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

FISSAC model and validation

Executive summary

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D6.8: FISSAC model and validation
WP6, T6.5

Author: RINA-C

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 642154.

Deliverable 6.8, "FISSAC model and validation", is aimed at summarising the main outcomes of FISSAC model: scenario, platform and methodology.

WP6 objectives

The main objective of WP6 was to develop the final version of FISSAC model for Industrial Symbiosis. Four main elements have been identified since the beginning of the project as fundamental pillars of the model itself:

- FISSAC Industrial Symbiosis scenario (construction value chain)
- Methodology: procedure to implement FISSAC model
- Software Platform: to support the methodology implementation
- FISSAC Material and process LCI library

These elements have been developed and refined throughout the project; in particular WP6 was aimed at defining all these results, thanks to the following activities/tasks:

- Analysis and design of the FISSAC software platform
- Development of an integrated FISSAC is monitoring tool
- Monitoring and evaluation of results with the platform
- Definition of the final version of FISSAC industrial symbiosis methodology
- Definition and validation of FISSAC model

In addition, also the feedback coming from external stakeholders have been considered, mainly thanks to the Living Labs established within the project.

DEFINITION OF THE FISSAC MODEL

The FISSAC project is an ambitious project aimed at improving the consciousness about circular economy and industrial symbiosis among different industrial sectors. The focus is on the construction value chain scenario, which includes steel, aluminum, natural stone, ceramics, chemical and demolition and construction sectors. Different industrial partners belonging to these sectors have put their efforts in establishing industrial symbiosis success stories.

The specific objectives of the project are manifold: it aims at demonstrating closed loop recycling processes and manufacturing processes, developing the eco-design of eco-innovative construction products and developing instruments to facilitate the instauration of IS establishment, such as the software platform and the living lab concept.

Closed loop recycling processes are necessary to transform waste into valuable secondary raw materials. Similarly, **eco-design** is a key element to manufacture innovative products (new Eco-Cement and Green Concrete, innovative ceramic tiles and Rubber Wood Plastic Composites) that are competitive with respect to the state of the art. Thanks to the knowledge developed within the project, different **necessary steps to establish IS** have been identified and solutions to overcome technical barriers have been proposed, in particular through activities related to the case studies.

At the same time, the necessity to investigate also less technological aspects has been highlighted during the project as it could really promote the success of the IS. The development of the **FISSAC ICT Platform** is considered as a key element, since different stakeholders can use this instrument as a support in decision making in material flow analyses and industrial clustering. Indeed, through the Platform the facilities can retrieve information about Industrial Symbiosis opportunities and obtain information for their instauration; perform feasibility assessment and assess the networks performances from the environmental and economic point of view; get in contact with other facilities through the marketplace and search for a list of solution providers, able to support facilities in this process.

In addition to that, the project has evaluated and successfully exploited the concept of **Living Lab**. A Living Lab is, as a user-centred, open-innovation ecosystem, often operating in a territorial context.

Since the necessity to create trust among stakeholders have been identified as a very important point in the formation of networks, guidelines and examples are provided to organize Living Labs and use this instrument to facilitate the IS establishment.

All these elements are summarized within the **FISSAC methodology and model**. The methodology is a part of the FISSAC model and describes the necessary steps to establish industrial symbiosis. Within the FISSAC project these steps are realized and applied to the construction value chain and validated through different case studies. The FISSAC Platform, supporting various steps of the IS methodology including opportunity identification, opportunity assessment and network design, acts as an enabler of the IS methodology and helps the FISSAC IS Model to be replicable beyond the construction value chain.

