Data were obtained through various research methods, i.e. through extensive literature review and price inquiries directly at equipment manufacturers / suppliers or at manufacturing sites that already use the equipment which is object of the inquiry. Cost data for different technologies with similar uses are compared. All cost data is presented in EUR and adjusted for inflation. In addition, each technology is modelled with a diagram which lists the input(s) and the output(s) streams.

The last economic value to be considered is **foregone income**. This negative type of value generally appears when extending the analysis scope to peripheral and external stakeholders. Their assessment is optional if the value assessment focus is on central actors, but it is recommended for systemic and complete assessments. Typical stakeholders losing revenues are:

- From upstream value chain of the resource substituted because of the synergy (e.g. by using a secondary fuel in its kiln, a cement factory will require less fossil fuel such as coal. It directly impacts extraction, transformation, transport, and wholesale activities related to coal as well as indirect activities such as utilities);
- From downstream value chain of the exchanged resource, i.e. all actors who are currently taking care of the resource (e.g. depollution activities). Waste management companies can have global service contracts with industries, recovering all undesired resources and cleaning sites. Some resources are valuable, others are not and need depollution actions to respect environmental regulations before disposal. By creating synergies with valuable resources, waste manager loose revenues. This can lead to negative effects for industries (e.g. increased waste treatment bills to compensate value losses) and for the nature (e.g. illegal dumping due to unviable contracts).

The nature and the intensity of these values highly depends on the synergy case and on the scope considered by the guide user. The latter is free to include some value typologies and

[12] Source: Strane Innovation
[13] https://hub.globalccsinstitute.com/publications/co2-liquid-logistics-shipping-concept-llsc-overall-supply-chain-optimization/101-cost (consulted the 2019/02/26)

stakeholders in its analysis, or not. However, it is recommended to consider all of them for a holistic analysis. By creating additional economic value for some actors, the synergy might destroy similar or even higher values for other stakeholders. In such a case, the synergy might not be relevant to implement for the whole economic system. This global viability can easily be checked according to the sign of the above-mentioned values sum:

$$\sum (new\ revenues + avoided\ costs - additional\ costs - foregone\ impacts) > 0$$

i. Other useful Data for economic calculation

Based on the work performed in SCALER WP3 T3.5 (Socio-economic Assessment), other useful data for the economic values inventory are suggested below. The practitioner can decide to use them or not depending the situation and its need.

Landfilling costs and taxes

The European Environment Agency provided in 2013 typical charge data (gate fee and landfill tax) for legal landfilling of non-hazardous municipal waste in EU Member States and regions. This document does not present landfilling taxes and costs for hazardous wastes.

The CEWEP agency published an update of the landfilling taxes in 2017.[33]

Table 9 gather the two documents data. In order to provide a worst cases estimation, maximum prices were retained.

Table 9: Gate fees and landfill taxes in EU Member States (Source: European Environment Agency / CEWEP / Strane)

Member State	Landfill tax (€ per tonne) In 2013	Landfill Tax (€ per tonne) updated	Year	Current typical landfill gate fee (€ per tonne)	Total typical charge for landfill (€ per tonne)
AUSTRIA	26,00	87	Applied since 2006	70,00	157
BELGIUM, FLANDERS	82,03	101,91	2017	50,00	151,91
BELGIUM, WALLONIA	65,00	113,01	2017	50,00	163,01
BULGARIA	3,00	30	2019		30
CYPRUS				56,00	56
CZECH REPUCLIC	20,00	20	2017	16,00	36
DENMARK	63,00	63,3	2017	44,00	107,3
ESTONIA	12,00	29,84	2017	40,00	69,84
FINLAND	30,00	70	2017	59,40	129,4
FRANCE	20,00	40	2017	60,50	100,5
GERMANY†	0,00	0,00	2017	140,00	140
GREECE†	0,00	60	2019 - 2020	23,50	83,5
HUNGARY	0,00	19,35	2017	35,00	54,35
IRELAND†	50,00	75	Since 2013	70,00	145

ITALY†	30,00	25,82	2017	90,00	115,82
LATVIA	8,00	43	2019	30,00	73
LITHUANIA	0,00	21,72	2019	16,25	37,97
LUXEMBOURG†	0,00	8	2017	149,48	157,48
MALTA	0,00	0,00	2017	20,00	20
NETHERLANDS†	107,49	13,11	2017	25,00	38,11
POLAND	26,60	40	2019	69,50	109,5
PORTUGAL	3,50	9,9	2019	10,50	20,4
ROMANIA	0,00	26	2018	3,70	29,7
SWEDEN†	49,00	50	2017	106,50	156,5
SLOVAKIA	0,00	9,96	Since 2016	6,80	16,76
SLOVENIA	11,00	11	2017	105,50	116,5
SPAIN	12,40	41,30	2019	32,75	74,05
UK	64,40	100	2018	26,80	126,8
EU 28	23,81	38,82		53,10	91,91

The average landfilling tax updated with the CEWEP publication is around **38,82€/t of landfilled wastes**. The average landfill gate fees in EU Members countries are around **53,10€/t**.

Incineration costs and taxes

Waste incineration gate fees are presented in the Waste Incineration BREF [34]. Value are old so the maximum value was retained.

Table 10 : European incineration gate fees (Source: BREF / Strane)

Member States	Municipal waste Gate fees in €/t	Hazardous waste Gate fees in €/t	Maximum gate fees
BELGIUM	57	100 – 1 500	57
DENMARK	40 – 70	100 – 1 500	70
FINLAND	50 – 100	NI	100
FRANCE	50 – 120	50 – 1 500	120
GERMANY	100 – 350	50 – 1 500	350
ITALY	70 – 120	100 – 1 000	120
NETHERLANDS	90 – 180	50 – 5 000	180
SWEDEN	38 – 67	50 – 2 500	67
UNITED KINGDOM	20 - 40	NI	40
AVERAGE	20 - 350	50 – 5 000	122,6 (Average)

The 100 synergies waste streams are randomly hazardous or non-hazardous wastes. The hazardous waste gate fees range of value is wide. Therefore, the retained value is based on the municipal waste maximum gate fees: 122,6€/t of wastes incinerated.

Strane used several sources to identify the variety of incineration taxes : a European comparative study of waste disposal taxation [35] carried out and published by the ADEME (French Environmental Agency) in 2017, Waste incineration BREF [34], a waste environment study by the European commission [36] and the French Custom [37]. Data available are gathered in the Table 11.

Table 11: Incineration taxes (Source: ADEME / Waste incineration BREF / European Commission / French Custom)

Countries	Incineration tax (€/t)	Date	Source
UNITED KINGDOM			[35]
AUSTRIA			[35]
BELGIUM – WALLONIE	11,3	2016	[35]
DENMARK	52	2011	[35]
SPAIN - CATALONIA	11,7	2016	[35]
FINLANDE			[35]
NETHERLANDS	13	2016	[35]
SWEDEN			[35]
FRANCE	15		[37]
AVERAGE	20,6		

An average value was estimated (20,6 €/t) but due to the lack of information regarding waste incineration taxes in Europe (only data for 5 countries), this indicator has not been assessed in this study.

Carbon tax

The COP 21 advised to apply a carbon tax of 40 – 80 € per tonne of CO_2 emitted.

The French environment and energy management agency ADEME published a document updated in 2016 and focused on the carbon tax in Europe. Rates vary from a symbolic level (2 €/t CO_2 in Estonia) to more than 120 €/t CO_2 in Sweden. If an average rate could be defined for all European countries, it would be between 20 and 30 € per ton of emitted CO_2 [38].

In the context of SCALER study, and **considering that all EU countries will try to reach the COP 21's targets**, the carbon tax retained is **40€ per ton of C02 emitted**. That would correspond to local authorities' potential benefits in case of the application of COP21's recommendations.

Value added tax

The definition of VAT provided by the European Union is the following one [39] : "The Value Added Tax, or VAT, in the European Union is a general, broadly based consumption tax assessed on the value added to goods and services. It applies to all goods and services that are bought and sold for use or consumption in the European Union. Thus, goods which are sold for export or services which are sold to customers abroad are normally not subject to VAT. Conversely imports are taxed to keep the system fair for EU producers so that they can compete on equal terms on the European market with suppliers situated outside the Union."

The European Commission lists the standard VAT rate in Europe [40] (situation in 2019).

Table 12 : List of VAT rates applied in the Member States, 2019 (Source: European Commission)

Country	Standard VAT Rate (%)	Country	Standard VAT Rate (%)
Belgium	21	**Lithuania**	21
Bulgaria	20	**Luxembourg**	17
Czech Republic	21	**Hungary**	27
Denmark	25	**Malta**	18
Germany	19	**Netherlands**	21
Estonia	20	**Austria**	20
Ireland	23	**Poland**	23
Greece	24	**Portugal**	23
Spain	21	**Romania**	19
France	20	**Slovenia**	22
Croatia	25	**Slovakia**	20
Italy	22	**Finland**	24
Cyprus	19	**Sweden**	25
Latvia	21	**United Kingdom**	20

Table 13 : Average VAT rate in EU (Source: Strane)

Average standard VAT Rate in Member State	21,46 %

The final VAT rate retained for the socio-economic assessment is 21,46%

Transport modes costs

It was assumed that a pipeline costs on average about 1.4 M€ per kilometre (Smith, 2015). The economics of pipelines depends on the resource to be transported, its physical characteristics (e.g. corrosion, temperature, risks, porosity, etc.) requiring different types of pipelines (materials, isolation, protections…), as well as its local characteristics (land ownership, type of land, landscape…).

