FOSTERING INDUSTRIAL SYMBIOSIS FOR A SUSTAINABLE RESOURCE INTENSIVE INDUSTRY ACROSS THE EXTENDED CONSTRUCTION VALUE CHAIN

# Initial outline of FISSAC Industrial Symbiosis Model and Methodology

*March 2017 – Month/Year (M19)*

**D1.8: Initial outline of FISSAC Industrial Symbiosis Model and Methodology / Report**
WP 1, T 1.6

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## Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)



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# Abbreviations and acronyms

| | |
|---|---|
| IS | Industrial Symbiosis |
| KPIs | Key Performance Indicators |
| LCA | Life Cycle Analysis |
| LCC | Life Cycle Costing |
| SPIRE | Sustainable Process Industry through Resource and Energy Efficiency |
| SRM | Secondary Raw Material |
| MFA | Material Flow Analysis |
| EAF | Electric Furnace Slag |
| WPC | Wood Plastic Composite |
| C&DW | Construction & Demolition Waste |


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# 0. Description of Task

The aim of this task is to set up the baseline of **FISSAC Industrial Symbiosis Model**.

The FISSAC project involves stakeholders at all levels of the construction value chain to develop a methodology, and software platform to facilitate information exchange that can support Industrial Symbiosis networks and replicate pilot schemes at local and regional levels.

The model is based on the **three sustainability pillars:**

- environmental (with a lifecycle approach);
- economic;
- social (taking into consideration stakeholders engagement and impact on society).

The ambition of FISSAC model is its replication in other regions different from the ones of FISSAC project (Turkey, Sweden, Spain, Belgium, Italy, Hungary, UK, Germany, and Check Republic) and other value chain scenarios different from the construction one.

The new model covers:

1) Methodology: procedure to implement FISSAC model that are demonstrated in the construction value chain scenario;
2) Software Platform: to support the implementation of the methodology.

Expected outcomes from Industrial Symbiosis Model are following:

- Demonstration of the software platform;
- Replicability assessment of the model through living lab concept (as a user-centered, open-innovation ecosystem, often operating in a territorial context).

Baseline of **FISSAC Industrial Symbiosis Methodology**:

The new methodology will consist of the procedure to implement the IS model that will be applied in the construction value chain scenario. The final version of FISSAC Industrial Symbiosis Methodology will be defined in WP6 (Task 6.4. Definition of the final version of FISSAC Industrial Symbiosis Methodology).

Baseline of the **Integrated Industrial Symbiosis Management Software Platform:**

Data collected in the previous following tasks will serve as an input for the baseline of the software platform that will be developed in WP6:

- The review and analysis of existing software tools and platforms for IS that will be carried out in task 1.1. will serve as input for the definition of the requirements of the integrated software platform.
- The outputs of task 1.2 will be a set of reliable and harmonised data for the estimation of composition, patterns of supply and quantity of wastes generated over the years. These data will be processed and recorded in the FISSAC Software platform including statistical mean values and standard deviations.
- The industrial process parameters of the considered processes such as emissions to air, emissions to water, process waste water, process losses/waste, energy consumption/$CO_2$ emissions, etc will be collected from task 1.3.
- The qualitative & quantitative indicators from task 1.4 for quantifying the environmental, economic and social dimension of IS initiatives will be integrated as well.

**Relationship between Task 1.6 and the other FISSAC tasks**



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| T 1.6 - Paving the way to FISSAC Industrial Symbiosis Model: Methodology and Software Platform | | |
|---|---|---|
| **Outputs from finished and on-going tasks** | **Task Description** | **Inputs for on-going activities and planning tasks** |
| Task 1.1. Stakeholders network and analysis of IS model<br>Task 1.5. Social strategies and engagement | Stakeholder Networks<br><br>Lessons learnt and identification of best practices of IS | Task 7.1. Establishment of a Living Lab for replicating FISSAC model and development of transition process from linear to circular economy<br>Task 10.4 Social engagement and acceptance |
| Task 1.2. Analysis of industrial processes and their flow values | Establishment of tentative synergies among industrial processes to minimize, reduce and recycle waste as a whole | WP2. Closed Loop Recycling Processes to transform waste into Secondary Raw Materials |
| Task 1.3. Analysis and Evaluation of Best Available and emerging Techniques to estimulate cross sectoral Industrial Symbiosis | Identifcation of best techniques and solutions (processes, products and services) to define closed loop flows. | |
| Task 1.4. Identification and development of ecoinnovation, waste and IS indicators | Definition, adoption, adequation, development and quantification of ecoinnovation, waste and IS indicators | WP3. Product eco-design and certification |
| Task 2.4. Overcoming non-technological barriers | Identification and how to overcome technical and non technical barriers in the specific scenario. | Task 7.2 Analysis of the condition of the various represented industries to detect technological and non-technological drivers and barriers for the purpose of creating industrial symbiosis and circular economy |
| Task 2.5. Quality assurance for secondary raw materials and Standarization | Following standardisation needs facilitating market uptake | Task 3.4 Standardisation of productsTask 3.5 Environmental Technology Verification (ETV) |
| | Validation of the ecodesign of the products in pre-industrial processes and real environments with a life cycle approach | WP3. Product eco-design and certification |
| | Demonstration at pre-industrial scale and at real scale | WP4. Pre-industrial scale Demonstration of the recycling Processes and Eco-innovative products<br>WP5. Industrial Production & Real Scale Demonstration |
| | Evaluation of the replication in other regions. | WP7<br>Task 7.3. Evaluation of the replicability of the model<br>WP9. Dissemination |


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| T 1.6 - Paving the way to FISSAC Industrial Symbiosis Model: Methodology and Software Platform | | |
|---|---|---|
| **Outputs from finished and on-going tasks** | **Task Description** | **Inputs for on-going activities and planning tasks** |
| Task 8.1 IPR Management and Task 8.2 Exploitation | Evaluation of the Exploitation potential | WP8<br>Task 8.3 New business models for industrial symbiosis towards a circular economy<br>Task 8.4. Business Plan outline |
| Task 6.1 Analysis and design of FISSAC Software Platform | Baseline for FISSAC Industrial Symbiosis Model | WP6<br>Task 6.2. Development of an integrated FISSAC IS monitoring tool<br>Task 6.3. Monitoring and evaluation of results with the platform<br>Task 6.4. Definition of the finalversion of FISSAC Industrial Symbiosis Methodology<br>Task 6.5 Definition and validation of FISSAC model |
| | Definition of new Bussines models for the IS model, products and services developed and business plans. | WP9 |


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# 1. Summary

## 1.1 Circular economy and Industrial Symbiosis

The linear 'take, make, dispose' economic model relies on large quantities of cheap, easily accessible materials and energy and is reaching its physical limits.

The circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions.

A favourable alignment of factors makes the transition possible. Resource-related challenges to businesses and economies are mounting. An unprecedented favourable alignment of technological and social factors enables the transition to the circular economy[i].

Industrial symbiosis, understood as strategy to achieve a circular economy transition, is the use by one company or sector of by-products, including energy, water, logistics and materials, from another. The precondition for an industrial symbiosis complex is cooperation among the companies, and these companies form a network as a result of that cooperation (Chertow, 2000; Harper and Graedel, 2004; Chertow and Lombardi, 2005).

Industrial Symbiosis can be achieved from three main perspectives: characterization of the conditions under which industrial symbiosis complexes form, the exchange relationships that sustain their development, and the benefits that accrue to industries that participate in them[ii].

## 1.2 FISSAC Model

Under the topic WASTE-1-2014 - Moving towards a circular economy through industrial symbiosis, the FISSAC project aims to accelerate the transition to a circular economy.

The overall objective of FISSAC Project is to develop and demonstrate a new paradigm built on an innovative industrial symbiosis model towards a zero waste approach in the resource intensive industries of the construction value chain, tackling harmonized technological and non-technological requirements, leading to material closed-loop processes and moving to a circular economy.


*Figure 1 FISSAC Industrial Symbiosis Framework*



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The FISSAC Methodology and the Software Platform tool aims to implement the innovative industrial symbiosis model in a feasible scenario of industrial symbiosis synergies between industries (steel, aluminium, natural stone, chemical and demolition and construction sectors) and stakeholders in the extended construction value chain.

It guides how to overcome technical barriers (transformations and adaptations of industrial and recycling processes) and non-technical barriers (social and cultural, legislative/regulatory, economic, organizational) as well as standardisation concerns to implement and replicate industrial symbiosis in a local/regional dimension.

The innovative model is based on the three sustainability pillars:

- Environmental
- Economic (with a life cycle approach)
- Social (taking into consideration stakeholders engagement and impact on society).

The ambition of the model aims to be replicated in other regions and other value chains symbiosis scenarios.

FISSAC Project demonstrates the applicability of the new industrial symbiosis model as well as the effectiveness of the innovative processes, services and products at different levels, such as:

A. **Manufacturing processes**, with the following targets:
   - Demonstration of closed loop recycling processes to transform waste into valuable acceptable secondary raw materials.
   - Demonstration of the manufacturing processes of the novel products at industrial scale.

B. **Product validation**, with the following targets:
   - Demonstration of the eco-design of eco-innovative construction products (new Eco-Cement and Green Concrete, innovative ceramic tiles and Rubber Wood Plastic Composites) in pre-industrial processes under a life cycle approach.
   - Demonstration at real scale in different case studies of the application and technical performance of eco-innovative construction products.

C. **FISSAC model**, with the following targets:
   - Demonstration of the software platform.
   - Replicability assessment of the model through living lab concept (as a user-centered, open-innovation ecosystem, often operating in a territorial context).



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# 2. Baseline of FISSAC Industrial Symbiosis Model

## 2.1 FISSAC IS methodology targets

The FISSAC methodology has been developed after the analyses of existing Industrial Symbiosis cases (Task 1.1) from Europe / International.

The Construction & Real State sector has been identified as one of the sectors with the highest potential for circular economy[i].

Using closed-loop circular design principles is one of the approaches that could, and should, shape the sector's future[iii], and the sector is considered not only as construction companies but also design companies, suppliers of technology and building materials or equipment, and others along the value chain.

A cross-industry collaboration along the value chain is needed not just between peer companies but also between companies of different types along the value chain. The current tendency is to push risk down the value chain instead of pulling innovations out of it.

The aim of this report is to set up the baseline of FISSAC methodology. The new methodology consist of the procedure to implement the Industrial Symbiosis model that are be applied in the construction value chain scenario:

The final compilation of the work from all partners was done by ACCIONA to create the Baseline for the Model: Methodology and Software Platform with technical and non-technical specifications. The previous deliverables are the starting point for Initial Outline of FISSAC Model.

The Industrial Symbiosis model is being demonstrated in the construction value chain scenario, using industrial waste or by-product from different industries (steel, aluminium, natural stone and chemical) as Secondary Raw Materials for construction applications establishing cross sectoral industrial synergies. Therefore, closing the loop of the construction value chain through circular economy approach. Previous experiences and best practices on the reuse and recycling of the C&DW stream have been analysed and data will be integrated in the FISSAC Software Platform.

FISSAC model results are being demonstrated and validated at three different levels:

- Processes, products and services
    - Manufacturing processes at semi-industrial scale in Spain, UK and Turkey
    - Product validation carries out in Case studies in Spain, UK and Turkey considering different construction applications and climate conditions.
- FISSAC Model Demonstration and Replicability
    - The whole FISSAC model is being demonstrated and validated in Spain, UK and Turkey, and will be replicated in all partners' countries through living lab concept (as a user-centered, open-innovation ecosystem, often operating in a territorial context).
- Stakeholders networks, Social engagement

## 2.2 Proposed Flow Chart

The most important needs and concepts for the industrial symbiosis development are discussed in the following chapters of this document, following the chart that appears on Figure 3. Figure 3 depicts a basic flows chart of the steps sequence and relationships that show how FISSAC model could be deployed and helps to the replicability of FISSAC scenario in other values chains. The optimal scenario contains processes, secondary raw material, stakeholders and information that can be considered for the replication of FISSAC model.