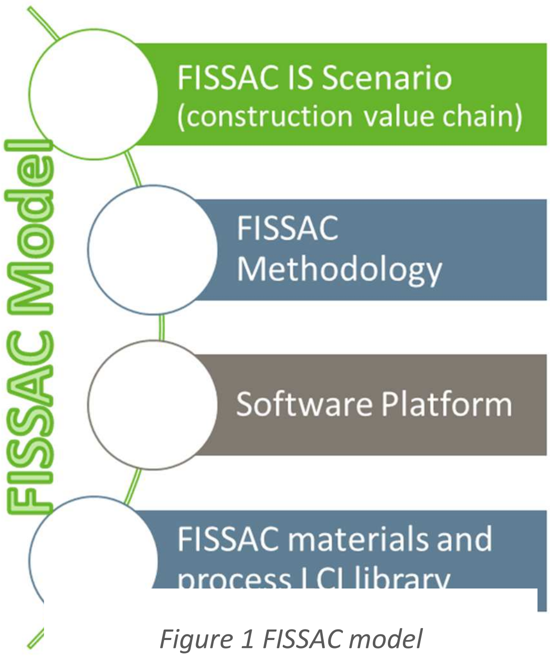

Figure 1 FISSAC model

The real experience gained (reported within the library/database) as well as the main outcomes of the projects (e.g. the platform or the Living Lab concept) are part, together with the methodology, of the final model of the project. The model includes the main achievements obtained and propose itself as a pathway for the replication of Industrial Symbiosis in other contexts.

FISSAC Industrial symbiosis scenario

The FISSAC project is focused on the extended construction value chain. The model that has been developed during the project has been implemented in this scenario, which can be considered the first target application. This implementation of the model to the construction value chain can provide insights for the further application of the model also in other contexts and value chains. The replicability potential of the model is assessed within WP7.
Basically, the FISSAC scenario consists of the different industries and sectors to which the model has been applied, but also of several stakeholders who have made this implementation possible.

Different **industries** have been involved as demonstrators of industrial symbiosis synergies:

- facilities providing waste/secondary raw materials:
  - steel slag
  - aluminium oxide based products (from aluminium salt slag valorisation)
  - ceramic waste
  - marble slurry
  - used tires
- facilities producing products:
  - eco-cement
  - green concrete
  - innovative ceramic tiles
  - rubber wood plastic composites

Different **stakeholders** have been part of the model implementation, taking part in the transition process (from linear to circular):

- representatives of facilities providing waste/secondary raw materials (providers)
- representatives of facilities producing products (producers)
- waste managers
- technology/solution providers involved in:
  - waste characterisation
  - support in the (eco-)design of new products
  - transport of waste
- symbiosis experts facilitating IS establishment (also through the application of the ITC platform)
- customers (i.e. construction companies, as final users of such products)

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Figure 2 FISSAC scenario

Within previous project work packages, a deep analysis of the involved sectors has been performed, to analyse the main characteristics and geographical distribution of the different types of waste streams of interest to the project, to identify best practices and BAT (Best Available Techniques) for theirs recycling and to preliminary detect the main drivers/barriers.
At the same time, networks of stakeholders have been established, also thanks to the different national Living Labs.

Methodology

The FISSAC methodology describes all the necessary steps to establish industrial symbiosis synergies.
A preliminary version of the methodology has been reported within D1.8 "*Initial outline of FISSAC Industrial Symbiosis Model and Methodology*" at M18, but then it has been further improved and enriched, following an iterative approach: indeed the results from the demonstration activities, as well as feedbacks from stakeholders, gathered through Living Lab and through the FISSAC ICT Platform have been used to refine the first released version.
The final version of the FISSAC platform is reported within D6.7 "*Final version of FISSAC Industrial Symbiosis Methodology*". Within this document, all the necessary steps to establish Industrial Symbiosis synergies are described, in order to depict a framework which can be used later by third parties who wish to form other industrial symbiosis networks.
In this way, the experience gained during the project can be used in other frameworks, with the same objective: to promote circular economy and industrial symbiosis.