Truck transportation generic price was provided by an industrial partner. It is assumed that the truck transportation costs are between 0,15 and 0,2 €/t/km. This generic price is not applicable for specific or exceptional lorry transportation (e.g. pressurised gas transportation).

Table 14: Transportation modes cost estimate (Source: Strane)

Transport modes	CAPEX	OPEX	Unit	Source
Pipeline	1400000	85000	€/km	Smith, 2015
Trucks		0,0298841	€/t/km	Strane
Trucks		15 – 20 0,15 – 0,2	€/t/100km €/t/km	Industrial partner

Transport viability radius

Pipeline transportation modes were not modelled in this study because of a lack of information regarding geolocated data. Geolocated data gathered in T3.1 will be crossed with the socio-economic assessment in the T3.6.

In this study, the viability distance assessed for lorry transportation is a rough estimation [41]. It considers only the viability radius for one ton of resource. The distance radius of viability is a data made in relation with the price of the resource studied. The formula used does not depend on the resources volume.

A deeper analysis will be provided for each synergy type in the D3.5.

$$\boldsymbol{Viability\ radius} = \frac{\boldsymbol{Resource\ valuable\ volume\ (t) * Raw\ material\ susbtitiuted\ price\ (€.t)}}{\boldsymbol{Tranport\ generic\ price\ (€.t.km) * \ Resource\ valuable\ volume\ (t)}}$$

A viability radius to estimate the maximum transportation is proposed. In order to have an industrial approach, it is assumed that the transportation costs do not exceed 10% of the transported merchandise value.

Labour share in added value

The IMF declares that the value-added share accrued to labour, commonly known as the labour share, the ratio of labour compensation (wages and benefits) to national income, was around 46% in 2017 [42].

In 2016, the European commission's database (AMECO) mentioned that the labour share represented 53% of the total added value in industrialised countries according to the Federal Reserve Bank of Cleveland [43]. That confirms the relevancy of the IMF data.

This value (46%) will be used to estimate the part of the labour share (including wages and benefits) in the global value added associated the synergies implementation at European level.

Total labour costs

In order to estimate the number of jobs generated by the synergies' added value, the wages and salaries in Europe where used. A survey performed in 2016 details the labour costs, wages and salaries by activity [44].

Table 15 : Labour costs indicators (Source: Eurostat)

Labour costs indicators	2016
Total Labour costs Sectors: Industries, construction and services per employee in full-time equivalent, per year	44 071 €
Wages and salaries Sectors: Industries, construction and services Per employee in full-time equivalent, per year	33 643 €

Tax to GDP Ratio

According to Eurostat publications [45] [46], in 2017, tax revenue (including social contributions) in the EU stood at 40.2 % of GDP, and accounted for around 90 % of total government revenue.

Maintenance costs

Due to the lack of information on synergies' OPEX and CAPEX, the maintenance costs were omitted during this study. The ratio that would be applied in the D3.5 is:

$$Maintenance = 0.02 \; to \; 0.06 * Capital \; Investment \; (€)$$

Resources price

Table 16 : Resources prices (Source: Strane)

Resource	Price	Unit	Year	Source
Hydrogen	0,204	€/m3		
Natural gas	0,260369888	€/Nm3		
Zinc dusts	2 315	€/t	2015	[47]
Raw zinc	1 717,6	€/t	2014	[47]
Iron ore	71	€/t	2018	[48]
Gyspum	36,2	€/t	2015	[47] [49]
Salt	Industrial salt: 66,5 Salt: 31	€/t €/t	2015 2012	[47] [50]
Lime	85	€/t	2012	[50]
Fuel gas	561	€/t	2018	[48]
Sulphuric acid	Around 90	€/t	2015	[47]
Hydrogen	2259	€/t	2018	[47]
Nickel bullion	13 013	€/t	2018	[48]
Ferronickel	3 152	€/t	2015	[47]
Rough Nickel	13 156	€/t	2015	[47]
Nickel Powder	20 265	€/t	2015	[47]
All type of sulphur	302	€/t	2015	[47]
Rough sulphur non-refined	118,1	€/t	2015	[47]
Silica	1453,5	€/t	2015	[47]
Alumina	488	€/t	2012	[50]
Granulated slag	16,5	€/t	2015	[47]
Aluminium	1824	€/t	2018	[48]
Aluminium oxide	341,1 488	€/t €/t	2015 2010	[47] [50]
Lead bullion	2 515	€/t	2018	[48]
Lead	1 789	€/t	2010	[50]
Lead debris and waste	1 053,7	€/t	2015	[47]
Pure benzene	919	€/t	2018	[48]
Benzene	701,8 €	€/t	2015	[47]
Copper	5 772	€/t	2010	[48]
Copper alloys	1 933,2	€/t	2015	[47]
Antimony	6 868,9	€/t	2015	[47]

Diethyl ether	2 636	€/t	2018	[51]
Sulfuric acid	90.9	€/t	2015	[52]
Hydrocloric acid	78.7	€/t	2015	[53]
Methanol	372	€/t	2018	[48]
Anhydre ammonia	423	€/t	2015	[54]
Sand	155	€/t		[55]
Cooling water	1.26	€/m3	1995 but consider the inflation	[56]
Nickel	13 013	€/t	2018	[48]
Cobalt	74 424	€/t	2018	[48]
Aluminium	1 824	€/t	2018	[48]
Zinc	3 440	€/t	2010	[50]
Chrome	298	€/t	2015	[57]
Calcium carbonate	151.2	€/t	2015	[58]
Calcium oxide	224.7	€/t	2015	[59]

LHV

Fuels and waste fuels LHV are presented in SCALER D3.1.

Resource density

Table 17 : Resources density (Source: Strane)

Resource	Density	Source
Hydrogen	0,08988 kg/m3	[60]
Vacuum gas oil	0,925 g/mL	[61]
Diethyl ether	713 kg/m3	[62]
Acetaldehyde	788 kg/m3	[63]
Ethyl acetate	902 kg/m3	[64]
Ethyl propionate	884,3 kg/m3	[65]
BOF Gas	1,33 kg/Nm3	[66]
BF Gas	1,250 kg/Nm3	[66]
Crude oil	0.88 kg/L	[67]

Exchange rate

For investment costs and operational costs, an exchange rate calculator website [68] was used to convert money in Euros. The source year is selected by using the date of the publication or the date mentioned in the paper.

Inflation

In case of old papers and data, a website calculator was used to quantify the inflation.

Energy and water prices

According to Eurostat [69], in 2017 for EU 28 members, the price 0,0779 €/kWh for medium size industries. In 2017, water average price in Europe is 4,01€/m3 according to a French bi-annual study [70].

ii. Socio-economic indicators to use

All data previously gathered will enable the calculation of several socio-economic indicators provided:

- **Waste stream price.** A synergy is a waste valorisation. A waste does not have any intrinsic value. Most of the time, it is a cost source. A waste can have a value if it can be valorised as a commodity or if it presents another intrinsic value, a calorific power for example. In that case, the waste stream can replace the use of a conventional fuel. The associated price chosen for the socio-economic modelling is the substituted resource equivalent price.

- **Resource estimated price.** Depending the resource and data availability, three types of resources prices calculation were used:
    - If the resource can be directly sold on the market, the price used is the resource market price (e.g. pure lime market price).
    - Equivalent price of the substituted resource (e.g. natural gas for a gaseous fuel), for the same energy content in case of a fuel.
    - Sum of the chemical element prices.

- **The waste stream volume** is the total waste volume produced by the emitter industry.

- **Final volume recovered** corresponds to the elements of interest volume, after considering the technology recovery rate.

- **Value Added** is calculated as follow:

$$Final\ recoverable\ flow\ volume * Resource\ estimated\ price - Waste\ stream\ volume \\ * Initial\ waste\ stream\ price\ (-OPEX\ when\ availabale)$$

- The **VAT** is 21,46 % of the value added.

- **Labour share** is considered 46% of the value added.

- **Direct jobs creation** is calculated through the total labour costs, 44 071€ per year and per employee.

- **Induced indirect jobs creation.** SCALER is a project funded under the SPIRE's public-private partnership. SPIRE is an alliance of 8 sectors of the European industry (cement, ceramics, chemicals, engineering, minerals and ore, non-ferrous metals, steel and water). These sectors include more than 450 individual enterprises, provide 6,8 million jobs and generate annually more than 1.600 billion euros in turnover, which represents 20% of the total European industry, both in terms of employment and turnover. SPIRE estimates that the process industry represents more than 56% of industrial value added in the EU and around 10% of all economic activity. It provides 6.3 million direct jobs in the EU and a further 19 million indirect jobs [71].