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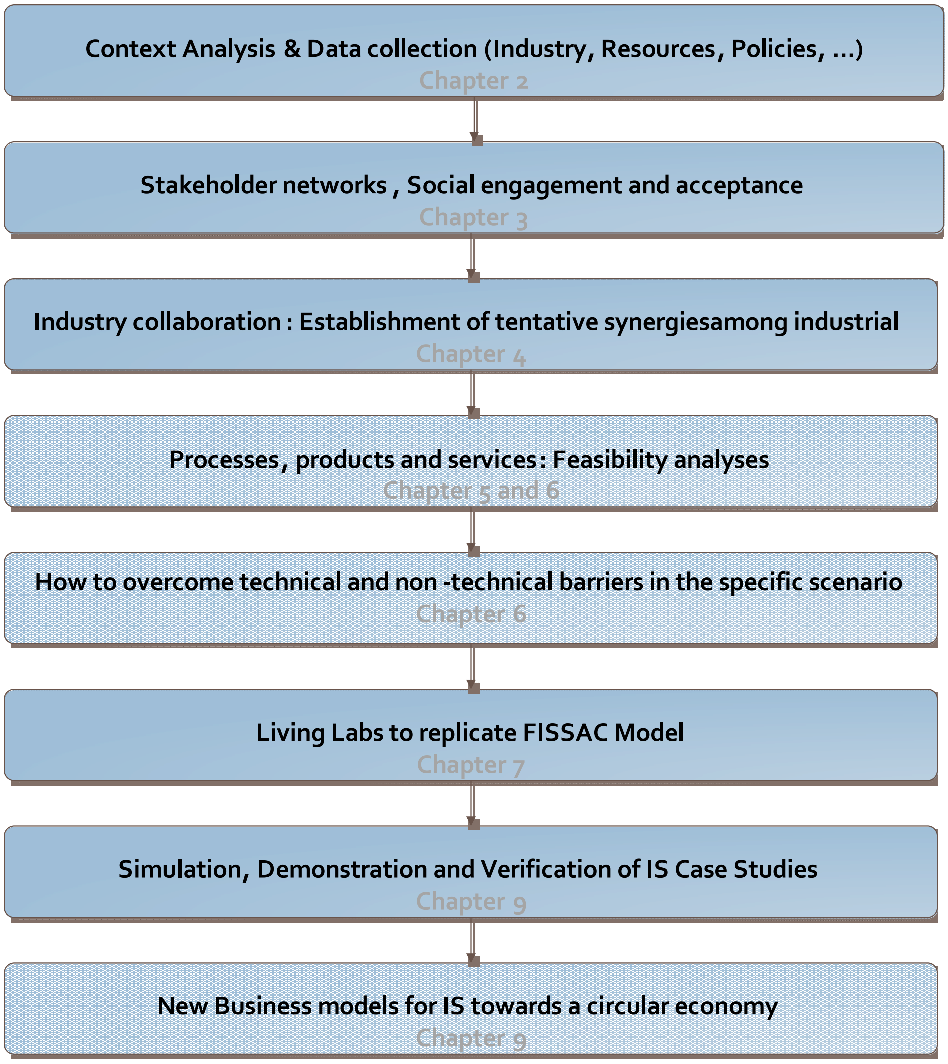


*Figure 2 . Flow Chart for FISSAC Model*

This flow chart introduces the research methodology used for the baseline of FISSAC model and how it aims to guide the context analysis, data collection, IS collaboration and replication. Firstly, a network of stakeholders has to be established and further developed, focused on sharing best practices and other Industrial Symbiosis experiences, key process aspect hampering current IS through the assessment of processes and the flow values of the considered industrial sectors, Best Available and emerging Techniques of the considered industrial sectors to estimulate cross sectoral Industrial Symbiosis; as well as connecting the generation of secondary raw materials, demand of primary raw materials and alternative supply in an efficient way.

The work performed in the previous tasks of WP1 (1.1 to 1.5) have been integrated into the definition of the Baseline for model and methodology. The initial outline of FISSAC IS model and methodology provides guidance on the conception of the model for the Industrial Symbiosis replication.

The proposed steps and the remaining phases of the FISSAC model development will be will be performed at Task 6.4: Definition of the final version of FISSAC Industrial Symbiosis Methodology and Task 6.5: Definition and validation of FISSAC model.


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The methodology is organized into 8 phases for its design, feasibility study, definition, implementation and demonstration. The subsequent seven sections of the report describe the achieved objectives from previous tasks and covers in details each step defined for this methodology, which consist of:

- Chapter 3: FISSAC Context analysis & Data collection
- Chapter 4: Stakeholders network and analysis of IS models
- Chapter 5: Establishment of tentative synergies among industrial processes to minimize, reduce and recycle waste as a whole.
- Chapter 6: Key Performance Indicators for ecoinnovation, waste and IS.
- Chapter 7: Recycling Processes and Product Eco-design (WP2 and WP3)
- Chapter 8: Baseline of FISSAC Industrial Symbiosis Software Platform (WP6)



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# 3. FISSAC Context analysis

This context analysis describes the FISSAC Scenario where the applicability of the new industrial symbiosis model as well as the effectiveness of the innovative processes, services and products are demonstrated.

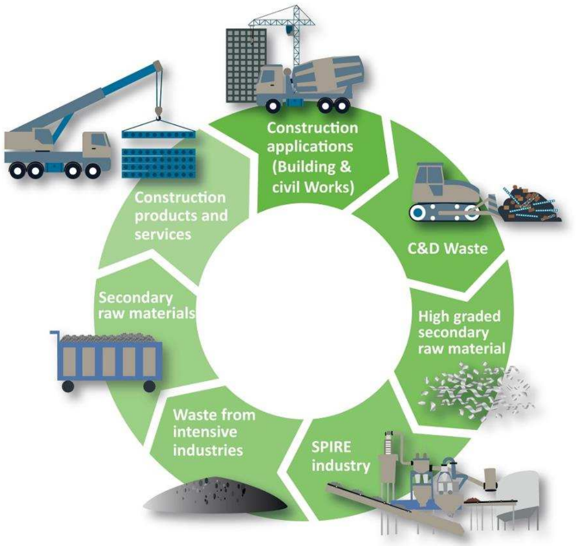


Figure 3 Circular economy approach across the extended construction value chain

The FISSAC scenario is based on the construction value chain. The construction sector is the largest consumer of raw materials in the EU; construction and demolition activities also account for about 33% of waste generated annually[iv]. Clearly, there is an environmental incentive to revamp the resource-intensive and wasteful construction sector: reducing resource use and re-using waste more effectively would significantly reduce the total material requirement of European societies. Therefore, the construction sector is central to any attempt to use resources more efficiently[v]. Waste or by-products from many industries are incorporated into materials used in the construction industry. The efforts will be focused to understand the nature of interim resource sharing (existing spontaneous symbiosis or exchanges) for the development of planned IS[vi].

The ambition is to develop a new scenario improving the efficiency, competitiveness and sustainability of the extended construction value chain using industrial waste or by-product from different industries (steel, aluminium, ceramic, natural stone and chemical) as Secondary Raw Materials for construction applications establishing cross sectoral industrial synergies. The project works on the development of new constructive applications favouring the use of Secondary Raw Materials which are not already used as raw materials for high grade uses. The framework of the FISSAC methodology includes system boundaries, incorporated indicators, rating and evaluation schemes, weighting factors, software platform and replication model.

## 3.1 Industrial sectors

The starting point for the definition FISSAC system boundaries is based on primarily on the Industrial sectors that are involved in the Project. Seven (of the eight) **SPIRE industrial sectors** are represented in the project**.** SPIRE (Sustainable Process Industry through Resource and Energy Efficiency) is the European Association, which is committed to manage and implement the SPIRE Public-Private Partnership. It represents innovative process industries, 20% of the total European manufacturing sector in employment and turnover, and more than 130 industrial and research process stakeholders from over a dozen countries spread throughout Europe. SPIRE brings together cement, ceramics, chemicals, engineering, minerals and ores, non-ferrous metals, steel and water sectors, several being world-leading sectors operating from Europe. The mission of A.SPIRE is to ensure the development of enabling technologies and best practices along all the stages of large scale existing value chain productions that will contribute to a resource efficient process industry.


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FISSAC Consortium is composed by 26 partners from 9 countries: 8 Member States, and Turkey. The consortium as a whole covers all the necessary roles for such an Innovation project (close to market project) with a participation of industrial partners of 61,5% which half of them are SMEs. Is a complementary combination between RTD organizations and companies in the proposed technologies, intensive industries (such as cement, non-ferrous, ferrous, glass, chemical), general contractors and engineering in the construction field, technology manufacturers and providers, industrial symbiosis and circular economy and social experts, policy makers, standardization body, providers and costumers of Industrial Symbiosis model. FISSAC Consortium is composed by the following organizations and expertise[vii].:

- Non for profit Research Organizations deal with recycling processes and validation of eco-innovative product manufacturing:
- ICV, as a research centre devoted to the Re-formulation of ceramic tiles composition and determination of measurable reduction of raw materials consumption by introducing waste in the ceramic tiles composition formula.
- CBI is the major Swedish research centre in cement and concrete with research experience on sustainable cement and concrete materials design and production improving environmental impact.
- FAB, as a Foundation on construction research will boost contribution of research to the management of waste and industrial symbiosis approach to the construction value chain.
- SP is a leading research institute working with innovations and industrial implementation of technological research thus playing an important role in boosting the competitiveness of industry and its development towards sustainability, with particular expertise on Life Cycle Analysis (LCA) and Life-cycle Costing (LCC) methods, Technological Innovation System analysis (TIS) and Transition Management (TM) possessed LLs and social issues.
- TECNALIA, as a Construction and Environmental Research Organization provides its knowledge and experience concerning environmental issues related to: development and testing of building materials manufactured with recycled waste materials (C&DW, waste wood, waste composites,…) and industrial by products.

Profit Research Organization CSM; deal with environmental issues of the steel industry and waste.
Intensive industries in the sectors concerned:

- Large: FERALPI (steel), KERABEN (ceramic), TCMB, AKG Gazbeton (cement, concrete), BEFESA (aluminium); HIFAB (IS services).
- SME: ECODEK (rubber wood plastic composites); GTS (glass, BGM).

General contractors and engineering in the construction field: ACCIONA; DAPP;

SMEs in different sustainable business fields:

- SMEs providing Industrial Symbiosis services & tools such as , SYMBIOSIS, EKODENGE, GEONARDO;
- An SME expert on eco-design: Ingenieurbüro Trinius;
- An SME expert on exploitation and business models: FENIX.

International Association of regional and local authorities for Recycling and sustainable Resource management: ACR+, that will disseminate and promote smart resource consumption and sustainable management of waste.

A public authority: OVAM, as a Flemish public authority which support its regional waste management policy and also, being members of ACR+ Association.
The Spanish Association for Standardisation and Certification (UNE) which is the national representative and member of the European (CEN/CENELEC), International (ISO/IEC) and Panamerican (COPOLCO) Standards Organizations, and member of the European Telecommunications Standards Institute (ETSI).


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## 3.2 Secondary raw materials

The second step is an initial assessment of resources (Secondary Raw Materials) within the framework of the European Industrial sector. The received results underlined the high potential of Secondary Raw Materials for Construction Sector Industrial Symbiosis Opportunities.

FISSAC project is focused on **9 Secondary Raw Materials:**

- Ladle furnance slag
- EAF slag
- Aluminium waste slag
- Glass Waste,
- Ceramic waste
- Marble Slurry
- Tyre rubber, Plastic waste and Wood waste.

The following table describes the different types of applications. It is divided in three construction sub-sector: cement based products: eco-cement and green concrete; Ceramic sector and WPC materials production. The SRMs column show the proposed waste exchanges and Applications column shows the opportunities for supply considered.

| CONSTRUCTION SUB-SECTOR | APPLICATIONS | SRMS INVOLVED |
|---|---|---|
| ECO CEMENT | Clinker Raw Meal | Ladle furnace slag (LF slag)<br>Aluminium waste slag<br>Glass Waste<br>Ceramic waste |
| | Mineral Additive | Ceramic waste from industry and CD&W<br>Glass waste |
| GREEN CONCRETE | Aggregates | EAF slag<br>Glass waste |
| | Mineral additions / admixtures | Ceramic waste from industry and CD&W<br>Glass waste |
| CERAMIC PRODUCTS | Source of aluminium | Aluminium waste slag |
| | Alternative source of calcium carbonate | Marble slurry |
| WPC PRODUCTION | Substitution of main components | Tyre rubber<br>Plastic waste<br>Wood waste |



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# 4. Stakeholders network and analysis of IS models

## 4.1 Stakeholder network and social engagement

This chapter describes the main achieved objectives of Task 1.1. The report ***Deliverable D1.1***[viii] establishes a network of stakeholders that may be interested in FISSAC model to foster future replicability in other countries and regions. This report summarizes the first exercise of identification and mapping of relevant stakeholders across the construction value chain. The stakeholders' network continues will be updated with new recommended contacts throughout the project lifetime.