The first step consists of **(i) engaging** facilities by getting their commitment to be part of the IS Network. Within the FISSAC projects, since the more stakeholders are involved, the more the community has the potential to grow further, Living Labs are considered strong enablers for the engagement process. The engagement can be considered mature when the stakeholders register to the Platform and start entering some data at the basic level. This phase indeed also involves the collection of quantitative and qualitative information from the participating facilities in a format that allows symbiotic relations to be identified and linkages to be made within the network. This step is followed by **(ii) identification of** possible IS opportunities between facilities and areas where there are specific needs in terms of the supply of and demand for materials, resources and facilities, thanks to specific matching algorithms. Facilities can further **(iii) validate** the information gathered by getting into direct contact with the identified facility and requesting detailed information. In the next phase, the collected data for each facility is reviewed to **(iv) design** the networks particularly in the case of industrial clusters or organized industrial districts through conceptual network design and system models and **(v) analyse** the identified possibilities. Based on various criteria including geographical proximity, by-product reuse and business-to-business resource optimization, identified possibilities need to be prioritized. Where necessary a technical moderator (symbiosis expert) may assist the participating facilities for further analyses and specialist expertise for feasibility studies or pilot trials of prioritized synergies. The next step for agreed opportunities is to **(vi) implement** the IS measures. The implementation is complete when the facilities start exchanging material flows through the marketplace. Depending on the need of employing intermediate processes or complexity of the application, this step can comprise preparations, procurements, investments, and other engineering work on field. After implementation of the IS measures the next phase is to **(vii) monitor** and **verify** the performance of the IS measures implemented between facilities.

Software platform

The FISSAC software platform has been conceived as an instrument to facilitate the implementation of the FISSAC methodology. The full details about the Platform are reported within D6.4 "*FISSAC Platform Final Version*". Here below, its main characteristics are reported.

All the platform functionalities are aimed at facilitating users who want to establish Industrial Symbiosis synergies.

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Different kind of **users** have been foreseen:

Facility representative: facilities representatives can join the platform to search, evaluate, establish IS opportunities for their facility and evaluate the related gain and advantages.

They can register their facilities and add several information about processes, materials flows, etc., as well as perform some analysis.

Symbiosis expert: consultants specialised in Industrial Symbiosis and its implementation can register to the platform to support facilities in searching, evaluating, establishing IS opportunities. They can also identify and add new industrial symbiosis opportunities.

Technology/solution provider: professionals responsible for the design, implementation and integration of the required technologies and solutions for IS establishment (e.g. waste characterisation/ conversion / recycling / transport, specific consultancy etc.).

Technology/solution providers can sell their services through the marketplace.

Observer: (read-only users) can join the platform to obtain an overview and collect specific information related to the Industrial Symbiosis experiences in Europe. They can be researchers, the authorized government officer or a third party agency user.

Network manager: users can register as network manager if they want to create/manage networks.

According to the type of user, different can the objectives when using the platform and the parts they have access to. In the following, a list of the major features is presented. To further investigate the details, please refer to D6.4.

Data gathering (at the basic level)**:** users can find some pre-compiled processes on the "Processes" tab under "Opportunity Identification" section, associated to different products. Here they can add/delete some flow and select the material flows of interest.

Design: Users can also create more detailed models in the "Models" tab under "Opportunity assessment" section. The models section has three main parts: Flow, Unit Process and System Model, which allows user to design even complex models.

Opportunity identification: Based on the inserted information, user can search for Industrial Symbiosis opportunities, thanks to specific matching algorithms.

Marketplace: Through the Marketplace, users can search for other facilities, with which establishing IS synergies. Thanks to a dedicated messaging tool, they can directly contact them. Users can also use the marketplace to search for professionals able to provide the specific services they need to establish the IS (e.g. waste characterisation/ conversion / recycling / transport, specific consultancy etc.).

Analysis: The analysis section consists of three parts. The user can perform analyses on models, facilities and networks. When the user selects one of three options, different available KPI indicators are listed (e.g. total GHG emissions, total virgin raw material consumption, total energy consumption, etc.).

Geo-clustering: In the geo-clustering section, users can visualise specific geo-referenced information on a map, related to on-going Industrial Symbiosis experiences.

Videos: To support users with the Platform, different tutorial videos have been uploaded.