The process industry indirect jobs creation is therefore directly correlated with the direct jobs creation with a ratio:

$$SPIRE\ Ratio : Indirect\ jobs\ created = Direct\ job\ created * 3{,}02$$

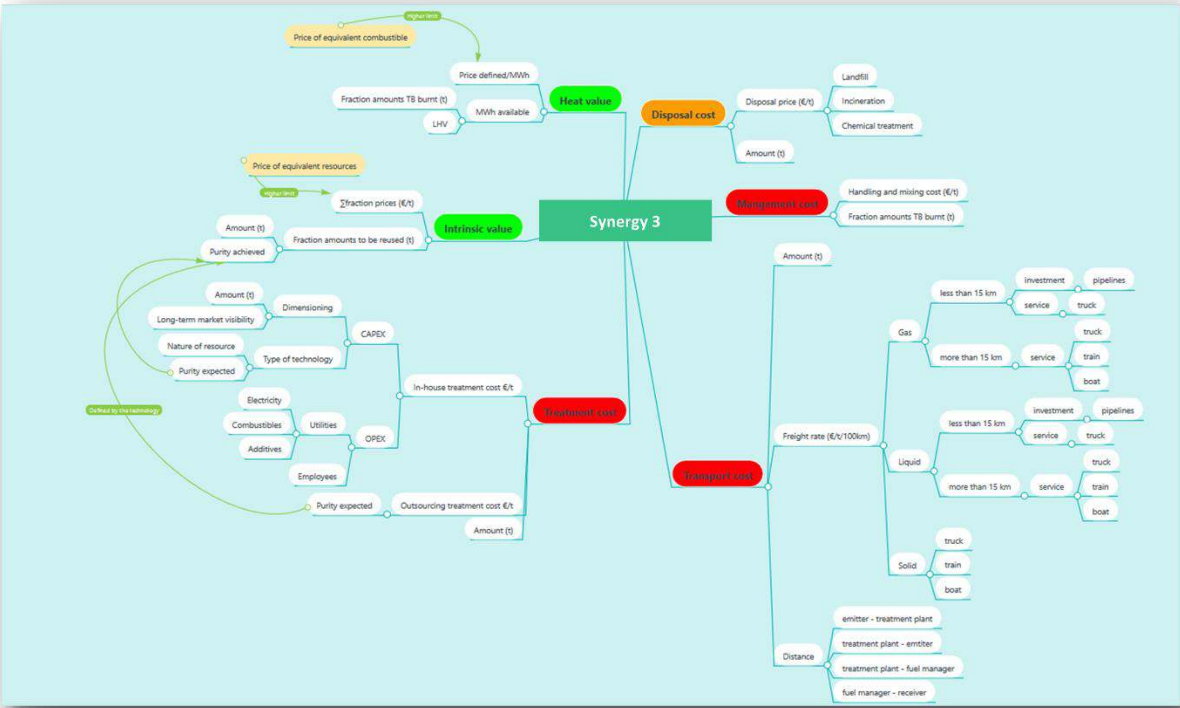
It is assumed that one industrial job creates 0.5 indirect jobs (this lower bound is largely underestimated, as an example, in France one direct job generates 1,5 indirect job [72])

- **Landfilling taxes** for both scenarios
- **Avoided waste management costs (landfilling and incineration) costs** for both scenarios
- **Economic viability radius** which is a rough estimation and will be deeply analysed in the D3.5.
- **Carbon tax reduction** based on the climate change indicator (CO_2 emissions decrease) provided by the LCA

Total investment required in EU (associated number of technologies), based on the CAPEX and operational yield

Table 18 is a mapping of all economics values to assessed in a synergy project.

Table 18: Mappin of economic values (Source: Strane)



B. Environmental values

Environmental values are necessary to consider in an IS project to (1) **validate the environmental positive performance** of a synergy and (2) **mobilise non-central stakeholders** impacted by these values and who might unlock decisions only based on economics. On the one hand, industries are facing environmental regulations, pressure from the society to reduce their footprint and to better consider their societal responsibility. In addition, environmental performance can be traduced as a new form of competitive advantage. Thus, these actors **need tools guiding them in assessing environmental impacts of their new projects**, and more specifically synergies. On the other hand, such information is of high interest for public authorities, at different scales, and citizens for whom synergies might create or destroy value and should be involved or at least considered in the decision-making.

The value analysis is made through a Life Cycle Assessment (LCA). The guide user **must first define the functional unit**, i.e. the unit of reference that enable comparison between several scenarios' analyses. It is recommended in the scope of IS to choose a certain volume of final product (e.g. production of 1 t of coke, 1 m^3 of gasoil, 1 kWh of electricity, etc.). Thanks to this first step, the guide user will be able to compare the environmental performance of the synergy scenarios and the reference scenario for the production of the same amount of goods and make the analysis more accurate[14]. If LCA results show that a synergy scenario has less environmental impact than the business as usual, it can be considered that the synergy will create environmental value. If not, the synergy destroy value.

To assess synergy environmental values, it is recommended to use an **LCA software** such as SimaPro, or subcontract expert services. Reference and alternative synergy scenarios defined in step 3 are modelled, using to the collected data (in line with the hypothesis used in the economic assessment). Relative performance of each scenario can be expressed according to:

- midpoints , i.e. environmental impacts per precise domain;
- endpoints (or damage), which are an aggregation of the midpoints. They give concretely where environmental effects occur and to what extent. They are expressed in DALY (Disability Adjusted Life years) for human health, PDF.m².y

[14] The LCA approach is "Cradle-to-gate", i.e. only resource extraction, refining and manufacturing phases are considered in the analysis, excluding packaging, distribution, use, and end of life ones. It is justified because synergies implementation will not likely affect the nature or the use of the manufactured product, but it will only modify the environmental performance of the productive system.

[15] carcinogens, non-carcinogens, respiratory inorganics, ionizing radiation, ozone layer depletion, respiratory organics, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification, land occupation, aquatic acidification, aquatic eutrophication, water use, global warming, non-renewable energy, mineral extraction

(Potentially Disappeared Fraction of species in a certain area during one year) for ecosystem quality, MJ (required energy for the extraction of the same amount of material in the future) for resources depletion and t CO_2 equivalent for global warming

- euros, corresponding to the damage economic value. Values are defined by the StepWise2006 methodology as such: QALY (Quality Adjusted Life Year) corresponds to the average economic production per capita in one year (74 000€), BAHY (Biodiversity Adjusted Hectare Year) is based on ecosystem services evaluation, and the two latter represent the actual cost of 1 MJ or 1 t CO_2 for the economic productivity.

Links between indicators at different aggregation level and values are given in Table 19.

The guide user can **decide the aggregation level** he needs to express the analysis results. The lower level provides detailed information through a dozen of indicators, but they can be difficult to interpret by actors. More importantly, it might require guide user to make ethical choices by prioritising one or another value (e.g. are land occupation impacts more important than global warming?). Endpoints are clearer for a person, who can understand what the effects on the society are. However, it might still require ethical judgement to priories one effect in regard to another, and their calculations needed additional uncertain hypotheses (e.g. to what extent respiratory inorganics contribute to decrease human health). Finally, the higher aggregation level provides a single indicator, i.e. a clear information to decision-makers but resulting on important number of underlying choices and assumptions. Such approach is risky as decisions will be made on indicators prioritisation not necessarily in line with decision-makers interests or vision.

LCA remains a science based on a certain amount of hypothesis that each guide user should decide or at least be aware of. In the case of monetarisation methods, they are highly debated by experts and are based on a utilitarian vision of nature assuming a perfect substitution of economic and natural capitals. While highly controversial, it has the main benefit to facilitate the internalisation of non-economic values in synergy business models (see step 5), inducing organisations behaviour changes toward ecologically and socially optimal production [74].

Table 19: Economic value for LCA endpoints indicators

Midpoints	Endpoints	Weighting factors
Human toxicity, carcinogens (kg C_2H_3Cl-eq)	Human health (DALY)	1 QALY= - DALY = 74 000 €
Human toxicity, non-carcinogens (kg C_2H_3Cl -eq)		
Respiratory inorganics (kg PM2.5-eq)		
Ionizing radiation (Bq C-14-eq)		
Ozone layer depletion (kg CFC-11-eq)		
Respiratory organics (kg C_2H_4-eq)		
Aquatic ecotoxicity (kg TEG water)	Ecosystem quality (PDF.m2.y)	1 BAHY= - 10 000 PDF.m2.y = 1 400 €
Terrestrial ecotoxicity (kg TEG soil)		
Terrestrial acid/nutri (kg SO_2-eq)		
Land occupation (m^2 org ara.y)		
Aquatic acidification (kg SO_2-eq)		
Aquatic eutrophication (kg PO_4-eq)		
Water turbines (m3)		

Non-renewable energy (MJ primary) Mineral extraction (MJ surplus)	Resources Productivity (MJ)	0,004 €/ MJ
Global warming (IPCC 2013, 100a) (kg CO_2-eq)	Climate change (kg CO_2-eq)	0,08 €/kg CO_2-eq

Environmental values traduced by these indicators may interest several stakeholders' typologies – private and public – at different scales – from local to global (e.g. decrease of respiratory organics interests the local community, while global warming reduction interests national to global institutions). These values can thus be captured by different stakeholders and LCA results should be discussed by the whole organisation's ecosystem created in step 3.

C. Social values

The guide user is provided with a set of 20 indicators helping the assessment of the social values created by the synergy. The step leader must **gather the ecosystem stakeholders** (e.g. workshop) and facilitate the **collective assessment of the indicators**. Their role is to help actors defining benefits that the network newly created could generate. A non-exhaustive list of typical values is provided:

- Improve companies' performance and innovation;
- Improve people/employee well-being;
- Facilitate future business opportunities;
- Initiate innovation strategies;
- Improve brand image and relations with local communities.