The stakeholder analysis identifies early enough those stakeholders that would provide a holistic overview of all technical and non-technical aspects pertaining to Industrial Symbiosis and circular economy.

The following table shows the methodology for Stakeholders network that have been followed in the project:

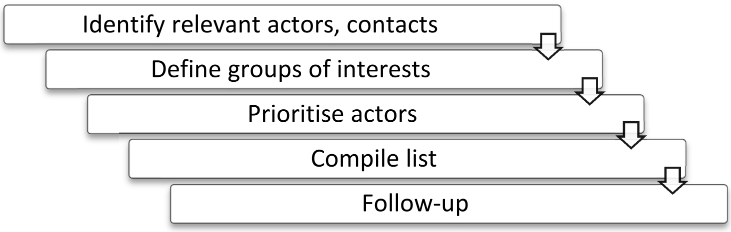
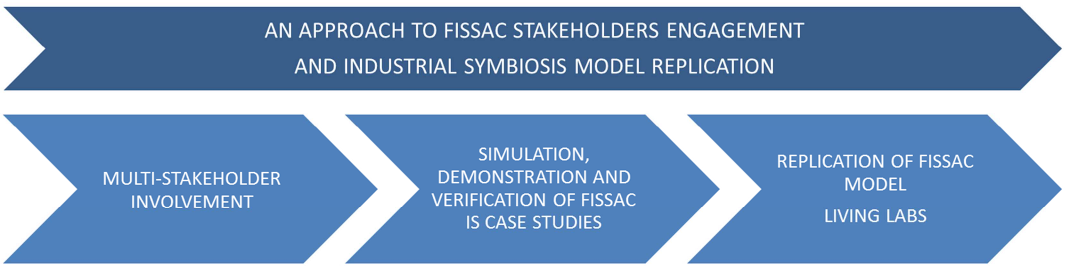



*Table 1 Stakeholders network strategies*

The idea is to foster the future replicability in other countries and regions allowed by the engagement with interested stakeholders on a regular basis, gaining insight from experts' views, assisting with communication and dissemination activities, ensuring an optimal outreach of project deliverables and maximising the impact of project deliverables




The analysis show the main achievements of the activity, a data base of one thousand and five hundred direct contacts[2] and more than nine hundred actors identified helping to stakeholders network development. Our strategy is that each partner takes charge of continuous update of stakeholder database under the management of ACR+ and ACCIONA.

[2] the wide majority comes from public authorities (41%), which can explained thanks to the contribution from ACR+ network of members. The second biggest target group is Research and Innovation groups (18%), followed by industry-materials producers and managers (10%), consultancies (8%), industry federations (8%), civil society organisations (6%) and industry- construction (3%).



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***Deliverable D1.4** identifies 3 target groups as shown in the Figure 4. This Figure shows the Stakeholders network: results and next steps. The framework of the on-going tasks and the next steps that aims to involve identified target groups for the successful replication of model in construction scenario through Living Labs planned in the project.*

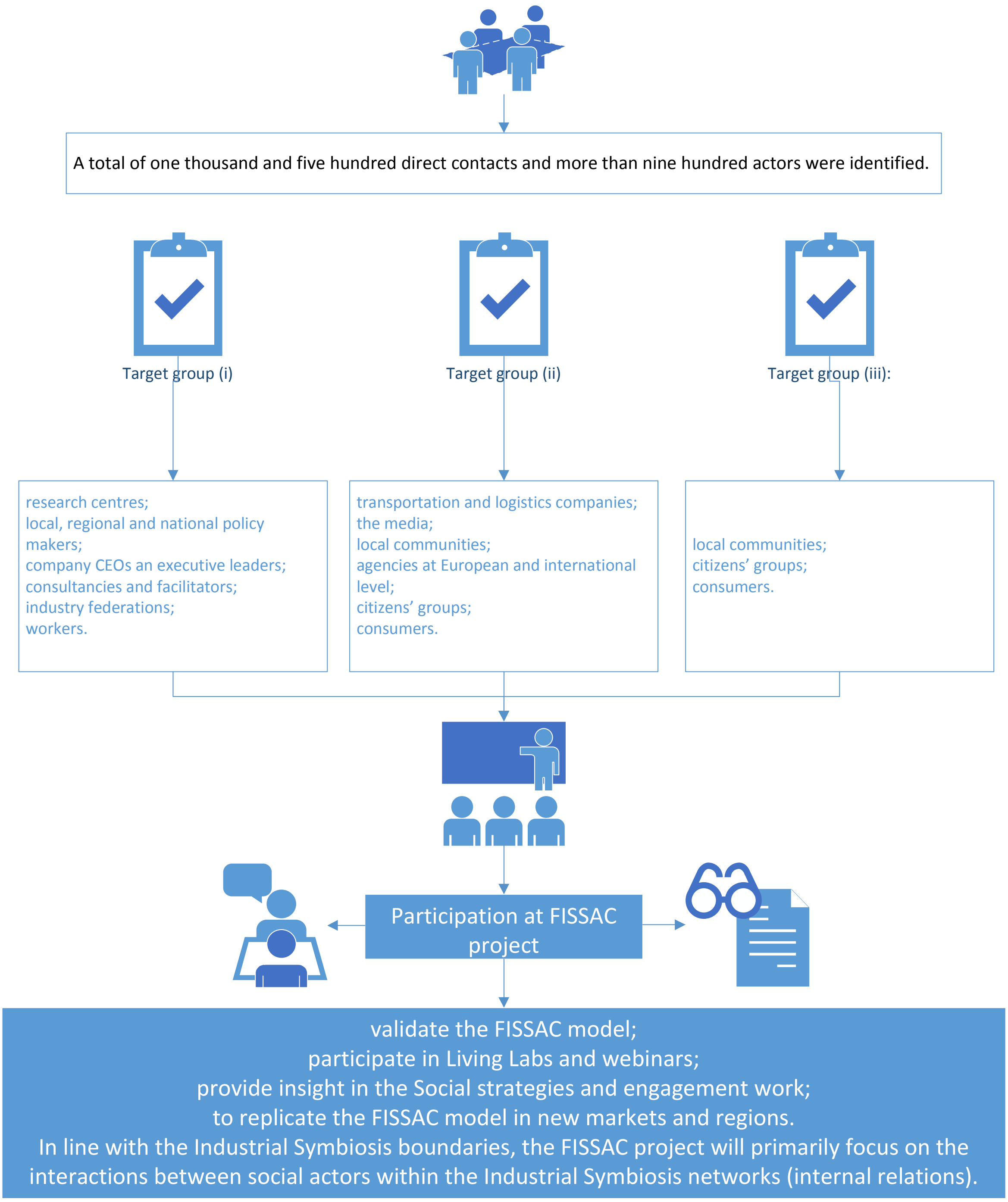


*Figure 4 Stakeholders network: results and next steps*



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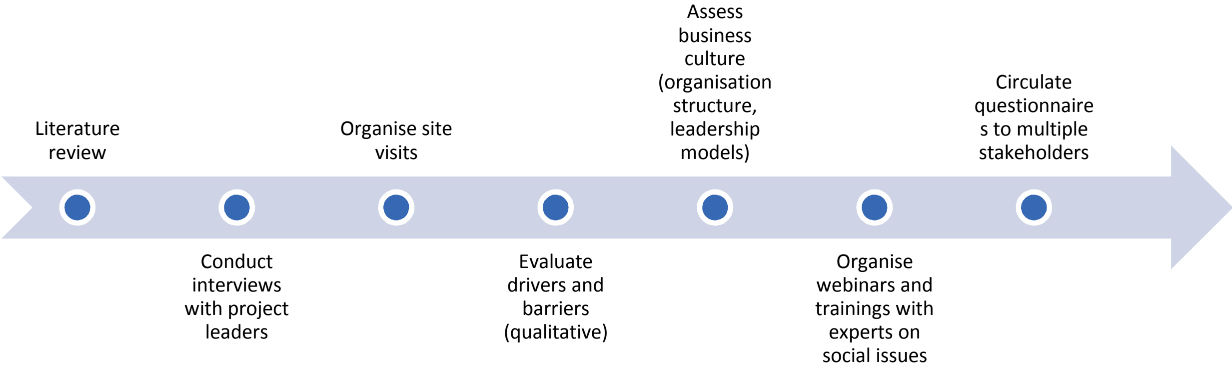
In addition, the project defines strategies for social engagement and acceptance. It is tackling in the project considering inputs from Advisory Board on Social issues´ members. The report
***Deliverable D1.4***[ix] introduces also the social aspects pertaining to the development of Industrial Symbiosis projects and highlights their importance for achieving successful results. Throughout the project duration, target groups as beneficiaries and influencers of the FISSAC model will be updated in the short- and long-term. This is an activity in continuous modification based on the Task 1.1, Task 1.5 and Task 10.4.

Following the mapping of social actors, it is considered for the development of social innovations as necessary to open the process to a wider range of stakeholders.




Beyond the technical feasibility of the IS exchanges, social elements also play a crucial role in the development of IS network. It is why,
The report ***Deliverable D1.7***[x] (strategies for social engagement and acceptance), describes the stakeholder engagement strategy, which establishes the objectives of stakeholder engagement and indicates how the involvement of stakeholders will be achieved at each stage of the project.

Concretely, a Five-step approach is used to establish the objectives of stakeholder engagement and indicates how the involvement of stakeholders will be achieved at each stage of the project. In this deliverable,

- A vision for the social engagement and acceptance has been developed
- Map stakeholders focused on main target groups for social engagement
- Identification of social aspect in project task and identification of FISSAC partners that will implement the social engagement and acceptance
- Next actions that will be implemented thanks to the support of the Social Advisory board
- Selection of indicators to monitor and to evaluate the social aspect.

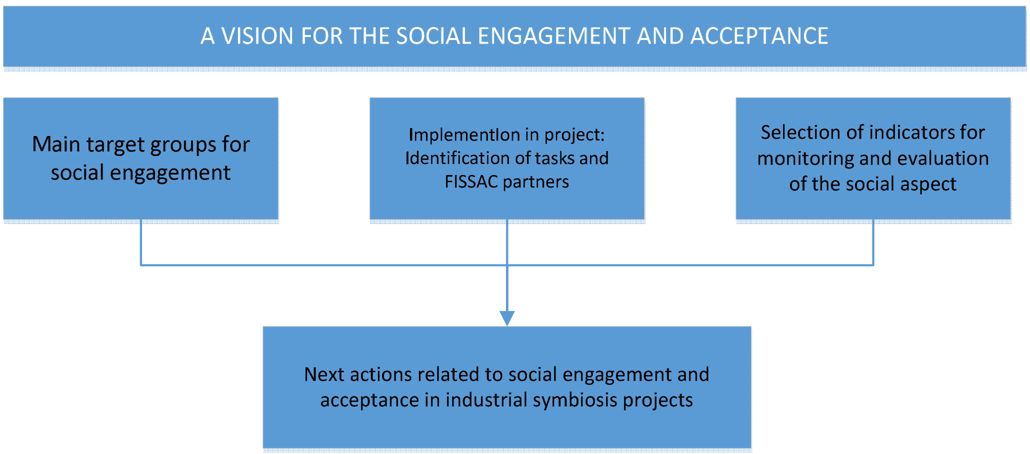



*Figure 5 Strategies for social engagement and acceptance*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The aim is to highlight the importance of non-technical and social aspects of IS as a key for achieving successful Industrial Symbiosis projects and to identify the main elements related to social engagement and acceptance in industrial symbiosis projects.

## 4.2 Review and analysis of existing IS models

An analysis of current models of industrial symbiosis was created in ***Deliverable D1.2***[xi], which identifies information, analyse them and gradually define the requirements of the new model to facilitate information exchange that can support ongoing and future industrial symbiosis networks.

The analysis shows a review of the state of the art of 60 ongoing industrial symbiosis projects and government initiatives in Europe and abroad, as well as the regulatory framework on waste management including technical specifications on the use of recycled materials as raw material for construction applications. Technical and non-technical barriers, risks and uncertainties which might hinder these developments but also drivers of new industrial symbiosis projects have been identified and analysed.

The role of different stakeholders in setting up industrial symbiosis networks, particularly in public private partnerships, and the long-term vision for scaling up is discussed in the end of the analysis. A public authority may take the lead in the majority of the aforementioned projects. A municipality takes quite often a coordinating function: it is important in the start-up phase to have a municipality with a strong commitment to sustainable development.