Material and process LCI library

One of the objectives of WP6 was to organize the data collected through the Platform in the FISSAC LCI database. As propaedeutic activity for this task, different free LCI databases (Inventories and Dataset) have been uploaded, to allow users to start from these to design their own models and build their own inventories. The full details are reported within D6.6 "*FISSAC LCI Database*".

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VALIDATION OF THE FISSAC MODEL

Within WP6, a validation of the model has been performed, with the aim of identifying its main strong and weak points. For the validation, different perspectives have been considered:

- **Validation from technical point of view:** the first step to validate the model is to demonstrate that it is feasible to implement the Industrial Symbiosis synergies proposed. The industrial production and the real scale demonstration performed within WP5 has been taken as a reference and the main steps followed and the main stakeholder involved were analysed, to detect the main difficulties encountered and, most important, the solutions adopted.

- **Validation from environmental/ economic point of views:** to consider the model valid, it is important to define if the application of the model is beneficial, from the environmental and the economic point of views, and if it can contribute to reduce emissions and costs. The quantification of the benefits that could arise when applying this model to the selected case studies has been performed within Task5.5 "*Sustainability assessment of the solutions*".

- **Validation from social point of view:** to apply the model on large scale, social acceptance is fundamental. This is why it is important to define if the model is socially accepted and which is its impact from the social point of view. Preliminary evaluation on this point have been made within Task10.4 "*Social engagement and acceptance*".

- **Validation from replicability point of view:** since the model has been applied to the construction value chain only, and only in certain countries, it is important to evaluate if it is applicable also to other contexts (i.e. other sectors and other countries). WP7 is devoted to the evaluation of the replicability potential of the model and to the identification of the main drivers and barriers for its application.

Validation from technical point of view

For the validation from the technical point of view, a questionnaire has been prepared and shared among the partners responsible for the case studies.
Full details about the case studies activities are available within D5.3 "*Real Case Study demonstration CS1 to CS5*".
The results of the questionnaires have been summarised and reported within 4 SWOT analyses.

SWOT analysis

A SWOT (*strengths, weaknesses, opportunities, and threats*) analysis is a framework used to assess drivers and barriers, both internal and external to the system under evaluation. In this framework, this assessment is applied to the specific Industrial Symbiosis opportunities investigated through the Case studies of the FISSAC project.
Strengths and weaknesses represent internal factors — things that are within the case study boundaries and can be changed.
Opportunities and threats are external — things that are going on outside the case study, e.g. in the larger market. It is possible to take advantage of opportunities and protect against threats, but not to have complete control over them. An example is represented by the issues that could arise with virgin raw materials supply: problems with provision of natural raw materials could represent an opportunity for the development of solutions based on secondary raw materials, since they represent an alternative to e.g. quarry extraction.

The results from the questionnaires, as well as the 4 SWOT analysis are reported within D6.8.

In general, it can be stated that the Industrial Symbiosis opportunities investigate within the project have shown **good performances**: in most of the case studies the innovative products developed within the project have technical characteristics that are comparable to the standard products (major difficulties have been encountered within the innovative ceramic tiles case study).
One of the drawbacks is that in all cases the secondary raw materials requires additional treatments[1] before their use (appropriate separation, cleaning, drying, etc) which could involve **extra costs**. Also transports

[1] Several closed loop recycling processes to transform waste into secondary raw materials have been developed and tested within WP2 and WP3

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constitute a cost that should be carefully evaluated: long distances could involve costs that could made the IS unprofitable.
The necessity of a **local value chain** is thus considered fundamental, also to avoid logistic and regulatory barriers (arising, for example, when crossing national borders).
Manufacturing processes are dependent on the **supply of materials**, which should be constant: a potential weakness of producing products with secondary raw materials is that their availability could be less stable. Anyway, it should be considered that also virgin raw materials could be subject to different issues in the future, not only because they represent non-renewable resources (e.g. clay, iron ore and limestone), but also because their provision could be limited by other issues (like for examples the environmental and landscape issues affecting the quarry extraction).