Values emerge from the social capital, i.e. an accumulation of resources collectively built through relational network involving various and diverse actors [75], [76]. Concretely these values are issued from new inter- and intra-companies' relations, their strength and frequency, etc. These values are subjective and must be qualitatively assessed by the stakeholders themselves. They have the best position to judge whether they can have an impact in synergy implementation decision-making and to what extent.

The 20 indicators are related to 5 issues: governance (G), actors (A), relationships (R), motivations (M), and effort (E) and provided in Table 20. They were selected, based on an extensive literature review, to widen stakeholder's perspective of the synergy impacts and to foster discussions and co-assessment.

Table 20: Social value indicators

Issues	Indicator	Metrics	Description
G	Actor governing type	Public/Private/PPP	Indicates the stakeholder typology governing the synergy creation process
	Leading actors	Natural Number (n° of actors in the steering committee)	This indicator gives the number of actors (person/organisation) managing, leading, coordinating the synergy creation.
	Facilitation	Yes, No	Answer Yes if the synergy is facilitated by a third party
A	Central actors	Natural Number (n° of actors directly involved)	Number of actors (person or organisation) centrally involved in the synergy, i.e. all actors actively participating (meeting, data, etc.)

	Peripheric actors	Natural Number (n° of actors indirectly involved)	Number of actors (person or organisation) indirectly involved in the synergy, i.e. all actors actively participating (meeting, data, etc.)
	External actors	Natural Number (n° of actor groups impacted)	Number of actors (person or organisation) impacted by the synergy, i.e. actors concerned by externalities
R	Actors' Links	Natural Number (n° of links)	This indicator gives the whole number of additional structured links (material or immaterial) created in the territory through the synergy creation process
	Informal Links	% (n° informal links/n° additional links)	Formal links are purely professional while informal are outside of the professional sphere. They might be intra or inter-company.
	Trust	% (n° trusted links/ additional links)	This indicator is the part of the new links created thanks to the synergy, that can be defined as trusted, i.e. no fear, long-lasting perspective.
	Actors' interdependencies	Natural Number (n° of inter-organisational links per org.)	This indicator is an average of the inter-organisational links created for each of the stakeholders directly involved in the ITE initiative.
	Interconnections	% (n° exchanged resources/n° resources ==> after/before)	Variation of the organisations' resources interconnectivity in the territory thanks to the synergy creation process.
	Geographic Scale	km separating organisations	This indicator statistically characterises the geographic scale of the synergy
	Relations' frequency	n° emails exchanged/month n° phone calls/months n° physical meeting/months	This indicator clarifies exchanges frequency between partners involved in the synergy.
	Relations' intensity	Natural Number (n° physical meeting / n° total exchanges)	Intensity of people exchanges inter or intra-organisation.
	Employees Engagement	Natural Number (n° hours spent in dialogue/consultation)	This indicator traduces the level of engagement of employees in the synergy creation process.
	Social Engagement	Natural Number (n° hours spent in dialogue/consultation)	This indicator traduces the inclusion level of parties from the society in the synergy creation process.
	Social Acceptability	Natural Number (n° complaints)	This indicator traduces the social acceptability of this synergy, which inherently creates several organisational changes and impacts.
M	Charismatic support	Yes, No	Answer Yes if the synergy is supported by a legitimate or powerful or charismatic local political or industrial actor
	Initial motivation	Environmental, Regulatory, Cost reduction, Image, Industrial performance, Additional benefits, Innovation, Risk reduction, Long-lasting relationships, individual willingness, Awards, Knowledge sharing, preserve activity	This indicator must clarify each stakeholder's main motivations to be part of the synergy. For each stakeholder, it is important to detail the motivations for each cited element and a statistical characterisation can give the global synergy motivations.
E	Initial time consuming	Natural Number (n° total hours)	This indicator traduces the effort, in terms of time, dedicated to initialise the synergy creation process by the steering committee.

These qualitative values will be considered in the business model canvas (see Step 5) and might influence stakeholders' relationships form and/or negotiations.

D. Territorial values

Similarly to social values this sub-section provides a set of 32 indicators fostering the assessment of territorial values. The main difference is that these values are mainly destined to public authorities (considered as guarantor of these value nature). The step leader must **gather the ecosystem public stakeholders** (e.g. through workshop) and facilitate the **indicators assessment**. Indicators help actors defining public goods that the synergy could develop, foster, create, i.e. public values. A non-exhaustive list of typical values is provided:

- Direct and Indirect jobs created;
- Saved activities;
- Additional public revenues;
- Improve territorial economic or energy/material performance;
- Improve territorial circularity;
- Reduce material dependency/importations.

These territorial values arise from the concept of territorial capital, i.e. a system of territorial goods of different natures: economic, cultural, social and natural, that enables the potential development of a certain territory [77], [78]. This multidimensional capital is a collective construction that determines the territorial competitiveness [79], [80] and its level of integration in the global economy [81]. Values result from the creation of territorial externalities which generally cannot be made private, nor restricted to an asset provision [82].

Proposed indicators address several key territorial issues: attractiveness (At), economy development/preservation (Ec), social (S) & environmental (En) impacts, planning (P), innovation (I) and autonomy (Au). They are introduced in Table 21.

Table 21: Territorial value indicators

Issues	Indicator	Metrics	Description
At	General Territorial Attractiveness	% (n° companies interested in setting up / n° companies surveyed)	This indicator shows the level of interest that companies might have to set up a plant in this territory and be part of the synergy.
	Saved activities	Natural number (n° saved activities)	Expected saved activities (that might have shut down otherwise) on the territory thanks to the synergy implementation.
	New products	Natural number (t/y, m3/y, n°/y)	Expected volume of new products from (new or existing) firms on the territory thanks to the synergy creation. If physical product: t or m3; if service, it can be the volume of these services.
	Total investment	€	Additional investments made on the territory thanks to the synergy.
	Private funding	% (€ private investment / € total investment)	Part of the total investments funded by private organisations.
Ec	GDP	€	This indicator gives the absolute territorial wealth variation thanks to the synergy creation.
	GDP Growth	% (€ GDP after ITE / € GDP before ITE)	This indicator traduces the yearly territory (industrial system) wealth variation thanks to the synergy creation.
	Public Benefits	€	This indicator shows the real economic benefits for public organisations on the territory generated thanks to the synergy creation.
	Private Benefits	€	The real benefits generated by industries thanks to the synergy

	Reinvestment	Ecological, Production, Employees, Innovation, Additional services, Social Economy	This qualitative indicator clarifies the reinvestment strategy of the different synergy beneficiaries (company, public authorities, etc.). Additionally, it should detail the amount and the goal.
	Economic Weight	% of territorial turnover (1) % of territorial added value (2) % of territorial jobs (3)	This indicator assesses the relative significance/weight of the synergy in the territorial economy.
	Economic Performance	€/t	This indicator traduces the economic added value (avoided costs + additional benefits) created by the synergy, for each tonne of final product
	Surface Area performance	€/ha (€/ha after synergy - €/ha before)	This indicator gives the synergy additional value. It can also be an absolute indicator representing the territory ground efficiency.
S	Employment balance	Natural number (n° jobs created - n° jobs destroyed)	The indicator evaluates the net synergy impact on direct and indirect employment.
En	Air quality	kg PM2.5 (Respiratory inorganic after - Respiratory inorganic before)	This indicator from IMPACT 2002+ compares the air quality, and especially the impact for human health (fines particle, ammonia, CO, NOx, SOx)
	Diverted Waste Volume	t/y	Sum of all the wastes diverted thanks to the synergy.
	End of life management	% (tonne diverted/ (tonne diverted+ tonne wasted))	This indicator shows the industrial system capacity to manage its materials' end of life thanks to the synergy.
	Material performance	t/t	This indicator defines the gains in terms of material uses for the production of each tonne of final product thanks to the synergy.
	Energy performance	MWh/t	This indicator defines the gains in terms of energy uses for the production of each tonne of final product thanks to the synergy.
	RRE	%(MWh RRE/MWh consumed after / MWh RRE/MWh consumed before)	This indicator shows the variation of the use of Renewable and Recuperation Energy compared to the whole energy consumption thanks to the synergy creation.
P	Regional Scheme	Yes, No	Answer yes if this synergy fosters outcomes defined in the local Agenda 21, SRDEII, PRPGD, PRAEC, SRADDET, S3, or other regional schemes.
I	New technologies	Natural number (n° of new technologies)	Additional technologies and/or infrastructures implemented thanks to the synergy (not on the territory beforehand).
	New competencies	Natural number (n° of people with new competencies)	Additional people with skills that were not (or under-) represented on the territory and who are hired thanks to the synergy.
	New training program	Natural number (n° of new training program)	Additional training programs created thanks to the synergy.
	Normalisation	Natural Number (n° of new ISO norms)	n° of ISO norms (social, health, environmental) collaboratively set up between partners of the synergy.
	Replicable Synergy	Yes, No	Answer Yes if the implemented synergy can be duplicated on the territory or replicated on other territories.
	Synergy replication potential	Natural number (n° of replicated synergies)	Synergies that can be implemented across a wider territory thanks to the synergy dissemination.
Au	Energy Dependency	% (energy imported/used energy ==> after / before)	Variation of the energy dependency of the industrial system before and after the synergy implementation.
	Material Diversification	% (specific material use/total material use ==> after/before)	Variation of the territorial economy dependency regarding one specific material in comparison to the whole material consumption.
	Material Dependency	% (material imported/used material ==> after / before)	Variation of the material dependency of the industrial system before and after the synergy implementation.