In addition to this, it summarises previous experiences and best practices on the reuse and recycling of C&DW stream in order to be integrated in the FISSAC software platform. FISSAC project representatives are closely collaborating with other EU-funded research projects since the project kick off and thanks to active networking, they have identified areas of future project collaboration.

FISSAC project partners compiled over sixty cases as mentioned before from across Europe and the world as part of Task 1.1 ‘From current models of Industrial Symbiosis to a new model’[vi]. Based on the information collected, four types of projects have been identified :

- Symbiosis based on heat and power;
- Industrial Symbiosis;
- Symbiosis based on (de)construction materials;
- Regulations, plans and R&D programmes.

Following the analysis of the collected cases about the opportunities and benefits created by IS projects, some conclusions can withdrawed:

- Promoting culture of cooperation, building transparency and open communication and trust is critical for synergistic projects. On the other hand, having companies engaged in Industrial Symbiosis projects is a way of starting building trust.
- Non-secretive leadership style and management profile of high-level executives in a company has proven to be inspirational for employees. In some cases, a passionate and committed CEO has initiated and driven such projects by solving a number of problems.
- The team can be motivated from the transformation of business, new source of inspiration.
- Having different firms collaborating at the very first stages of the project (idea, partnership, concept) is important.
- Investing in Industrial Symbiosis can often be associated with the ‘green’ and sustainable profile that a company wants to promote.
- Stability and long-term vision provided by local and regional policy makers will provide a favourable environment for investing in Industrial Symbiosis.



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- Developing a sense of community between the companies within a network will make them realise a multitude of resources to be shared (e.g. waste streams, water, energy, by-products, ideas, people) and gradually develop their willingness to collaborate.

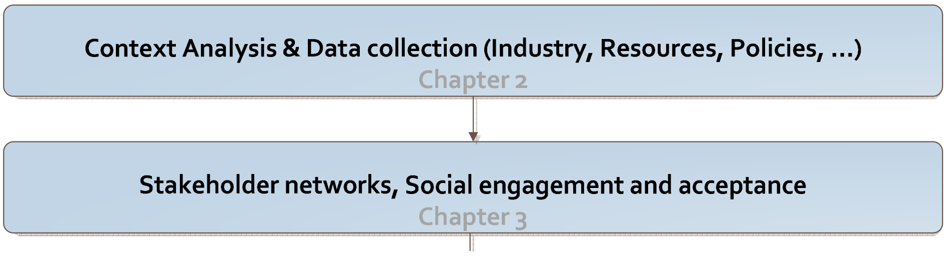
Finally, a review and analysis of various existing ICT tools and methodologies for industrial symbiosis has been undertaken as part of this activitiy. The data collected will serve as input for the definition of requirements of the FISSAC software platform.

### 4.3 Stakeholders network and analysis of IS model: Conclusions

This chapter describes the FISSAC scenarios that have been identified, the first steps regarding Stakeholder networks, Social engagement and the conclusions from the analysis of the collected cases .

Therefore, based on the previously presented conclusions and existing methodologies[xii] the Preparation phase for the methodology is divided on two main steps, which facilitators can work off in a structured work process. The  current phase are defined as followed:

- Context Analysis and Data Collection
- Stakeholder networks, Social engagement and acceptance




In the next chapter, the objective is to define the establishment of tentative synergies between partners, and the basis for the replicability of new IS Case Studies across other industrial scenarios.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# 5. Establishment of tentative synergies among industrial processes to minimize, reduce and recycle waste as a whole.

## 5.1 Material Flow Analysis (MFA)

This chapter describes the main achieved objectives of Task 1.2. and Task 1.3.
The Report, ***Deliverable D1.3***[xiii], delivers a preliminary study in order to identify the material and energy inputs and outputs of the processes. These processes have been studied and detailed material/energy flow analysed. Results of this detailed input-output study has been utilized for Life Cycle Analysis - LCA inventory and for Life Cycle Costing - LCC inventory, and will be utilized for the final version of FISSAC Model. The waste generation factors used for estimating the quantity of wastes in this study can be used as key performance indicators (KPIs) and benchmark values. This potential has been explored in the identification of Indicators. The waste quantities and their geographic distribution are valuable inputs to identify barriers for industrial symbiosis (IS) networks, replicability of IS scheme of FISSAC Project and the last but not the least the georeferencing tool under FISSAC IS Monitoring Platform. Waste quantities can also be utilized while shaping the new business models and the exploitation strategies.

FISSAC project works to valorise a number of waste streams originating from steel, secondary aluminium, ceramic, natural stone, and construction demolition sectors in a symbiotic network for production of eco-cement, green concrete, innovative ceramic tiles, and rubber-wood plastic composites. The establishment of such a network contributes to circular economy and supports End-of-Waste approach. The analysis addresses a number of topics on waste streams studied under FISSAC project and the industrial sectors generating them. These topics include:

- Study of the **industrial sectors** in terms of a sectorial overview, distribution of production capacities in EU-28, and future trends based on historical production data,
- **Manufacturing processes**, which lead to generation of target waste streams, with their brief description, unit processes within the manufacturing line, and material/energy input and outputs,
- Evaluation of **waste streams** covering the definition of waste stream, Waste Generation Factors (WGFs) used for estimation of waste amounts, quantities generated along with their spatial distribution over the FISSAC countries and rest of the EU, future waste generation trends based on sectorial forecasts.

The identification of these topic consisted of the Collecting and documenting through an extensive literature review to obtain data on target waste streams from literature and from FISSAC partners and stakeholders input all real or perceived examples of existing barriers, without evaluation.

This approach involves use of WGFs and capacity information and its distribution across Europe rather than utilizing direct waste generation data from industry. Future trends in waste generation are also provided based on simple sectorial capacity projections considering historical production volumes.

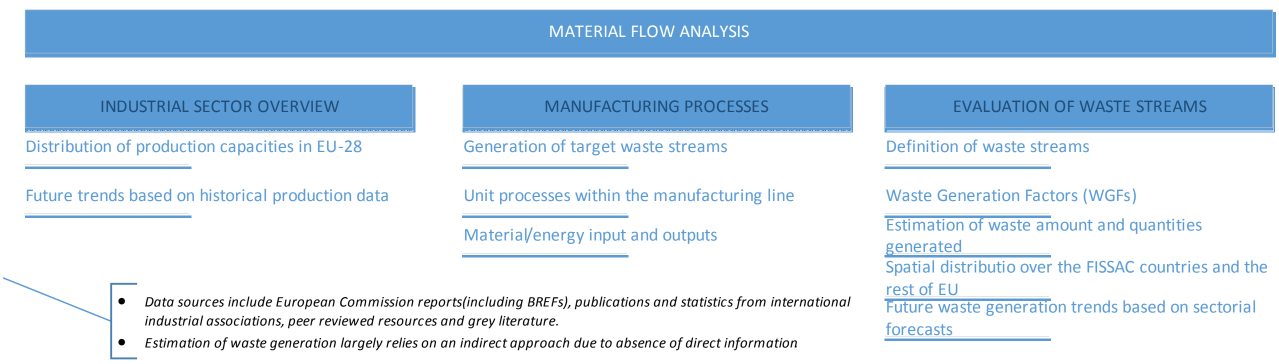


*Figure 6 Material Flow Analysis, Methodology overview*


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The following tables summarized of generation of selected waste streams.

*Table 2 Summary table for waste generation from manufacturing processes (average values between maximum and minimum waste generation is presented for slags and aluminium based materials)*

| | | EAF Slag | LF Slag | $Al_2O_3$ Based Materials | Calcined Clay | Natural Stone Slurries | Tyre Rubber |
|---|---|---|---|---|---|---|---|
| | | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) |
| FISSAC COUNTRIES | Belgium | 295.65 | 70.96 | | 4.00 | 28.00 | 69.00 |
| | Czech Republic | 44.55 | 10.69 | 0.75 | 30.00 | 27.40 | 55.00 |
| | Germany | 1,630.20 | 391.25 | 39.59 | 57.00 | 819.80 | 475.00 |
| | Hungary | 23.25 | 5.58 | 2.49 | 15.00 | 60.20 | 29.00 |
| | Italy | 2,147.81 | 515.48 | 33.12 | 368.00 | 2,439.40 | 571.00 |
| | Spain | 1,251.38 | 300.33 | 12.09 | 324.40 | 916.60 | 22.00 |
| | Sweden | 178.88 | 42.93 | 1.59 | 1.00 | 0.16 | 78.00 |
| | Turkey | 2,966.50 | 711.96 | 7.46 | 205.00 | 2,456.97 | 188.00 |
| | United Kingdom | 243.51 | 58.44 | 9.85 | 8.80 | 29.80 | 335.00 |
| OTHER EU | Austria | 86.90 | 20.86 | 7.46 | 1.00 | 20.40 | 50.00 |
| | Bulgaria | 75.00 | 18.00 | 0.65 | 22.50 | 11.60 | 20.00 |
| | Cyprus | | | | | | 8.00 |
| | Denmark | | | 1.24 | 0.90 | 4.20 | 37.00 |
| | Estonia | | | | 0.90 | | 10.00 |
| | Finland | 157.70 | 37.85 | 1.79 | 1.00 | 6.00 | 40.00 |
| | France | 686.26 | 164.70 | 11.04 | 29.20 | 61.20 | 302.00 |
| | Greece | 125.00 | 30.00 | 0.15 | 9.60 | 87.20 | 47.00 |
| | Ireland | | | | 1.30 | 28.00 | 28.00 |
| | Latvia | | | | 0.80 | 0.74 | 10.00 |
| | Lithuania | | | | 3.60 | 3.40 | 11.00 |
| | Luxembourg | 275.00 | 66.00 | | | | |
| | Netherlands | 15.75 | 3.78 | 1.24 | 10.20 | 4.40 | 50.00 |
| | Poland | 438.60 | 105.26 | 0.95 | 113.00 | 51.20 | 219.00 |
| | Portugal | 262.50 | 63.00 | 0.90 | 63.00 | 197.00 | 71.00 |
| | Romania | 166.40 | 39.94 | 0.55 | 13.80 | 26.40 | 33.00 |
| | Slovakia | 45.24 | 10.86 | | 11.50 | 0.92 | 22.00 |
| | Slovenia | 75.00 | 18.00 | 1.00 | 8.50 | 1.00 | 11.00 |
| | **TOTAL** | **11,191.10** | **2,685.86** | **133.86** | **1,301.76** | **7,281.99** | **2791.00** |



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*Table 3 Summary table for C&DW (average values between maximum and minimum waste generation is presented for separate waste streams)*

| | | C&DW in General | Plastic | Glass | Ceramic | Concrete | Wood |
|---|---|---|---|---|---|---|---|
| | | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) | (Kt/yr) |
| **FISSAC COUNTRIES** | Belgium | 11,020 | 115.71 | 55.10 | 4,022.30 | 2,865.00 | 330.60 |
| | Czech Republic | 14,700 | 154.35 | 73.50 | 5,365.50 | 3,822.00 | 441.00 |
| | Germany | 72,400 | 760.20 | 362.00 | 26,426.00 | 18,824.00 | 2,172.00 |
| | Hungary | 10,120 | 106.26 | 50.60 | 3,693.80 | 2,631.00 | 303.60 |
| | Italy | 46,310 | 486.26 | 231.55 | 16,903.15 | 12,040.50 | 1,389.30 |
| | Spain | 31,340 | 329.07 | 156.70 | 11,439.10 | 8,148.50 | 940.20 |
| | Sweden | 10,230 | 107.42 | 51.15 | 3,733.95 | 2,660.00 | 306.90 |
| | Turkey | 68,640 | 720.72 | 343.20 | 25,053.60 | 17,846.50 | 2,059.20 |
| | United Kingdom | 99,100 | 1,040.55 | 495.50 | 36,171.50 | 25,766.00 | 2,973.00 |
| **OTHER EU** | Austria | 6,600 | 69.30 | 33.00 | 2,409.00 | 1,716.00 | 198.00 |
| | Bulgaria | 7,800 | 81.90 | 39.00 | 2,847.00 | 2,028.00 | 234.00 |
| | Cyprus | 730 | 7.67 | 3.65 | 266.45 | 190.00 | 21.90 |
| | Denmark | 5,270 | 55.34 | 26.35 | 1,923.55 | 1,370.00 | 158.10 |
| | Estonia | 1,510 | 15.86 | 7.55 | 551.15 | 392.50 | 45.30 |
| | Finland | 5,210 | 54.71 | 26.05 | 1,901.65 | 1,354.50 | 156.30 |
| | France | 85,650 | 899.33 | 428.25 | 31,262.25 | 22,269.00 | 2,569.50 |
| | Greece | 11,040 | 115.92 | 55.20 | 4,029.60 | 2,870.50 | 331.20 |
| | Ireland | 2,540 | 26.67 | 12.70 | 927.10 | 660.50 | 76.20 |
| | Latvia | 2,320 | 24.36 | 11.60 | 846.80 | 603.00 | 69.60 |
| | Lithuania | 3,450 | 36.23 | 17.25 | 1,259.25 | 207.69 | 103.50 |
| | Luxembourg | 670 | 7.04 | 3.35 | 244.55 | 174.00 | 20.10 |
| | Netherlands | 23,900 | 250.95 | 119.50 | 8,723.50 | 4,781.43 | 717.00 |
| | Poland | 38,190 | 401.00 | 190.95 | 13,939.35 | 2,299.14 | 1,145.70 |
| | Portugal | 11,420 | 119.91 | 57.10 | 4,168.30 | 2,969.00 | 342.60 |
| | Romania | 21,710 | 227.96 | 108.55 | 7,924.15 | 5,644.50 | 651.30 |
| | Slovakia | 5,380 | 56.49 | 26.90 | 1,963.70 | 1,399.00 | 161.40 |
| | Slovenia | 2,000 | 21.00 | 10.00 | 730.00 | 520.00 | 60.00 |
| | **TOTAL** | **600,050** | **6,300.53** | **3,000.25** | **219,018.25** | **156,013.00** | **18,001.50** |