Validation from environmental/ economic point of views

In the initial phases of the project, some preliminary activities were performed to evaluate the environmental and economic impacts associated with the innovative products developed in the FISSAC project: in D3.1 ("*Lifecycle assessment of new processes, materials and products – Eco cement, Green concrete, Ceramic tiles and Rubber wood plastic composite"*) and D3.2 ("*Life Cycle Costing of new processes, materials and products - Eco cement, Green Concrete, ceramic tile, rubber wood plastic composite"*) the preliminary results of the assessment were reported.
These findings have been refined within the final report D5.5 ("*Life Cycle Assessment of real case studies"*).
Indeed within Task5.5, "*Sustainability assessment of the solutions: LCA and LCC of real case studies*", the eco-innovative products and manufacturing processes have been compared to the state-of-the-art ones, to detect potential benefits arising from the application of the FISSAC model.
To evaluate if and how much it is possible to reduce emissions and costs thanks to the innovative approach proposed, i.e. substituting virgin raw materials with secondary raw materials, LCA and LCCA methodologies can be applied to provide a clear and objective answer.
Data from the real scale implementation of the different solutions are gathered to build models, which can be compared with the respective benchmark.

Validation from social point of view

Since social engagement and acceptance are considered important elements to facilitate the market uptake of the proposed model, they have been investigated during the project.
In general, Living Labs can be considered effective instruments to investigate and even improve the social acceptance: indeed, during the project they have been established in different countries and have represented one of the channels to disseminate the project results and consequently to enhance stakeholder awareness and acceptance. The main finding of the LLs are reported within D7.3 "Final Publications regarding living lab for FISSAC model".

In addition, in the framework of Task10.4 activities, the coordinators of the Living Labs established within the project were asked to define, in a scale going from *very much* to *not at all*, the social impact categories that have been taken into consideration or perceived as relevant over the development of the living labs.

The results show that the majority of the impact categories have been properly addressed by the living labs. This is a positive index in terms of stakeholder engagement and topics addressed by the living labs activities. In addition, all the impact categories corresponding to the inter-company interaction level show value above the threshold value, meaning that the living labs are an effective tool to facilitate the matchmaking between companies.

In general, **lack of trust and collaboration among stakeholders** has been identified as one of the potential barriers for the establishment of IS network; this is way putting in contact stakeholders and creating trust among them is considered fundamental: the organisation of the Living Labs offered ideal **networking opportunities**, easily replicable also in the future. Collaboration among relevant actors should be promoted to make IS synergies possible.
Another element that should be taken into account is the consumer role: **well-informed consumers can drive the transition** to alternative and circular business models, while at the same time fake news and poor reliability of scientific communication can represent a real problem for the transition from a linear to circular economy. Providing to the consumer reliable information about the environmental impacts of the products, for example, can represent an enabler for their market uptake.

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Validation from replicability point of view

One of the ambitions of the project, once the model is defined and validated, is to replicate it outside the project itself, in other countries and other sectors.
Within WP7 and in particular within T7.3, the replicability potential of the FISSAC model has been investigated; the main results are reported within D7.5 "*Project validation, SWOT and concept replicability*".

According to the SWOT analysis performed, it can be stated that **the Case studies investigated within the FISSAC project has a high replicability potential**, since they have presented good results from the technical point of view, if compared to standard products (except for innovative ceramic tiles, for which some improvements are still necessary).

To assess also the replicability potential at country level, and the replicability potential in other sectors, specific criteria have been developed and reported in D7.2 "*Report on Industrial segmentation, criteria and correlation to the FISSAC first application*": these criteria have been used to guide the evaluations performed. To each criteria, it is possible to assign a score, from 1 to 5, where in general 1 indicates low potential and 5 high potential.

With reference to the replicability potential in other countries, the FISSAC partners responsible for the organization of the LLs have been involved: they have been asked to compile the matrix with the criteria for their country, to provide some insight; of course, this assessment can't be exhaustive, but can provide a first overview at country level.
In Figure 3, the countries and the partners involved in the assessment.