	Circularity	% (secondary raw material/total raw material ==> after / before)	Variation of the part of reused, revalorised or secondary raw material used as raw material in the industrial system.
	Long-term Material Autonomy	% (material use/material deposit ==> after/before)	Variation of the long-term territory autonomy by comparing the resources currently consumed vs. the amount of identified resources on the field.

As previously, these indicators do not aim at being exhaustive but have the main function to raise awareness and encourage discussion between organisations to identify and characterise unexpected values. IS has the potential to revitalise deindustrialising territories in a sustainable way, and these values must be considered in the decision of implementing a synergy or not.

To conclude this section on the value inventory, several outcomes are expected from the value mapping. It is the guide keystone and probably its main conceptual and practical added value. At this stage, the guide user finds a detailed methodology enabling the **assessment of a wide range of values** (economic, environmental, social, territorial) which are generally not considered in decision-making. Inherently, the chosen approach leads to the **inclusion of wider stakeholders** that are affected, positively or negatively, by the synergy creation, while generally not involved in negotiations or consultations.

The guide user is supposed to engage **collaborative** value assessment actions (e.g. workshops) to (1) **clarify values recipients**, (2) **capture all individual stakeholders' values** (that can sometimes rely on subjectivity) and (3) better characterise and **capture the so called "co-created" values**. Thanks to this step, the consortium can integrate more value propositions in the synergy business model (see step 5). Step 4 is a **lever to change decision-making paradigm** through more systemic, holistic and likely, fairer impacts assessment.

This guide provides all the required blocks to manage such challenges. However, **each user is free to select the ones** he wants to assess, depending on its profile, resources and motivation.

3.3.3 Business Model and Business cases definition

Thanks to the previous steps, synergy assessment process and the inventory of value, the SBMC can now be filled completely.

3.4 Mechanisms to be activated

To foster the implementation of a synergy in case of non-direct and immediate economic benefits (massive investment costs, current low waste treatment costs blocking the decision-making, no sufficient cash to invest) several mechanisms are to be activated for unlocking the process. Implementing resource synergies can result in increased income but financial gains can also be made via direct incentives, often governmental, that support companies to collaborate more.

3.4.1 Taxation

In some countries and regions, policy supports tax incentives to help companies switch to more sustainable practices. Other examples of incentives are compensations via carbon credits and government funds. For example, in Finland a tax relief is used to incentivise industries and encourage the uptake of resource sharing [11].

3.4.2 Subsidies

The provision of subsidies for the development of waste exchange networks and projects can also be a way to deliver financial support to companies. Regions that aim to revitalise their territories and transition them to more sustainable societies may provide financial support to companies that help achieve their targets [11]

As an example, The Bussi chemical site, one of Italy's oldest industrial clusters, was identified as being in need of economic and social revitalisation due to the impacts of the financial crisis and increasing unemployment. As a result, the local government decided to stimulate interest in industrial resource sharing within the Bussi area through its legislation 'Ecologically Equipped Estates'. This legislation gave way to financial incentives for businesses that use coordinated systems in relation to the management of air, water and soil pollution in addition to service facilities, infrastructure and technologies [11].

3.4.3 Investment

Governments (national or local) can also provide assistance by stimulating private sector investments that can support resource exchanges. This could be either directly related tothe reuse and recycling of waste, or even looking at investment in innovation and technology to make resource sharing more efficient. State-owned companies in China have been incentivised by local governments to invest in and implement innovations to help spur more synergies. For example, this led to a smeltery for zinc and tin production in South West China developing innovations in technology, equipment and production techniques that allow output materials to become feedstock for a cement factory [11].

4. Synergy Example

This section details an example of the use of the Business Model and Business Cases Framework applied to a SCALER's synergy. The synergy analysed is the n°3 from the 100 synergies list [4]. This indirect synergy was selected since it is technically fully characterised and the associated procedure required is clearly detailed. It presents a concrete application of the whole methodology. The following steps are presented for this synergy to show how to use the process to the practitioner:

1. Synergy identification
2. Synergy assessment and inventory of values
3. Business model canvas filling
4. Business cases definition

4.1 Synergy identification

This synergy is part of the 100 synergies list developed within SCALER. It now constitutes a knowledge repository the practitioner can consult/use to replicate this synergy at its level. This synergy was identified by following an ambitious methodology calling upon a systemic analysis of industrial sectors and processes and "matchmaking" algorithms.

Nevertheless, this synergy would also have been identified by performing a LESTS and SWOT applied at a cluster level or at the emitting/receiving industry level.

Usually, primary liquid fuels and acid rich aqueous effluents from ethyl acetate production are mainly sent to utilities to be burnt for heat, steam and electricity generation. An opportunity of synergy is identified by extracting the organic fraction for burning and returning the acid fraction to the emitting process.

The synergy is detailed as follow:

- **Resource involved:** PRIMARY LIQUID FUEL (PLF)
- **Element of interest:** ACETALDEHYDE / DIETHYL ETHER / ETHYL ACETATE / ETHYL PROPIONATE
- **Sender sector and process:** ORGANIC CHEMICALS / ETHYL ACETATE PRODUCTION (7 sites in Europe)
- **Receiver sector and process:** CEMENT / BURNING
- **Annual volume per site:** 2 400 t/site
- **Baseline scenario:** The primary liquid fuel from organic chemical industry is mainly burnt to generate heat and avoid fuel consumption on site.

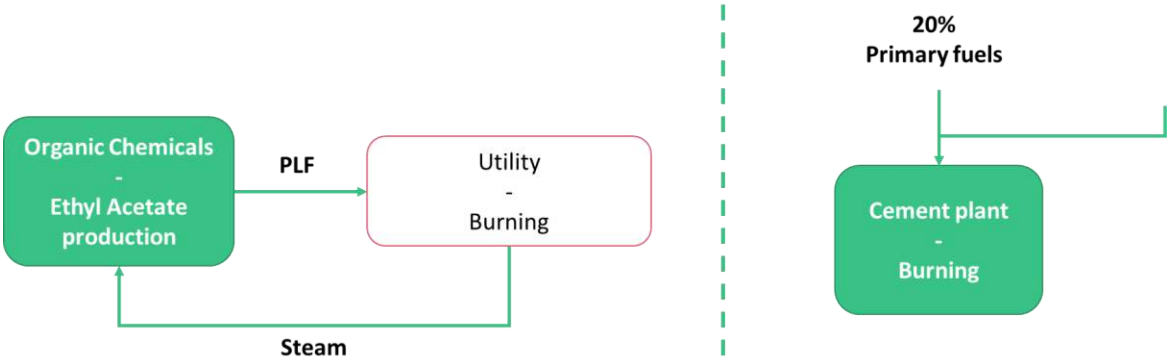


Figure 15: Business as Usual

- **Synergy description:** The aim of this synergy is to recover waste fuels from ethyl acetate cleaning operation and send it to a cement plant for clinker burning operation (fuel supply). This stream is composed by two fractions, organic and acid. The organic one, composed by a mix of waste fuel: (Acetaldehyde, Diethyl ether, Ethyl acetate, ethyl propionate), is sent to the cement plant to provide fuel for kiln. The acid acetic fraction is directly reused in the ethyl acetate production process.

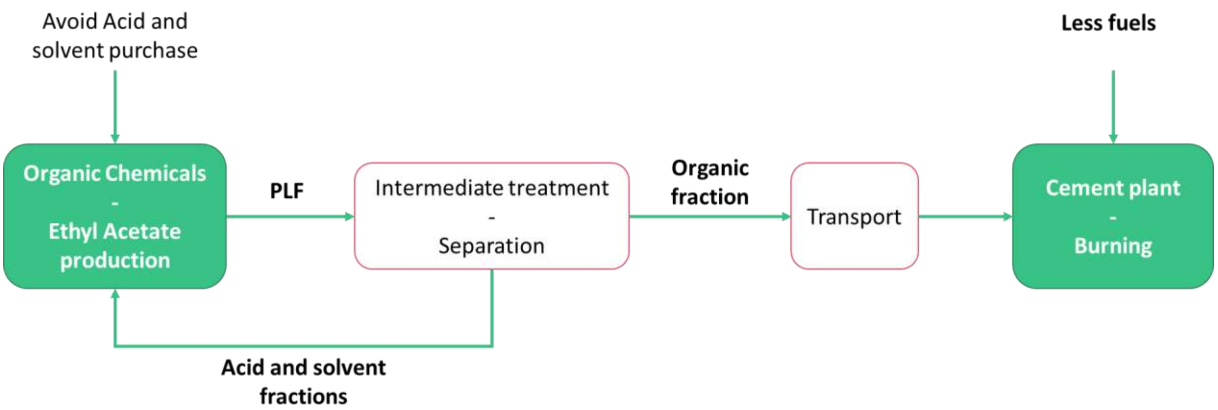


Figure 16: Synergy functioning

- **Synergy pre-feasibility assessment:** It seemed to be technically easy to implement, in case of adequate and qualified local partners, and economically viable. While the quantity is low, if the synergy does not impact significantly the actual organisations, it should not be a barrier.

4.2 Synergy assessment and inventory of values

4.2.1 Mapping

Once a potential receiving activity is identified, the first question to verify is the distance between the two potential partners. For this synergy, all possible emitting and receiving sites were mapped to make sure an opportunity is found within a reasonable radius.