## 5.2 Best Available Techniques (BATs)

The report ***Deliverable D1.5***[xiv] main aim was to focus on Resource Efficiency measures, considered among Best Available and Emerging Techniques, on individual plant scale and assess the impact of these measures on industrial symbiosis potential of the waste streams envisioned to be valorised within the scope of FISSAC industrial symbiosis network. Finally, material and energy flows for production processes of eight sectors (Electric Arc Furnace Steelmaking, Secondary Aluminium Production, Ceramic Tile Production, Natural Stone Processing, Used Tyre Processing, Cement Production, Concrete Production) were delivered within the report to present a baseline for quantification of industrial symbiosis indicators, LCA and LCC.

The amount, availability and composition of secondary raw materials are changing constantly. The BATs implemented in the sectors supplying SRMs to end-users of industrial symbiosis networks have the potential to change these characteristics of SRMs. This fact should be taken into account in the mid-term planning of the industrial symbiosis network.


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Furthermore, any symbiosis model including FISSAC's aim to reach high level performance throughout the entire network for overall environmental impacts to be minimized across sectors. The assessments presented in D1.5 show that alternative technologies have tremendous potential to decrease waste intensity of all individual FISSAC Sectors. Currently, FISSAC sectors are experiencing waste minimization and eco-efficient production through the use of BATs although with varying pace of technology diffusions.

The most relevant conclusions from the analysis and new information that could be useful in the framework of the exchange of information for next BREF review:

1. alternative techniques/technologies including BATs and emerging technologies/ techniques with potential to influence future industrial symbiosis activities between these processes
2. pre-processing, main processes and post-processes
3. Novel and resource efficient products
4. Other reuse options
5. More detailed cost figures for life cycle costing analyses

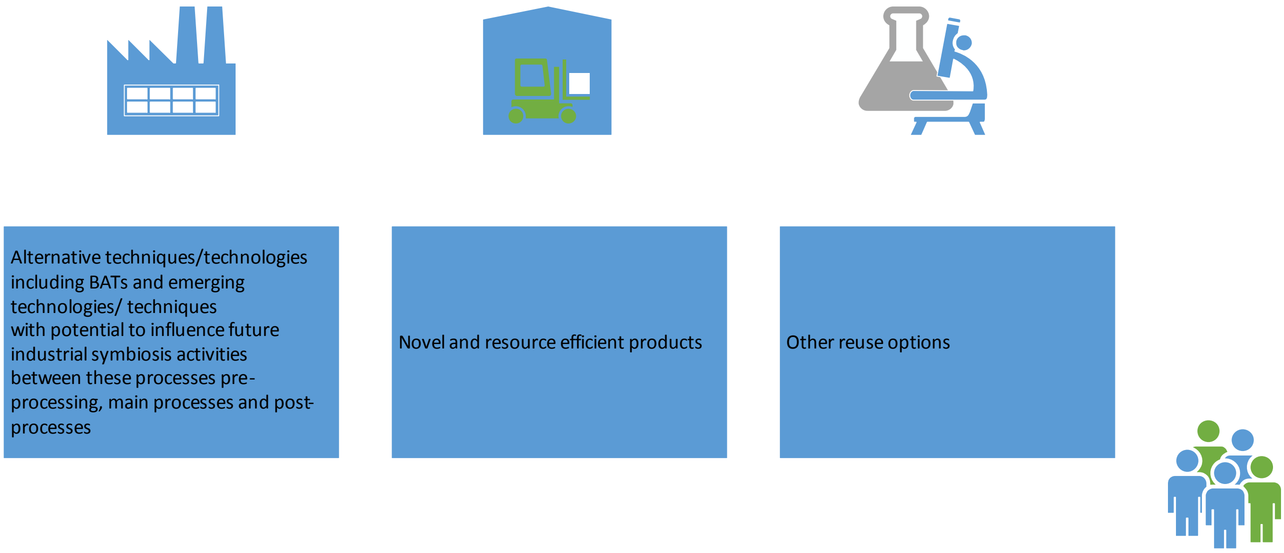


*Figure 7 Framework of the exchange of information*

The list of all evaluated techniques/technologies are presented in Table 5

| | Pre-processing | Main Processes | Post Processes | Novel and Sustainable Products | Others |
|---|---|---|---|---|---|
| *EAF Steelmaking* | Charge material | • Contiarc furnace<br>• EAF process optimization | N/A | N/A | Internal and External Reuse of Slag |
| *Secondary Aluminium Production* | N/A | • Use of a tilting rotary furnace<br>• Cold pressing and melting with salt flux | • BEFESA process<br>• Electro dialysis<br>• Freeze crystallization<br>• Solvent/anti-solvent extraction<br>• Common ion process<br>• High-pressure/high temperature process | N/A | N/A |


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| | Pre-processing | Main Processes | Post Processes | Novel and Sustainable Products | Others |
|---|---|---|---|---|---|
| *Ceramic Tile Production* | N/A | • Modern Firing Techniques<br>• Radiant Tube Burners<br>• Improved Design of Kilns and Dryer<br>• Microwave Assisted Firing and Microwave Dryers | N/A | Ceramic Tile Development by Geopolymerization | • Re-Use of Solid Process Losses as Raw Materials<br>• Addition of Calcium Rich Additives |
| *Natural Stone Processing* | N/A | • Extra thin cutting discs<br>• Water jets<br>• Bridge saws<br>• Laser technologies for cutting and finishing | • Wastewater treatment and reuse<br>• Slurry drying and sieving | N/A | N/A |
| *Used Tyre Processing* | • Mechanical shredding<br>• Cryogenic shredding | • Ambient grinding<br>• Cryogenic grinding<br>• Wet grinding<br>• Use of ultra-high pressure water jets | • Mechanical Devulcanisation<br>• Chemical Devulcanisation<br>• Steam Devulcanisation with or without Chemicals<br>• Ultrasonic Devulcanisation<br>• Microwave Devulcanisation<br>• Biological Devulcanisation | N/A | N/A |
| *Cement Production* | N/A | • Rotary kilns equipped with preheaters<br>• Rotary kilns with preheater and precalciner<br>• Cement suspension preheater calcining technology with high solid-gas ratio<br>• Fluidised bed advanced kiln systems | • Vertical roller mills (VRM)<br>• Horizontal roller mills<br>• High-pressure roller press<br>• High activation grinding | • Blended cement<br>• Calcium sulfoaluminate cement<br>• Calcium aluminate and calcium alumina–silicate cements<br>• Magnesium-oxide based cement<br>• Alkali-activated cements/geopolymers<br>• Sequestrated carbon cement | Use of waste as raw materials in cement production |
| *Concrete Production* | N/A | N/A | N/A | • Geopolymer Concrete<br>• Self-Consolidated/ Compacting Concrete (SCC)<br>• Ultra-Lightweight Fibre Reinforced Concrete<br>• Geopolymer Foam Concrete<br>• Fibre-Reinforced Aerated Concrete (FRAC)<br>• Use of Synthetic Fibres in Self-Compacting Lightweight Aggregate Concretes | Using particle packing technology |

*Table 4 List of all evaluated techniques/technologies*


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## 5.3 Establishment of tentative synergies among industrial processes to minimize, reduce and recycle waste as a whole: Conclusions

For the establishment of tentative synergies the following information has been analyzed:

- Industrial processes
- Material and energy inputs and outputs
- Potential synergies between industrial processes
- Minimization, reduction and recycling alternatives
- Other reuse options

The document details how to establish the tentative synergies defined for FISSAC project. It identified the material and energy inputs and outputs of the processes; secondly, they were classified in terms of industrial symbiosis interactions to obtain better result of exchanges and interactions.

The material flow information presenting the so-called life cycle inventory in LCA methodology is crucial for LCA and LCC analyses to be completed by the FISSAC IS Platform. Furthermore, it will help to assess the key environmental, economic and social indicators of the indicator-based assessment methodology (delivered in D1.6), which will be a part of the FISSAC IS Platform. Indicator-based assessment covering LCA and LCC analyses will enable scenario comparisons targeting before and after establishment of an IS network as well as provide insight on how to replicate it at regional contexts (Chapter 8. Baseline of FISSAC Industrial Symbiosis Software Platform). FISSAC stakeholders can visualize alternatives of industrial symbiosis scenarios and plan how potential waste streams are valorised, enabling them to design the potential improvement for cleaner production within the sector.

The BATs applied in industry change the material flows within the production processes and therefore, effect the life cycle inventories. Beyond this, through waste minimization measures, a decrease in local availability of waste may be experienced. Therefore, it is important to understand how waste prevention and minimization activities impact waste valorisation schemes such as industrial symbiosis. BATs will be represented in the FISSAC Platform through changing the life cycle inventories of the traditional production processes as well as their applicability to estimate the availability of a certain secondary raw material across the EU.

Finally, D1.5 addressed the potential synergies between the FISSAC industrial sectors that are not limited to the waste valorisation scheme studied by FISSAC. The aim of this evaluation was to be able to bring an understanding in FISSAC Model on the extend of waste/SRM exchange possibilities. This understanding is important for the FISSAC IS Platform to perform under industrial symbiosis networks other than FISSAC's in an exclusive manner.