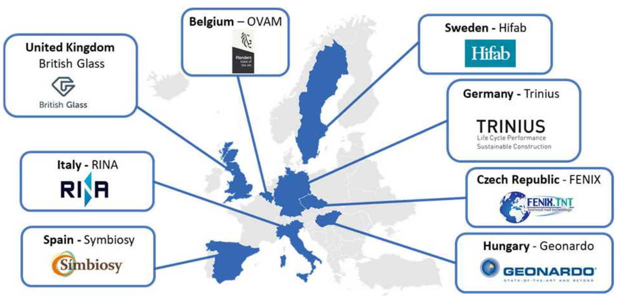

Figure 3 Framework of the replicability potential evaluation in different EU countries

Analogously, different criteria have been developed and used to evaluate the replicability potential of the FISSAC model, if applied to different sectors. This assessment represents a sort of pre-evaluation of the potential for different secondary raw materials and sector investigated.

The material streams investigated are:

- Wood and plastic from C&DW
- Gypsum plasterboard
- Copper and copper slags
- Fly ashes.

Generally, it can be stated that the scores assigned in the Evaluation Matrix have shown a good replicability potential of the FISSAC model, for both assessments performed (replicability in different countries and replicability in different sectors). Full details and explanation about each criteria are available in D7.5.

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CONCLUSIONS

Summarising, it can be stated that the **FISSAC model** mainly consist of four different elements: the FISSAC IS scenario, the Methodology, the Software Platform and the FISSAC material, and process LCI library.
Basically the methodology is a part of the FISSAC model and describes the necessary steps to establish industrial symbiosis; within the FISSAC project these steps are realized and applied to the construction value chain and validated through different case studies. The FISSAC Platform, supporting various steps of the IS methodology including opportunity identification, opportunity assessment and network design, acts as an enabler of the IS methodology and helps the FISSAC IS Model to be replicable beyond construction value chain.
The real experience gained (reported within the library/database) as well as the main outcomes of the projects (e.g. the platform or the Living Lab concept) are part (together with the methodology) of the final model of the project.

To provide a **validation** of the model that has been developed during the project, different perspectives have been considered: in particular, the technical, environmental/ economic, social and replicability point of views have been taken into account.
To assess the technical point of view, the different case studies investigated during the project have been taken as references and the main drivers and barriers have been highlighted. For each case study, a SWOT analysis has been reported, to present the main strong and weak points. In general, the innovative products manufactured within the project using secondary raw materials present good performances, comparable to the state of the art ones, and consequently high replicability potential. At the same time, the scores assigned in the Evaluation Matrix aimed at evaluating the replicability potential of the FISSAC model in different countries and different sectors have shown in general a good replicability potential of the FISSAC model.
To assess the social point of view, during the project a large number of different stakeholders has been involved through the Living Labs and a wide range of topics have been discussed. Analysing different social impact categories, it can be noticed that the majority of them have been properly addressed by the living labs, and this represents a positive index in terms of stakeholder engagement and subjects addressed by the living labs activities.

References

FISSAC D1.8 “Initial outline of FISSAC Industrial Symbiosis Model and Methodology”
FISSAC D6.7 “Final version of FISSAC Industrial Symbiosis Methodology”
FISSAC D6.4 “FISSAC Platform Final Version”
FISSAC D6.6 “FISSAC LCI Database”
FISSAC D5.3 “Real Case Study demonstration CS1 to CS5”
FISSAC D3.2 “Life Cycle Costing of new processes, materials and products - Eco cement, Green Concrete, ceramic tile, rubber wood plastic composite”
FISSAC D5.5 “Life Cycle Assessment of real case studies”
FISSAC D10.5 “Report of social engagement and acceptance”
FISSAC D7.3 “Final Publications regarding living lab for FISSAC model”
FISSAC D7.2 “Report on Industrial segmentation, criteria and correlation to the FISSAC first application”
FISSAC D7.5 “Project validation, SWOT and concept replicability”

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