Figure 17 and Figure 18 present respectively the number of couple of sites combinations in the first 300km (per 5km) and the distance between each individual emitter and the nearest possible receiver.

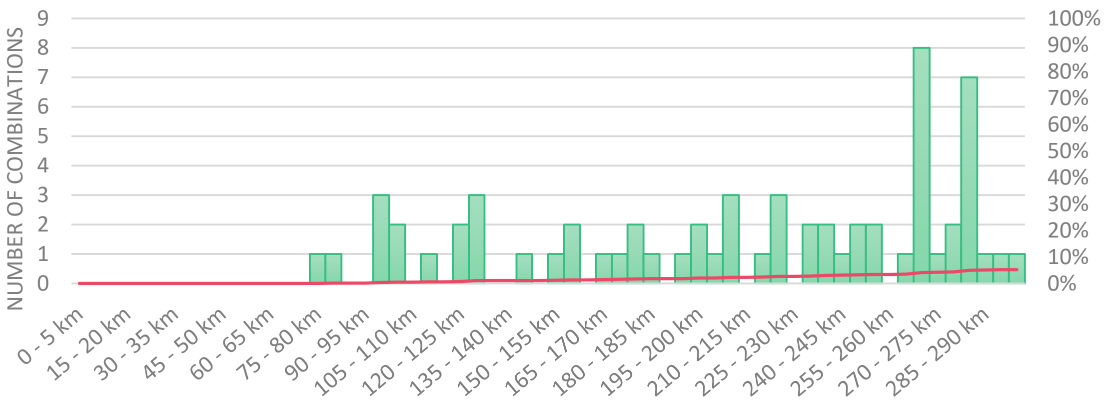


Figure 17: Synergy 3 Number of combinations of couple of sites in the first 300 km per 5 km (Source: Strane)

Ethyl Acetate production plants	Distance with a clinker burning plant (km)
1	75,7
2	96,2
3	99,9
4	151,7
5	232,8
6	362,1
7	384,3

Figure 18: Distances between each emitting site and the nearest receiving sites (Source: Strane)

By analysing the geographical distribution and the distance between each possible emitters and receivers, it appears 64 couple of sites combinations are possible in the first 300km. The 7 Ethyl acetate production plants have access to a potential receiver for the organic fraction at less than 385km. Transport can therefore be carried out by tanker truck for all cases. The Acid fraction is to be reused internally. Then, the probability of implementing this synergy is therefore high that is why it is necessary to assess deeper technical, economic and environmental aspects.

4.2.2 Technical assessment

The technical assessment performed in the T3.3 lead to identify the adapted process for the two fractions separation. It is summarised below (Source: ISQ):

- Name of the procedure required: Acid/Organic fractions separation
- Description of the procedure: The mixture enters the column of fractional distillation to separate the organic part from the acid part.
- Name of the technology: Fractional distillation
- Technology description: The mixture of two or more substances (liquids) with different boiling points is heated to a high temperature. The mixture boils and

the vapour enters in the bottom of a long column (fractional distillation column) that is filled with trays or plates. The trays have many holes in them to allow the vapour to pass through. When a substance in the vapour reaches a height where the temperature of the column is equal to that substance's boiling point, it will condense to form a liquid. The trays collect the various liquid fractions. The substance with the lowest boiling point will condense at the highest point in the column; substances with higher boiling points will condense lower in the column. Fractional distillation is the best way to separate the organic from the acid fraction because the difference between their highest boiling points is less than 20 degrees. Acetaldehyde (20,2°C); Dielthylether (34,6°C); Ethyl Acetate (77,1°C); Ethyl Proprionate (98,9°C); Acid Acetic (118,1°C). The components are not azeotropics. Operating pressure impacts all aspects of column design. The distillation columns can be trayed column or packed bed columns. Packing is preferred for smaller towers while trays are mainly used in lager columns, with diameters greater than 1 m. The use of tray columns with diameters in the 457 mm to 610 mm range is not usually economical and a packed tower in such cases will prove the best economically. On the other hand, packed towers are not limited to small units and the use of larger-diameter packing columns may still provide the less expensive choice for some specific applications. In packed columns, some of the ultimate performance depends on the column diameter.

- Yield: Flowrates ranging of the column depends on the scale, it can be from less than 1 to greater than 1,000 kg/h.
- Recovery rates: Tray efficiency is between 50%-98%. The performance of a distillation column is determined by feed conditions, internal liquid and fluid flow conditions, state of trays, operating pressure, temperature.
- Transportation: Road; Railroad. Store under an inert atmosphere. Keep container tightly closed in a dry and well-ventilated place. Use non-sparkling type tools and equipment, including explosion proof ventilation. Containers may be hazardous when empty since they retain product residues.
- Final viability result: Distillation makes about 95% of all current industrial separation processes. It has been used in chemical industries, pharmaceutical and food industries, environmental technologies and in petroleum-refineries.
- Key cost source: Procedure
- Electricity demand: A consumer of enormous amounts of energy in terms of cooling and heating.
- OPEX: Mostly associated to maintenance costs
- CAPEX: Proper sizing of the column diameter is also crucial for other economic considerations as the costs of fractionation equipment are markedly influenced by the column diameter.

The tray efficiency can be estimated more accurately considering the design of fractionation columns, normally made in two steps; a process design, followed by a mechanical design. The purpose of the process design is to calculate the number of required theoretical stages and stream flows including the reflux ratio, heat reflux and other heat duties. The purpose of the mechanical design, on the other hand, is to select the tower internals and calculate column diameter and height. For the efficient selection of tower internals and the accurate calculation of column height and diameter, many factors must be taken into account. Some of the factors involved in design calculations include feed load size and properties and the type of distillation column utilized. This phase of column design has a major impact on column costs, for the choice of internals influences all costs of the distillation system including the column, attendant structures, connecting piping and auxiliaries such as reboiler, condenser, feed heater, and control instruments. In industrial applications, diameters of fractionation columns vary greatly and may range from about 65 cm in smaller towers to about 6 m and more in larger columns, even up to 15 m in some applications.

4.2.3 Economic values

The analysis revealed that transport and management costs are negligible. Treatment costs must be considered but they are from far lower than the positive values created thanks to the internal reuse of the acid and solvent fractions. Other positive values are avoided costs for disposal and heat value. They are also much lower than the internal reuse. It is important to note that the initial synergy idea was to use the whole waste as a combustible, but discussions with stakeholders enabled to identify new source of economic revenues (acid and solvent fractions recovery), unlocking the synergy viability.

Economic benefits were calculated for this synergy based on the following assumptions:

- The incineration charges are 200 €/t.
- The price of liquid fuels has been based on the price of the diethyl ether (2636 €/t)
- The recovering rate is considered around 75% (between 50% and 98%).
- Price of the crude oil: 390,72 €/t.

Table 2 presents the socio-economic assessment of the synergy n°3.

Table 22: Synergy 3 (Source: Strane)

Synergy 3	
Waste stream price in Baseline scenario (€/Unit)	197
Waste stream volume (Unit/y)	2400
Substituted material equivalent price (€/Unit)	2636
Final volume recovered (Unit/y)	1026
Operational costs (€/y)	NA
VA	2 231 277 €
VAT	478 832 €
Labour Share (€/y)	1 026 388 €
Direct jobs (€)	23
Indirect jobs (min)	12
Indirect jobs (max)	70
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO_2-eq)	-4998581
Human health (DALY)	-2,2620575
Ecosystem quality (PDF.m2.y)	-334880
Use of resources (MJ)	-49503758
€ Climate change	399 887 €
€ DALY	167 392 €
€ Ecosystem quality	468 832 126 €

€ Use of resources	198 015 €
Sum of external economic impacts (€)	469 597 420 €
Carbon tax evolution (€/y)	-199 943 260 €
Waste tax	
Waste tax Baseline scenario (€/y)	294240
Waste tax Synergy (€/y)	125788
Waste tax balance (€/y)	-168452
Viability distance (100% of the resource price)	12427
Viability distance (10% of the good transported price)	1506
Waste treatment costs Baseline scenario (€/y)	480000
Waste treatment costs Synergy (€/y)	205200
Waste treatment costs balance (€/y)	-274800

The value added of the valorisation of the whole flow is around 2,2 M€/y, and the associated VAT is around 479 k€. The investment for the synergy implementation is not defined because it is related to the diameter column of the equipment and this service can be provided by utilities with existing installations.

The obtain a **deeper** socio-economic assessment of this synergies, all economic values below should have been considered:

- Heat value: new revenues generated by using a waste combustible (organic fraction), compared to traditional fossil fuel;
- Intrinsic value: avoided costs corresponding to the internal reuse of acid and solvent fractions;
- Disposal cost: avoided costs related to business as usual waste treatment and foregone revenues for the traditional waste treatment manager;
- Management cost: additional costs corresponding to the handling and blending of the organic fraction;
- Transport cost: additional cost to transport the resource to the third party in charge of the distillation and send the separated fraction;
- Treatment cost: additional cost related to the distillation service by the third party.

All these elements are detailed in Figure 19.

Figure 19: Economic value mapping

4.2.4 Environmental values

The LCA carried out by Quantis lead to identify environmental benefits through some indicators presented in Table 23.