The assessment for replication shall be included the following steps and they will be further discussed especially under WP6 and WP7:

- Definition of regional industries
- Definition of the industrial process and the current management for the resulting waste streams
- Definition of the tentative synergies between different industries
- At regional level, other influence conditions necessary for synergy implementation[xv]: origin-destination classification, onsite storage, proposed treatments, external industries (i.e. treatment plants) and geographical boundaries,
- Economic and environmental benefits assessment


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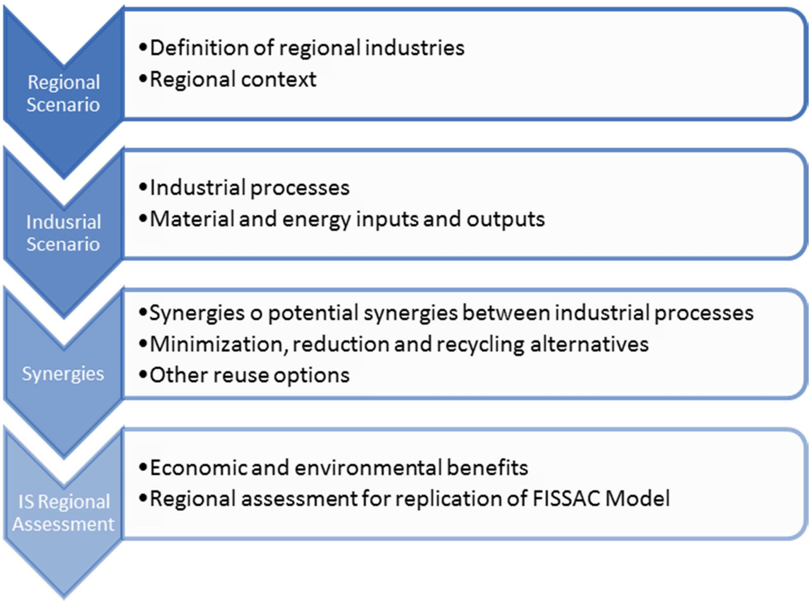
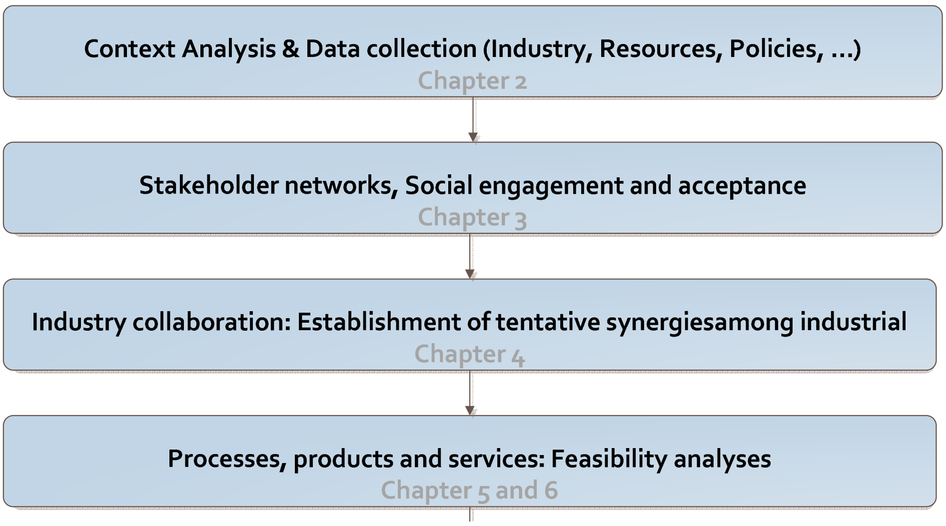



*Figure 8. Establishment of tentative synergies among industrial processes for FISSAC Project*

The results of the previous analysis and studies have shown the following steps regarding Industrial Collaboration. Based on these conclusions the following phases are proposed:

- Industry collaboration: Establishment of tentative synergies among industrial partners
- Processes, products and services: Feasibility analyses




In the next step, the objective is to define the Key Performance Indicator for ecoinnovation, waste and industrial symbiosis.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# 6. Key Performance Indicators for ecoinnovation, waste and IS.

## 6.1 Proposed indicators for FISSAC Project

Task 1.4 identifies indicators that have been proposed for the project. The report ***Deliverable D1.6***[xvi] proposes various indicator categories including IS indicators, circularity indicators, eco-innovation indicators, resource efficiency indicators, sustainability indicators, and network strength analysis indicators. The purpose of the report is to provide existing IS and sustainability related indicators, establish a scope and methodology for the selection of indicators relevant to the FISSAC Project.

The proposed list of indicators entail basic environmental, economic and social indicators, LCA indicators, circularity indicators and indicators on network strength analysis. Basic indicators are selected rather than composite indices to provide higher ease of use by different stakeholders of the IS networks and to avoid possible problems with aggregation. Exception to use of basic indicators is the life cycle indicators such as water, carbon or ecological footprint. In addition to basic environmental, economic and social indicators and life cycle indicators, network strength analysis indicators are proposed to facilitate establishment and monitoring of the IS network. Table 6 summarize the proposed indicators to the FISSAC Project. The list has been compiled after a detailed literature review on existing indicators used within the EU and available indicators in peer-reviewed articles.

Among the set of indicators proposed for the FISSAC network are environmental, economic, social, network analysis and circularity indicators. Under environmental indicators, material and energy related indicators are found to be highly relevant to the FISSAC IS network as energy and material intensive sectors are represented in the FISSAC network. Material indicators address utilization of primary and secondary raw materials separately. In relation to SRM valorisation, indicators on solid waste and by-product generation are also present in the proposed list of FISSAC indicators. SRM, solid waste and by-product indicators provide insight on the waste exchanges on receiving and supplying end of the flows. On the other hand, energy indicators cover fuel consumption, energy utilized from renewable sources, use of thermal energy etc. In order to account for the quality of energy, exergy indicators are also proposed both in terms of basic indicators and as a part of life cycle indicators in the form of energy and exergy embedded in the final product. Air emissions, in particular GHG emissions constitute to a portion of outflow related indicators. Another important group of environmental indicators, termed as life cycle indicators, aim to go beyond simple input/output quantities and provide an insight on the impacts of consuming the inputs and creating emissions on the environment. These indicators share a similar scope with the environmental indicators based on material and energy flows.

Economic indicators cover important topics including product quantity, turnover, net value added, as well as operational and capital costs. Among these, the first three can be used as stand-alone indicators or can be used for normalization of other indicators to obtain specific (or intensity) indicators.

Finally, the range of social indicators included in the proposed list are based on the possible social benefits of IS. Main criteria of selection was the ability to quantify these social aspects as the list of the indicators suggested in this deliverable are mainly limited to quantitative indicators to minimize subjectivity of analysing qualitative aspects.

The proposed a list of indicators will be utilized to set up the baseline for FISSAC model and their analysis will help to FISSAC Model replicability. It can be tailored for use in IS network other than the construction value chain IS initiative studied in FISSAC Project.

The list of indicators can be streamlined or indicator groups such as air emissions can be further disaggregated on a case-to-case basis during the indicator based assessment.



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| | Indicators | Including | |
|---|---|---|---|
| ENVIRONMENTAL INDICATORS | *Material consumption* | PRM consumption | Overall raw material consumption |
| | | SRM consumption | |
| | *Energy consumption* | Fuel consumption | Overall energy consumption |
| | | Thermal energy consumption | |
| | | Electricity consumption | |
| | | Renewable energy consumption | |
| | *Exergy* | | Overall exergy consumption |
| | *Air emissions* | GHG emissions | Air emissions |
| | | Emissions of specific air pollutants | |
| | *Solid waste generation* | Hazardous wastes | Total solid waste generation |
| | | Non-hazardous wastes | |
| | *By-products* | | |
| | *Life cycle indicators* | Abiotic resource depletion | |
| | | Water depletion (water footprint) | |
| | | Global warming potential (carbon footprint) | |
| | | Land occupation and transformation | |
| | | Cumulative energy demand | |
| | | Cumulative exergy demand | |
| | | Ecological footprint | |
| | | Life cycle cost | |
| ECONOMIC INDICATORS | *Product quantity* | | |
| | *Turnover* | | |
| | *Net value added* | | |
| | *OPEX* | Material cost | Total OPEX |
| | | Water cost | |
| | | Energy cost | |
| | | Land use cost | |
| | | Labour cost | |
| | | Maintenance cost | |
| | | Environmental cost savings | |
| | | Revenues as a result of IS activities | |
| | *CAPEX* | | Total CAPEX |
| SOCIAL INDICATORS | *Job creation and retention* | | |
| | *Creation of IS* | | |
| | *Social responsibility* | | |
| | *Lifelong learning* | | |
| | *Health and safety at work* | | |
| | *Rate of community participation* | | |
| | *Level of social acceptance* | | |
| | *Community development* | | |
| | *Innovation and investment in R&D* | | |
| CIRCULARITY IDICATORS | *Environmental impact momentum* | | |
| | *Utility* | | |
| | *Environmental cost effectiveness* | | |
| NSA | *Betweenness and closeness* | | |
| | *Reciprocity* | | |
| | *Intensity* | | |

*Table 5 Proposed indicators for the FISSAC Project*



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The evaluation of the selected FISSAC IS indicator set has been made in terms of methods of quantification, applicability, special provisions for use and their relation with the existing indicator sets. As a result, the indicator list proposed in the report should be regarded as a compilation of possible relevant metrics, which will be used and evaluated through the course of the Project, in particular in life cycle assessment, eco-design and ETV tasks. Furthermore, as the studies on technical aspects of valorisation of SRMs under FISSAC scheme progresses, indicators may be prioritised or composite indicators may be added.

In addition to these indicators, the Deliverable 1.7 identifies the link with the United Nations Sustainable Developments Goals (SDGs) that are a universal set of goals, targets and indicators that UN member states will be expected to use to shape the agendas and political policies over the next 15 years (2015 – 2030). This ambitious agenda for all of humanity seeks to finish what the Millennium Development Goals started, while adding its own elements. Industrial symbiosis projects are helping to meet the SDGs' target and are playing an essential role and acting as an important engine for innovation in many various sectors. Industrial symbiosis supports a number of the Goals, in particular: SDG 8 Decent work and economic growth, SDG 9 Industry, innovation and infrastructure, SDG 12 Sustainable consumption and production, SDG 13 Climate action, SDG 17 Partnership for the goals.

## 6.2 Industrial Symbiosis and circularity Indicators

Other indicators studied under Task 1.4 do not fall strictly under the categories of environmental, economic or social indicators. These indicators include circularity indicators and network indicators. These aim to assess how well the IS network is established in terms of network strength and how well the established network responds to "circularity" criteria and needs.

The indicators proposed in the report corresponding to these benefits can be seen in Table 7.

| For communities and local authorities | Possible indicators that can be linked to these benefits |
|---|---|
| Boost local economy and growth | Job creation and retention, revenues as a result of IS activities |
| Local business opportunities | Creation of IS |
| Improved health for citizens and workers | Health and safety at work |
| Knowledge transfer and new skills | Lifelong learning |
| Enhanced quality of life | These can all be quantifies through investments and charity programmes as cooperation with the local community; reduced traffic, noise, air pollution. |
| Improved aesthetics | |
| Improved local environment | |
| Reduced cost for waste disposal | Environmental cost savings |
| 'Sense of community' | Rate of community participation, community development, level of social acceptance |
| **For the environment** | **Possible indicators that can be linked to these benefits** |
| Improved air quality and reduced pollution | Air emissions, Solid waste generation |
| Ecosystems protection | Ecological footprint, carbon footprint, land occupation and transformation, global warming potential |
| Avoided water use | Water consumption, water efficiency, water footprint |
| More efficient use of resources | All resource (material and energy) efficiency indicators |
| Waste reduction | Waste generation, avoided emissions |
| Reduced carbon emissions and climate change mitigation | Avoided emissions, carbon footprint |
| Raw material availability | PRM and SRM consumption, abiotic resource depletion |
| **For business** | **Possible indicators that can be linked to these benefits** |
| Cost savings | Environmental cost savings |
| Increased energy efficiency | Energy and exergy indicators |
| New partnerships | Creation of IS |
| Speed up innovations and invest in R&D | Innovation and investment in R&D |


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| | |
|---|---|
| New patents | Innovation and investment in R&D |
| Additional sales and increased turnover | Revenue from creation of new products and services, revenues as a result of IS |
| Reduction of operation costs | OPEX indicators |
| Green profile, better public image | Level of social acceptance, community development |
| Decrease footprint | Carbon, water and ecological footprints, LCA indicators, resource efficiency indicators |
| Income from sale of by-products | Revenues as a result of IS |
| Infrastructure sharing | Creation of IS |

*Table 6 Monitoring benefits of IS with indicators*

## 6.3 Key Performance Indicators for ecoinnovation, waste and IS: conclusions

The indicator list will be incorporated into the FISSAC IS Platform (Chapter3) with the feedback received from task 1.6 and WP6. The FISSAC ICT Platform is expected to be able to allow the use of most of the indicators proposed in this report, which will allow the evaluation of them in the project environmental performance assessments.

To support the sustainable management of material resources, FISSAC project will developed approaches based on an integrated model (methodology and software) that links secondary raw material use and resource-efficiency models in order to evaluate different scenarios and policy options in terms of efficiency and cost-effectiveness.

The conclusions from KPIs for ecoinnovation, waste and IS can be considered as a first step of finalization of the indicator-based assessment of the FISSAC IS model. The FISSAC core indicators will be a set of indicators that will been chosen based on the indicators from the FISSAC full list. They are being agreed upon during discussions in the consortium and through interviews in WP6 and they will be essential indicators for the assessment.

The list of indicators proposed have been further discussed especially under WP3 and WP6.

Some adjustments to the list, if deemed necessary, can be made during LCA, eco-design, and ETV activities. Furthermore, during establishment of FISSAC IS model, in particular while developing the FISSAC Platform, the indicator list is expected to be revisited. As the studies on technical aspects of valorisation of SRMs under FISSAC scheme progresses, new indicators may be added or some indicators may be prioritized over others to obtain an even more tailored list of FISSAC IS indicators. In this sense, the reader is urged to consider work on IS indicators as iterative as changes may occur on the final list in the light of forthcoming project activities.


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# 7. Recycling Processes and Product Eco-design (WP2 and WP3)

## 7.1 Technical Requirements and Characterization of selected Industrial waste streams

The report ***Deliverable D2.1***[xvii], compiles diverse technical requirements for each FISSAC waste stream within the context of their application. To reach this objective, the following list of references was considered:

- Technical requirements for the currently used Raw Materials
- Current technical requirements for already standardized by-products to be used in the construction sector at European level and Local
- Waste and by-products regulations
- Previous research works and own experience.

According to this, the technical requirements for each sector (Cement production, Green Concrete, Ceramic Industry and Wood Plastic Composites) and SRMs were gathered and listed. These conclusions have helped to FISSAC partners to identify those critical characteristics needed for the manufacturing of the target materials and products, as well as quality standards and the environmental regulatory framework (emissions, content and release of pollutants). The technical requirements were therefore classified into physical (grading, shape, density,), chemical (composition, pozzolanic activity,…), mineralogical, mechanical (strength, swelling, , etc.) and environmental in order to classify them and be more useful for subsequent uses within the FISSAC Work Programme.

Finally, every case study includes the main properties of the FISSAC waste streams based on previous works aiming to define which requirements are more relevant to put the focus on it, and which ones can be dismissed. For this purpose, every case study includes basic data of chemical, mineralogical and physical properties of the waste streams, comparing those characteristics with the identified needs for every sector.

The conclusions from the report help to define the technical requirements of the secondary raw materials used in the sectors where industrial tests will be carried out. The outputs from each type of secondary raw material technical specifications expected could be included into FISSAC IS Platform to develop and enhance FISSAC industrial symbiosis scenario.

***Deliverable D2.2***, based on the requirements proposed in Deliverable D2.1, deals with the characterization of the industrial waste streams covered in FISSAC.

It covers up to 10 types of waste streams and by-products from six main industrial sectors, such as Steel Industry, Secondary Aluminium Industry, Ceramic Industry & Recycling Industry from C&DW and Recycling Industry from Quarry/Mining. Concerning the potential applications, four construction sub-sectors are considered: 1) eco-cement; 2) green Concrete and Autoclaved Aerated Concrete AAC; 3) ceramic products and 4) wood plastic composites (WPC), focusing on those countries (Turkey, Italy, Spain, Sweden and UK), where a specific sector is of great relevance or the final applications are going to be demonstrated. Characterization was performed in function of the target applications; those are, potential use as clinker raw meal and mineral additives, additions/aggregates, source of alumina, source of $CaCO_3$.

Waste characterization covered physical, chemical, mineralogical, morphological and environmental properties of waste materials. Results were classified into physical (grading, shape,…), chemical (composition, mineralogy,…) and mechanical (strength, swelling, activity index, etc.). For each waste material and industrial application, a list of favourable characteristics, technical constraints, and potential treatments were identified aiming to set the basis for Task 2.3 and other ulterior WPs.



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The results of this report identify the potential technical barriers that are being improved within the Task 2.3, through the implementation of enhanced recycled routes. In addition, this document also identifies potential lack of harmonized standards hampering full acceptance in construction applications that are being developed in Task 2.5.

WP2 general purpose is to adapt innovative technological and non technological processes for obtaining cost-effective secondary raw materials from different industrial waste streams (industrial sectors) to be used in the design and manufacturing of eco-innovative construction products to be applied in FISSAC scenario.

By taking into account the requirements of the raw materials defined in the task 2.1 as well as the previous results referred to the best available technologies for valorisation of waste, task 2.3 is focused on the design the suitable routes for carrying out the production of the secondary raw materials. The use of secondary raw materials in new production processes (WP3) will be validated at pilot and industrial scales in the production chains (WP4 and WP5).

## 7.2 Non technological barriers analysis and mitigation mechanisms

FISSAC project involves the study of the extent of obstacles and failures affecting the functioning of the SRMs market with the aim of identifying the critical barriers and opportunities and to formulate improved strategies which could increase the use of those materials. The report, ***Deliverable D2.4***[xviii], has been conducted collecting literature research studies, using interviews with stakeholders involved in the construction sector, research centers including designers, construction companies, demolition enterprises, waste management companies, reuse agents and authorities.

Technological barriers have been demonstrated to be surmountable but obstacles still exist for many SRMs to reach the market despite its proved value. These obstacles have been extensively studied for the last years and several classifications have been proposed. This report has distinguished the non-technological barriers into four large groups; Economic, Regulatory, Social Perception and Structural.

An Industrial Symbiosis scenario can be seen as a learning process where the non-technological barriers appear at different stages and levels. Firstly, they affect internally to the organization which is thinking about trying new options for their waste streams (waste generator). In an incipient stage, once several actors are involved, it affects to several organizations and waste managers, and finally, when the strategy is replicated at sectorial level, several barriers appear hampering the market uptake of the SRMs, affecting mainly at end-user level.

The whole system is controlled by economic criteria; consequently, economic factors are a key point in the valorization process. Some constraints such as the low cost of original raw materials or the high costs of transportation or processing of SRMs are among of the main barriers. Some recycling systems are unprofitable at certain point of the value chain, producing the so-called “losers” of the system. This barrier could be removed internally, by adjusting the revenues of all actors, or externally, by means of the regulatory framework. In this sense, one of the main drivers identified is the landfill fee, which acts as a motivating factor for the industrial symbiosis, introducing some budget in the system that can be rerouted to the “looser of the value chain”.

Accordingly, the policy makers play a fundamental role in guaranteeing the value chain, fostering landfill fees and taxes on disposal to make the SRMs market profitable in the first stage of the Industrial Symbiosis. Public support on R&D activities would help the system to be more feasible and to reduce the technological gap, making the market less dependent on external grants. The waste consideration and the bureaucracy to get the End-of-Waste consideration also hinder the process.


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Society tends to see SRMs as low quality materials and frequently are associated to risk of pollution. Moreover, the potential environmental benefits of recycled materials are confused within a wide variety of eco-labels. The rules on products should be amended to make it easier for consumers to choose recycled and resource efficient products.

Finally, the structure of the organizations can be an internal constraint for the setup of symbiosis scenarios. The rigid structure in certain key-departments, such as supplies may hinder the process. Some very well established logistic structures are also a barrier to changes and provokes a kind of technology lock-in that may impede the evolution once the SRM is really close to reach the market. Any activity aimed at ensuring visibility of success stories, large-scale demonstrators as well as standards may positively contribute to overcome these barriers.

Further analysis of non-technological barriers and drivers of the various represented industries in FISSAC will be carried out in Task 7.2. to create industrial symbiosis and lay path for a circular economy model of the given industries

## 7.3 Lifecycle assessment and Lifecycle cost of new processes, materials and products – Eco cement, Green concrete, Ceramic tiles and Rubber wood plastic composite.

The results of report *Deliverable D3.1*[xix] gives a first input to the rest of the project concerning what to consider when it comes to environmental impacts from the FISSAC products. As the FISSAC projects evolves and concepts are further developed, material and energy flows for the FISSAC products will be essential in order to give further and more detailed feedback on how the industrial symbioses should be designed in order to deliver a decreased environmental impact.

The overall environmental impact from the conceptual FISSAC Eco-industrial Park is lower than the baseline scenario. All the environmental impacts categories determined to have highest significance for individual production process has decreased in case of establishment of an eco-industrial park. Leveraging multisectorial synergies and logistics optimization for shorter transportation distances play the most important role in obtaining these results.

Based on the quality and quantity of data used in this screening assessment coupled with the preliminary nature of product formulations and uncertainties surrounding for instance the requirement for secondary raw material pre-processing, the conclusions to be drawn should be considered more general and focused towards pointing out important aspects to consider in the forthcoming actions within the FISSAC project.

The purpose of conducting a LCC was to pave the way for forthcoming developments in the project, and for the final LCC to be conducted in WP5. The generic LCC is comprised of five steps; some concluding remarks with relevance to these five steps are presented in the report *Deliverable D3.2*[xx].

Three of the steps, namely problem definition, methodology definition and model development**,** are presented in the report. The problem has been clearly defined in coherence with the LCA, and the system boundaries and purpose of the study have been explained. The methodology has been selected and a model for analysis developed.

The difficulties inherent in conducting the LCC estimate this early in the project are mainly related to step 4, i.e. data collection. This will in turn also affect step 5, i.e**. results evaluation,** since data is needed in order to generate results relevant enough to analyze. Considering that the problem is defined and the methods and models developed, the recommendations for the remainder of the project will be focused on the two latter steps. Making improvements in data collection will also improve the evaluation of the results, and thus the value of the LCC conducted. As a final recommendation regarding the evolution of LCA and LCC results in this project the collection of data should be in focus. Then, based on the quality and amount of data retrieved, the evaluation of economic results could be improved substantially (and in coherence with the LCA, i.e. including the evaluation of a conceptual industrial park).


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## 7.4 Conclusions

The inputs from WP2 and WP3 (and previous work package 1) to FISSAC IS Model are the following information for each type of secondary raw material and new construction product processes:

- Secondary Raw Material type and composition
- Current use and production data
- Technical requirement expected
- Acceptable contamination
- Quantity expected to be consumed
- Supply cost
- Possible interactions with the process
- Danger and health and safety


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# 8. Baseline of FISSAC Industrial Symbiosis Software Platform (WP6)

## 8.1 Summary

Detecting and assessing potential industrial symbiosis and promoting eco-industrial development on a multifunctional territory call for decision support methodologies and tools. Information on material flows needs to be stored in a way that allows data treatment to detect potential exchanges of waste and service mutualization and to assess their feasibility.

The FISSAC Software Platform emerges from the new methodology to facilitate its implementation in a practical way. It will address the two major decision making support of Industrial Symbiosis (IS):

**Simulation, demonstration and verification of IS case studies with a spatial perspective**. Stakeholders will be registered in the geo-referenced platform including data on waste availability, physical and chemical characteristics and other relevant data to be shared, which enable the exchange of resources, facilitate contacts among industrial players of the construction value chain and encourage research and development for underdeveloped waste streams.

**Evaluation of the environmental impact and material flow costs of the proposed IS solutions**, through an LCA based material flow analyses and industrial clustering, will allow the calculation and evaluation of the life cycle impact of the proposed solutions as well as monitoring and verification of the pilot studies. The tool will have the capability of using the geographical position of the solutions, thus in data exchange with the geo-referencing tool to allow a large scale IS evaluation capability.

FISSAC Software Platform aims to go beyond the existing platforms by integrating capabilities of EPESUS and GEOCLUSTERING software and adding network analysis functionalities to assess the roles of partners within the industrial symbiosis network and evaluate the success of overall operation using social network analysis (SNA) methodologies. The FISSAC Industrial Software Platform therefore will be able to respond to resource efficiency and environmental performance concerns (by the help of LCA), logistic issues (GIS data) and support decision-making processes during design, implementation and monitoring of the symbiosis operations (through SNA/industrial symbiosis indicators). It will also facilitate Industrial Symbiosis scenarios providing networking among stakeholders and any other group such as public authorities, academia or NGOs interested in exploitation, replication and impact of project results by the midterm of the project, when it will be an open forum for information sharing. Moreover, it would promote also the feed of other industrial symbiosis synergies and/or scenarios, out the Consortium and the project, enriching platform interdependence and results (end of the project).

A knowledge repository will be developed to be used as source of data for dynamic geo-database web service and provide semantic information on graphical layers regarding climatic, socio economics, financial, energy, material, mobility and all the geo-referenced data useful to the stakeholders. The FISSAC platform will be used for the evaluation of the material, energy flow as well as evaluating the environmental impacts and cost of the studied flows.

## 8.2 Analysis and design of the FISSAC Software Platform

The initial definition for the software tool is based on the progress of the activities developed within the WP6. The purpose of Task 6.1 and **Deliverable D6.1**[xxi] "FISSAC Software Platform Requirement Analysis Report" is to give a detailed description of the requirements for the "FISSAC Platform". It will illustrate the purpose and explanation about complete declaration for the development of system. It will also explain system constraints, interface, integration of developed parts and interactions with other external applications.



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The “FISSAC Platform” should be helper software for Industrial Symbiosis model, which will be defined in FISSAC project. The platform should be served, as a cloud service to make IS processes stronger and easy to use for FISSAC project. The software also should detect and share possible opportunities to help decision-making processes of Industrial Symbiosis.

Facilities shall provide their waste production, needs and related information by help of the platform. This information will be verified by responsible actor(s). The information will be the base for the opportunity finding process. In addition, it will be possible to manage clusters using platform. An authorized actor can, for instance, verify firms, verify practitioners and manage user information. The platform also will have the capability of representing detailed information about the firms, reports and processes.