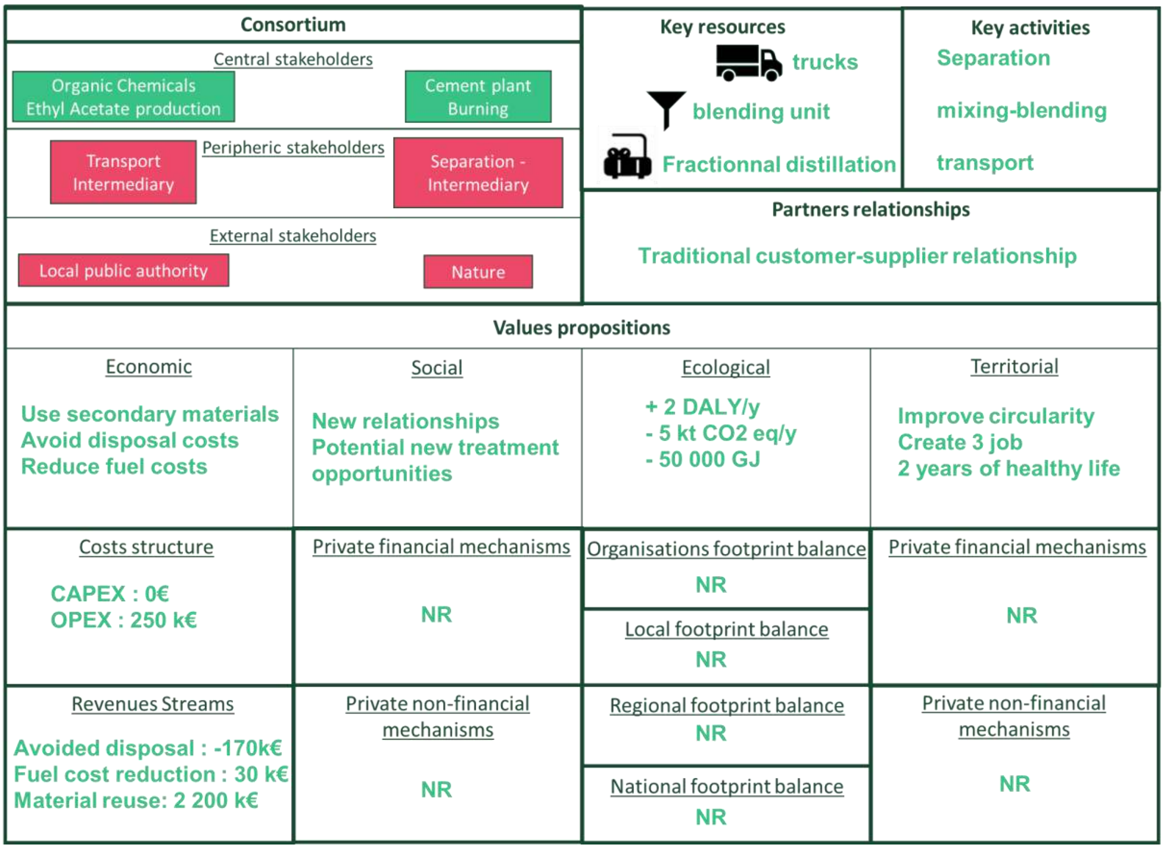
Table 23: Environmental assessment of the synergy 3 (Source: Quantis)

Synergy #	3
Baseline	Incinerated
Current practice?	YES
Annual Volume	2400 t/y
Receiving sector demand	UNKNOW
Can be modelled?	YES
Climate change [kg CO2-eq]	-4'998'582
Human health [DALY]	-2
Ecosystem quality [PDF.m2.y]	-334'880
Resources [MJ]	-49'503'758
Water withdrawal [m3]	-8'979

These indicators enable the Business Model filling in the next section.

4.3 IS Business Model definition

The following figure summarise all relevant information within the dedicated IS SBM canvas. It must be noted that no value transfer mechanisms from public or private entities is necessary for this synergy as the economic value was high enough to ensure the project uptake and launch.



*NR = Non relevant

Figure 20: PLF synergy sustainable business model

4.4 Business cases definition

Once the SBMC is define, it is necessary to provide relevant quantified and qualified data to convince the decision makers of each central or external stakeholder.

Based on these analyses, business cases dedicated to the 5 central and peripheral stakeholders can be built detailing properly:

- the synergy added value for each of them;
- their benefits and required expenses;
- the risks associated;
- their new responsibilities;
- the organisational changes.

Figure 21 details a business case for the 2 central stakeholders:

Organic Chemicals
Ethyl Acetate production

- 2,2 M€ of new benefits
- 250k€ of additionnal costs
- News partnerships
- Significant environmental footprint improvements (human health, global warming, biodiveristy)

Cement plant
Burning

- 30 k€ of benefit
- No inrastructur nor organisation modification
- No adiitional risks

Figure 21: Example of a business case for two stakeholders of the synergy n°3 (Source: Strane)

By analysing the business case, the project managers know:

- The emitting site benefits are about 2,2M€/year and an operational cost of 250k€ is expected. A new partnership is created with another company and could lead to significant environmental and human health benefits.
- The receiving site benefits are about 30k€ with minor efforts (it does not require new infrastructures nor organisational modification) and no risks are expected for this operation.

With this information, both central stakeholders can take the decision to implement or not the synergy and create a partnership on a quantified and qualified basis. Economic benefits as well as other possible non-monetary values and risks are listed. Based on this result, the decision makers are aware of all and can decide the work plan to activate to modify the current organisation and reach an efficient synergy implementation.

5. Conclusions

This guide provides a step-by-step approach to set up a full business case for an industrial synergy. It is intended towards practitioners and industrial representatives willing to set up a new industrial synergy from scratch.

It consolidates most inputs from the SCALER project, and from 2 other projects on industrial symbiosis (MAESTRI and EPOS), as well as field experience from the spinoff from SCALER called Seitiss.

A 10-module business model framework is proposed to structure the initial research for a synergy. It serves to prepare the business case of the synergy which aggregates all information from the comprehensive assessment of the synergy.

A step-by-step process has been provided for assessing a synergy in detail, defining the associated business model and setting-up as many Business Cases as necessary for all individual stakeholders:

- **Step 1, "Identification of opportunities",** consists in identifying opportunities on-site with the LESTS method (Legal, Economic, Spatial, Technical, Social) to generated opportunities ideas, the well-established SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) to screen the positive and negative aspects of each idea, the Value Mapping Tool to identify value surplus, absence, missed or destroyed, the Material Flow Cost Analysis to quantify costs deposits to optimise and finally some selection criteria to prioritise opportunities.
- **Step 2, "Synergy identification",** requires to identify potential partner sectors and spot relevant facilities nearby. This is a crucial and challenging step in the process of setting up synergies. A list of most applicable synergy identification software tools is provided based on a worldwide study (100+ tools). Examples of intermediaries who can support and facilitate the process are described. Finally, databases of synergies and knowledge repositories are listed to share information on existing synergies.
- **Step 3, "Synergy assessment process",** proposes a method to assess in detail the identified synergies. It lists information required: qualities of resources, constraints from potential partner, technical aspects related to possible treatments and logistics, the mapping of relevant facilities, the questions to raise with potential partners, the steps to test and confirm their willingness to use the resource, the procurement of logistics services. A simple decision tree synthesises the different steps. The quantification of every economically relevant value is provided, both for monetised aspects (value of heat, fuel and raw materials, taxes, waste management costs, logistic and labour costs) and non-monetised aspects (human health, ecosystem quality, resource productivity, climate change, social and territory values). This synergy assessment phase enable filling the SBMC and defining the most suitable Business Model and Business Cases for each individual stakeholder.

Business Model and Business Case examples were also provided to illustrate a concrete application of the methodology to the guide user.

This guide will hopefully support practitioners and industrial representatives in creating new, sustainable industrial synergies, and therefore create a positive impact on the European economy, environment and society.

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7. Annexes

7.1 Open bibliographic resources enabling synergies identification

Table 24: Open bibliographic resources enabling synergies identification (Source: MAESTRI [12])