Furthermore, the software shall be cloud-based, so users need active and reliable internet connection to use. The software platform should compose different software parts from responsible members of this project.

The report provides an overview of:

- the operational model and the system functionality based on operational model
- different types of stakeholders and their interaction with the system
- the system constraints and assumptions about the product
- requirements specification in detailed terms and a description of the system interfaces
- Existing software background stakeholders
- Detailed definition of non-functional requirements of FISSAC platform

The “FISSAC Platform” should be helper software for Industrial Symbiosis model, which will be defined based on this initinal outline during the Task 6.5 development. The software also should detect and share possible opportunities to help decision-making processes of Industrial Symbiosis.

## 8.3 FISSAC Platform Description

FISSAC platform is going to be delivered by additional features to the two main platforms of the consortium partners:

- EPESUS Software, from Ekodenge
- Georeferencing Capabilities, from D’Appolonia et.al.

The FISSAC concept will have the capacity to analyse Material Flows with multiple equivalent values

- Mass flows
- Energy Flows
- Cost flows
- Life cycle impact and other equivalent data
- The tool will be compliant with the LCA methodology standards and available Life cycle inventories



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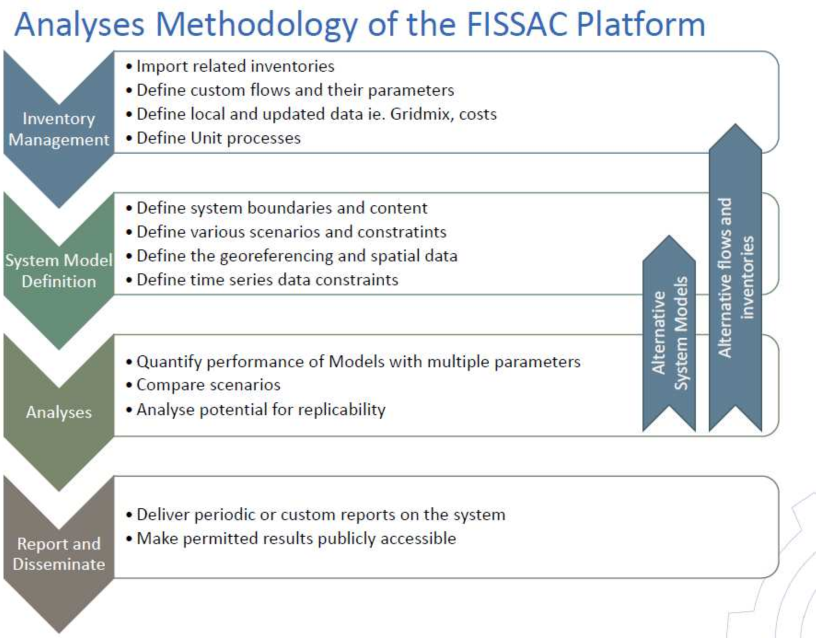


*Figure 9 Analysis of the methodology of the FISSAC Platform*

Relationship between the industrial actors and the ICT system requirement definitions were analysed based on interviews with stakeholders target group. The general questions included as a base for all interviews were:

- How to establish networks of stakeholders?
- Best practices of IS and lesson learnt?
- How to monitor progress through ecoinnovation, waste and IS indicators?
- How to overcome technical and non-technical barriers?
- Validation of eco-design with a life cycle approach
- Demonstration at pre-industrial and full scale

The conclusion from this interview will be used to define the ICT system requirement and the results will be explained in the Deliverables of Work Package 6.

### 8.4 FISSAC Platform Description

FISSAC Platform aims to provide a tool for IS process and IS network management. Managing IS networks and processes with help of a tool, will make following up processes simpler. Moreover, FISSAC Platform will offers a sophisticated and semi-automated (verification by authorized user(s)) way for match making process which is another important part of IS processes. Objective of this platform is providing these two core functionality and making IS network management easier.

- Network and User Management
- Data Acquisition and Management
- Model and Process Design
- Opportunity Assessment & MarketplacePerformance Evaluation & Monitoring


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**FISSAC Platform Specific Software Requirements**

- FISSAC Module 1: Network and User Management
- FISSAC Module 2: Data Acquisition and Management
- FISSAC Module 3: Model and Process Design
- FISSAC Module 4: Opportunity Assessment and Marketplace
- FISSAC Module 5: Performance Evaluation and Monitoring

**Existing Software Background and Functionality**

- Existing software capacities
  - EPESUS Platform
  - Ge2O Platform

FISSAC project aims to facilitate and interactive stakeholder involvement in FISSAC IS project, germ for the emergence of new synergies in the project and new Industrial Symbiosis projects. It also aims to help the stakeholders to analyse possible new scenarios.



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# 9. Conclusions

The report gives an overview of our understanding on FISSAC Industrial symbiosis networks and the connections between the methodology and platform software tool.

The deliverable shows under Chapter 2 which targets and objectives are the main drivers for FISSAC IS networks and how these identified targets can be achieved. The result shows that the identified steps can be grouped into the Figure 2.

The last 4th GA meeting (29th and 30th March 2017, Sheffield UK) has bring the opportunity to define goals, share knowledge, to discuss about model, methodology and software concept and how they would support the IS networks in particular FISSAC network across the FISSAC IS scenario.

The Figure presented the work under different WPs and how come together to provide the FISSAC IS methodology. The General Assembly discussion reveals that different actors identified their own links between different components and the needed to be better identified and how it becomes from a linear form to a more interlinks structure between the components.

The following figure represents an example of a more interlinks structure. The framework conditions was identified and the interlinks will be identified and further in WP6.

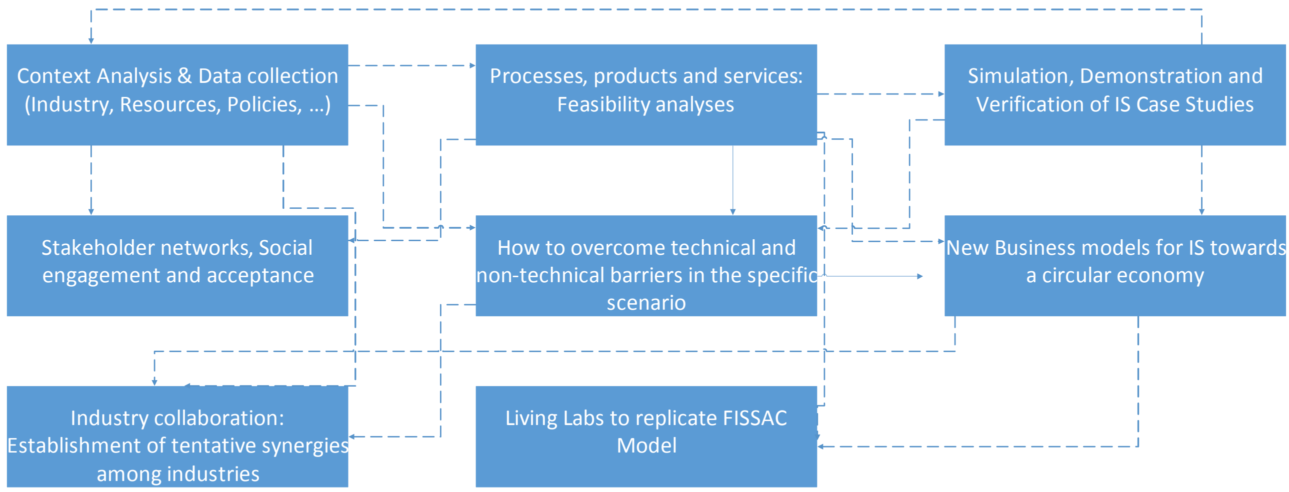


*Figure 10 Example of interlink structure based on Flow chart for FISSAC Model (Figure 2)*

Moreover, the deliverable defines a specific context analysis of Industrial Sectors and Secondary Raw Material. The main achievements on WP1 are highlighted in the following chapters (4, 5 and 6). The chapter 7 also shows achievement on WP2 and Wp3. Finally a software platform that is been developed in WP6 are included on Chapter 8.

The Figure 11 shows the identification of the relation between methodology and platform. The WP6 development will be focused on the integration of methodology and platform as a one model, as complimentary parts forming the model. The following activities are focused in how they support and provide input to each other.


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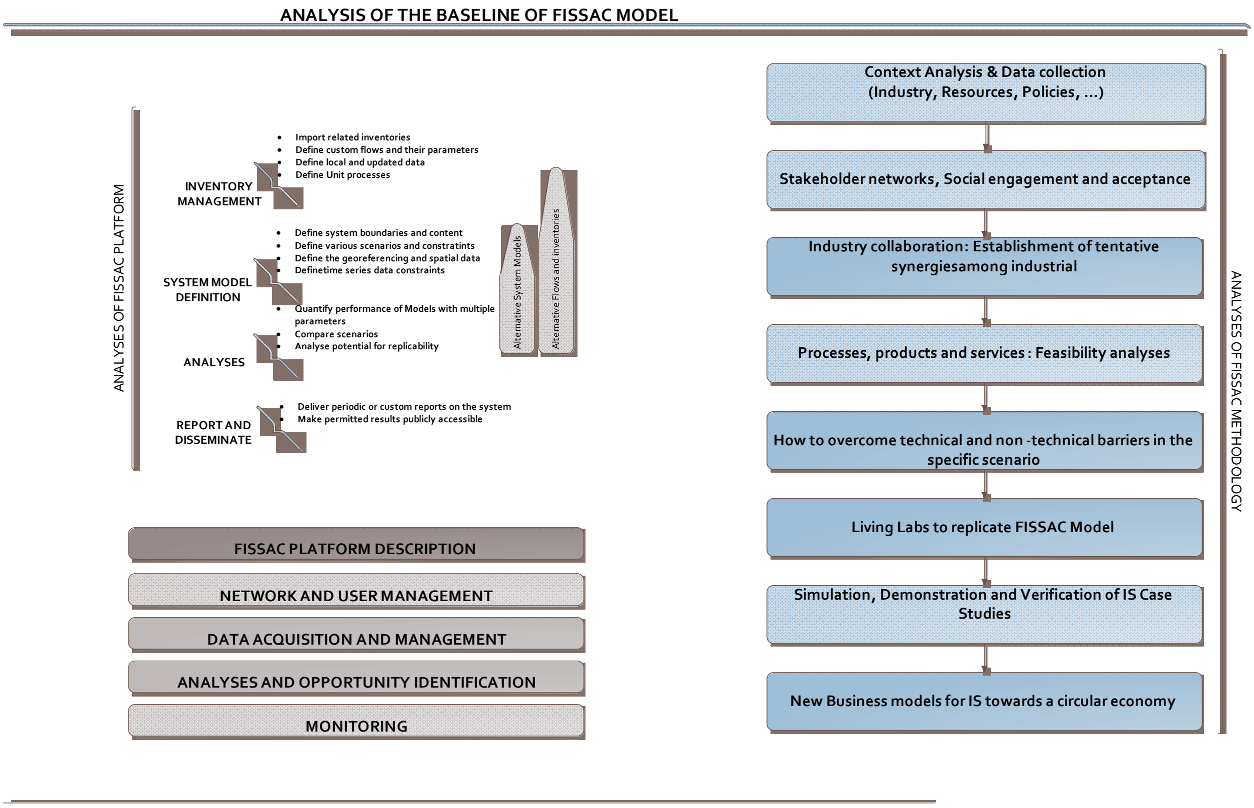


*Figure 11 Relation between FISSAC methodology and platform*

Combined, FISSAC IS scenario, FISSAC methodology and the Software Platform will serve the purpose of realizing potential synergies in a holistic manner.

The purpose of this report is to set up the baseline for FISSAC Model was to pave the way for FISSAC Model and for the final Methodology and Model to be defined in WP6:

- **FISSAC methodology will be defined in task 6.4** (Task leader ACCIONA M19-54), which will consist of:
    - Procedure to implement the IS Model in the construction value chain scenario

- **FISSAC model will be defined in task 6.5 –** (Task leader D' APPOLONIA M19-54), which will consist of:
    - FISSAC IS Scenario
    - Methodology to implement FISSAC model
    - Software Platform to support implementation
    - FISSAC LCI library

The results of this report give the first inputs to the development of FISSAC methodology and model. Therefore, the methodology and the model will be updated and fine-tuned (T6.4 and T6.5) in order to validate the suitability and applicability of the model in WP7.



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