Title	Link
Industrial symbiosis in the Taranto industrial district: current level, constraints and potential new synergies	http://www.sciencedirect.com/science/article/pii/S095965261600233X
Sustainability and industrial symbiosis - The evolution of a Finnish forest industry complex	http://www.sciencedirect.com/science/article/pii/S0921344910001369
A case study of industrial symbiosis development using a middle-out approach	http://www.sciencedirect.com/science/article/pii/S0959652610001071
"Uncovering" Industrial Symbiosis	http://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.1110/abstract
Industrial ecosystems as technological niches	http://www.sciencedirect.com/science/article/pii/S0959652608000814
Promoting industrial symbiosis: empirical observations of low-carbon innovations in the Humber region, UK	http://www.sciencedirect.com/science/article/pii/S0959652615007477
Experiences fromearly stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges	http://www.sciencedirect.com/science/article/pii/S0959652604000848
Industrial Symbiosis in the Australian Minerals Industry: The Cases of Kwinana and Gladstone	http://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.1161/abstract
Industrial symbiosis in Gladstone: a decade of progress and future development	http://www.sciencedirect.com/science/article/pii/S095965261300454X
Evolution of industrial symbiosis in an eco-industrial park in China	http://www.sciencedirect.com/science/article/pii/S0959652614011019
Strategies for sustainable development of industrial park in Ulsan, South Korea—From spontaneous evolution to systematic expansion of industrial symbiosis	http://www.sciencedirect.com/science/article/pii/S0301479707000175
Industrial Symbiosis in Puerto Rico: Environmentally Related Agglomeration Economies	http://s3.amazonaws.com/academia.edu.documents/3442003/Chertow_et_al_IS_and_agglomeration_economies.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1481741080&Signature=m%2Bz0BRsX8OSQYKN48JN2UCvVHUw%3D&response-content-disposition=inline%3B%20filename%3DIndustrial_Symbiosis_In_Puerto_Rico_Envi.pdf
Understanding the organisation of Industrial Ecosystems - A social network approach	http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2008.00002.x/abstract
Industrial Symbiosis in China. A Case Study of the Guitang Group	http://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.929/abstract
Industrial Symbiosis in Iskenderun Bay: A journey from Pilot Applications to a National Program in Turkey	http://uest.ntua.gr/conference2014/pdf/alkaya_et_al.pdf
Case study spremberg: RDF-fueled CHP plant for a paper mill	http://www.enea.it/it/pubblicazioni/pdf-volumi/ExperiencesofIndustrialSymbiosisinItaly_Proceedings.pdf
A case of industrial symbiosis: Nanning Sugar Co., Ltd. In China	http://www.sciencedirect.com/science/article/pii/S0921344907002224
Industrial symbiosis and waste recovery in an Indian industrial area	http://www.sciencedirect.com/science/article/pii/S0921344910001102
Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme	http://www.sciencedirect.com/science/article/pii/S0959652604002653
Industrial ecosystems as technological niches	http://www.sciencedirect.com/science/article/pii/S0959652608000814
Industrial Symbiosis in the Australian Minerals Industry: The Cases of Kwinana and Gladstone	http://onlinelibrary.wiley.com/doi/10.1162/jiec.2007.1161/abstract
PODEBA: an industrial symbiosis case	http://www.enea.it/it/pubblicazioni/pdf-volumi/ExperiencesofIndustrialSymbiosisinItaly_Proceedings.pdf
Case study 2: A sackful of dram fine firewood	http://www.orbuk.org.uk/article/the-national-industrial-symbiosis-programme-nisp
Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site	http://www.sciencedirect.com/science/article/pii/S095965261200234X
Experiences fromearly stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges	http://www.sciencedirect.com/science/article/pii/S0959652604000848
Experiences fromearly stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges	http://www.sciencedirect.com/science/article/pii/S0959652604000848
Industrial symbiosis: harnessing waste energy and materials from mutual benefit	http://www.sciencedirect.com/science/article/pii/S1755008415000204
Opportunities through Industrial Symbiosis: UK NISP and Global Experience	http://www.endustriyelsimbiyoz.org/wp-content/uploads/2013/02/industrial-symbiosis_uk-nisp-and-global-experience_31.01.2013.pdf

Industrial symbiosis: harnessing waste energy and materials from mutual benefit	http://www.sciencedirect.com/science/article/pii/S1755008415000204
Industrial Symbiosis - Improving productivity through efficient resource management - Guide for Businesses in Northern Ireland	https://secure.investni.com/static/library/invest-ni/documents/industrial-symbiosis-guide-for-businesses-in-northern-ireland.pdf
Industrial Symbiosis - Improving productivity through efficient resource management - Guide for Businesses in Northern Ireland	https://secure.investni.com/static/library/invest-ni/documents/industrial-symbiosis-guide-for-businesses-in-northern-ireland.pdf
Plastica Alfa	http://www.international-synergies.com/wp-content/uploads/2015/10/G7-International-Synergies_Birmingham_print.pdf
L'esperienza pilota di Simbiosi Industriale in Emilia Romagna: metodologia e risultati del Progetto "Green"	http://www.ucer.camcom.it/comunicazione/notizie/pdf-2014/All.2_Risultati_prog.GREEN.pdf
Quantifying the environmental performance of an industrial symbiosis network of biofuel producers	http://www.sciencedirect.com/science/article/pii/S0959652615004382
Norrkoping Industrial Symbiosis Network	http://www.industriellekologi.se/symbiosis/norrkoping.html
Case study 1: All puffed up with pastry power	http://www.orbuk.org.uk/article/the-national-industrial-symbiosis-programme-nisp
Industrial symbiosis of very large-scale photovoltaic manufacturing	http://www.sciencedirect.com/science/article/pii/S096014810700242X
Industrial symbiosis as a countermeasure for resource dependent city: a case study of Guyang, China	http://www.sciencedirect.com/science/article/pii/S0959652615004643
Towards preventative eco-industrial development: an industrial and urban symbiosis case in one typical industrial city in China	http://www.sciencedirect.com/science/article/pii/S0959652615005557
Promoting low-carbon city through industrial symbiosis: A case in China by applying HPIMO model	http://www.sciencedirect.com/science/article/pii/S0301421513005910
Uncovering opportunity of low-carbon city promotion with industrial system innovation: Case study on industrial symbiosis projects in China	http://www.sciencedirect.com/science/article/pii/S0301421513010410
Uncovering opportunity of low-carbon city promotion with industrial system innovation: Case study on industrial symbiosis projects in China	http://www.sciencedirect.com/science/article/pii/S0301421513010410
Boosting circular economy and closing the loop in agriculture: Case study of a small-scale pyrolysis-biochar based system integrated in an olive farm in symbiosis with an olive mill	http://www.sciencedirect.com/science/article/pii/S2211464514000888
Industrial Symbiosis in Puerto Rico: Environmentally Related Agglomeration Economies	http://s3.amazonaws.com/academia.edu.documents/3442003/Chertow_et_al_IS_and_agglomeration_economies.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1481741080&Signature=m%2Bz0BRsX8OSQYKN48JN2UCvVHUw%3D&response-content-disposition=inline%3B%20filename%3DIndustrial_Symbiosis_In_Puerto_Rico_Envi.pdf
Industrial ecosystems as technological niches	http://www.sciencedirect.com/science/article/pii/S0959652608000814
Opportunities through Industrial Symbiosis: UK NISP and Global Experience	http://www.endustriyelsimbiyoz.org/wp-content/uploads/2013/02/industrial-symbiosis_uk-nisp-and-global-experience_31.01.2013.pdf
Industrial Symbiosis - Improving productivity through efficient resource management - Guide for Businesses in Northern Ireland	https://secure.investni.com/static/library/invest-ni/documents/industrial-symbiosis-guide-for-businesses-in-northern-ireland.pdf
Industrial Symbiosis - Improving productivity through efficient resource management - Guide for Businesses in Northern Ireland	https://secure.investni.com/static/library/invest-ni/documents/industrial-symbiosis-guide-for-businesses-in-northern-ireland.pdf
Industrial Symbiosis: Literature and Taxonomy	http://www.annualreviews.org/doi/pdf/10.1146/annurev.energy.25.1.313
Industrial Symbiosis: Literature and Taxonomy	http://www.annualreviews.org/doi/pdf/10.1146/annurev.energy.25.1.313
Life cycle perspective in environmental strategy development on the industry cluster level: A case study of five chemical companies	http://www.sciencedirect.com/science/article/pii/S0959652614008385
Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors	http://www.sciencedirect.com/science/article/pii/S0959652613008093
Achieving carbon emission reduction through industrial & urban symbiosis: A case of Kawasaki	http://www.sciencedirect.com/science/article/pii/S0360544213009675
The potential of Industrial Ecology in agri-food clusters (AFCs): A case study based on valorisation of auxiliary materials	http://www.sciencedirect.com/science/article/pii/S092180091500018X
Quantitative assessment of industrial symbiosis for the promotion of circular economy: a case study of the printed circuit boards industry in China's Suzhou New District	http://www.sciencedirect.com/science/article/pii/S0959652614002625
From Refining Sugar to Growing Tomatoes: Industrial Ecology and Business Model Evolution	http://onlinelibrary.wiley.com/doi/10.1111/jiec.12171/epdf

7.2 Main source of values

Table 25: Main sources of value captures at the beginning of life (Source: [20])

Table 3
Main sources of value uncaptured at BOL.

BOL-VU	
Sources	Details
Design	• Redundant design • Insufficient design • Excess design • Low design efficiency • Repeated design • Design too early • Poor design quality • Poor system of rewards and penalties for designers • Lack of design theory • Lack of method for new designs • Lack of new design thinking (e.g. life cycle thinking, sustainability) • Poor communication between designers and manufacturers • Not use of service data to improve design
Production	• Over procurement or too early procurement • Poor production technology • The seven wastes from lean production • Pollution (e.g. noise) • Quality problems
Operations management	• Poor flexibility • Bad mechanism for assessing rewards and penalties • Bad project time management • Inefficient inter-department collaboration and resource sharing • Poor execution ability • Insufficient use of information management systems • Reluctance to adopt new management systems • Unable to adapt to new technology and products • Inefficient workflow
Customer needs	• Unknown potential customers • Potential customer needs • Future customer needs • Unclear customer needs • Overpromising to meet customer needs
Human resources	• Excess capacity of managers, designers, production workers • Lack of excellent human resources • Insufficient and inefficient use of labour
Contract	• Low-profit contracts • Unclear service contracts
R&D	• Lack of R&D in basic scientific research • Lack of R&D into products' products • Lack of IP protection
Finance	• High initial investment and low profits
Planning	• Unclear strategic plan
Knowledge & technology	• Lack of knowledge and technologies • Wasted knowledge, technology, experience and skills