RESOURCE AUDIT AND INDUSTRIAL SYMBIOSIS

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ABSTRACT

Improve resource efficiency through circular economy is one of the key element of the EU Green Deal. Besides being beneficial for the reduction of raw materials supply, moving towards a circular economy will parallelly contribute to reach important objectives of the EU Green Deal, such as the reduction of greenhouse gas emissions and the decrease of environmental pollution.
Industrial symbiosis allows to implement the concept of circular economy in specific territorial contexts.
This paper briefly describes the methodological approach and the tools developed and tested by the Italian National Agency for New Technologies Energy and Sustainable Economic Development (ENEA) to support small and medium enterprises to improve their resources efficiency. This approach includes the resource audit and the methodology for the definition of industrial symbiosis networks and it is structured in four steps: data collection, identification of possible valorisation options for resources either internally to the company or externally though industrial symbiosis, the analysis of potential benefits and barriers, and the preparation of a summary report.

INTRODUCTION

The Green Deal of the European Commission has posed a set of ambitious intercorrelated challenges for our society (EC, 2019). Increasing the circular use of resources is, per se, an important step towards a sustainable future (EC, 2020), and it is instrumental to several of the abovementioned challenges, such as carbon neutrality (EU, 2020) and reduction of pollution (EC, 2021). Moreover, circular economy may contribute to reduce the dependence of Italy and, more in general, EU member states from imports of raw materials opening new business opportunities for companies and, at the same time, potentially limiting negative effects associated with variations in the supply of raw materials, as it happened in 2021 with the raw materials crisis.

Circular economy allows optimising the use of resources, contributing to decouple economic growth from the use of resources and related environmental impacts. By supporting the physical sharing of materials, energy, water, by-products, services, competences and/or capacities between different industries, industrial symbiosis supports the implementation of the concept of circular economy in specific territorial contexts.

Circular economy and industrial symbiosis not only can bring benefit to the reduction of the extraction and use of raw materials and associated environmental impacts, but also represents a competitive advantage for companies that, through industrial symbiosis, have the opportunity to cut costs for the supply of raw materials and/or to increase the economic gain associated with the management of waste streams or by-products. Hence, moving towards a circular economy implies a parading shift. Waste and by-products should not be seen by organisations as a burdens to be managed as much efficiently as possible, but rather as opportunities to improve their business.

However, to be effective, the optimisation of resource efficiency and the implementation of industrial symbiosis practices should be based on a strategical planning.

To this purpose, the Italian National Agency for New Technologies Energy and Sustainable Economic Development (ENEA) has developed operational methodologies and tools for the

implementation of industrial symbiosis (for clusters, areas and/or networks) and for the audit of resources at micro-level (e.g. company level) (e.g. Cutaia et al, 2020; Beltrani et al., 2019).

As the industrial symbiosis, the resource audit has the aim to boost resource efficiency at micro-level, deeply analysing the way resources are used and their streams in input, in output and through the processes, thus obtaining both economic and environmental advantages. It focuses on both internal aspects of the company, by means of an efficiency increase and processes optimization, and on the possible cooperation of the company with other companies and stakeholders at territorial level (industrial symbiosis). While industrial symbiosis can be seen more as a systemic approach, resource audit has its main application at the micro scale. Nevertheless the two can work together for the most effective optimisation of resources. Furthermore, resource audit can complement the mandatory energy audit to which companies are more familiar. The integration of energy and resource audits is beneficial for companies that can optimise the method of analysis and collecting information and the use of the collected information, instrumental for the two types of audit. Opposite to energy audit, the resource audit is not mandatory for any kind of company neither it is required as voluntary initiative. However, the experience of ENEA in the application of this approach demonstrates that an improvement in the management of resources can contribute to increase organisations' competitiveness thanks to tangible positive economic effects on costs reduction and/or revenues increase.

THE METHODOLOGICAL APPROACH TO THE CLOSURE OF CYCLES

Thanks to the experience gained in different research projects at the national and European scales, ENEA has defined a methodological approach to support companies in the implementation of circular economy and industrial symbiosis practices.

The methodological approach is structured in two main interlinked components: the resource audit and the definition and implementation of industrial symbiosis.

The resource audit is focused on the company scale and guides the company in the identification of potential inefficiencies along the production process. Based on the information collected with the resource audit, the company is provided with the elements to identify solutions to reduce inefficiencies either internally, for example thought he recirculation of material or energy flows or involving other companies.

The methodology for industrial symbiosis, instead, refers to a broader scale, e.g. cluster or regional scale. It involves a set of stakeholders and its aim is to foster the sharing of any kind of resources between different companies.

The synergy between the two components, i.e. resource audit and industrial symbiosis, allows to identify and implement the preferable solutions to optimise the circular use of resources.

The methodological approach developed by ENEA is briefly described in the following section. More detailed information on the methodology are reported by Cutaia et al. (2018, 2020).

RESOURCE AUDIT AND IDENTIFICATION OF INDUSTRIAL SYMBIOSIS SYNERGIES

This section describes the general principles of the methodological approach developed and applied by ENEA. Although the methodology has been developed to be as much as possible applicable in different contexts, it has to be highlighted that specific circumstances such as the business model, sector, geographic, cultural and legal operating context, ownership structure, and the size and nature of impacts may affect the way these general principles are applied in specific contexts.

The methodology for resource audit is especially developed for small and medium enterprises (SMEs) that may need support in the identification of inefficiencies along the production process and solutions to improve their resource management. ENEA can support companies in the pathways for the resource audit in order to facilitate the application of the methodology.

The methodology for resource audit is designed following the approach of the energy audit (D.lgs. n. 141/2016), that, from previous experiences at the national level, has demonstrated to be effective in supporting companies to increase their energy efficiency (ENEA, 2017).

The resource audit is structured in four steps (Figure 1).

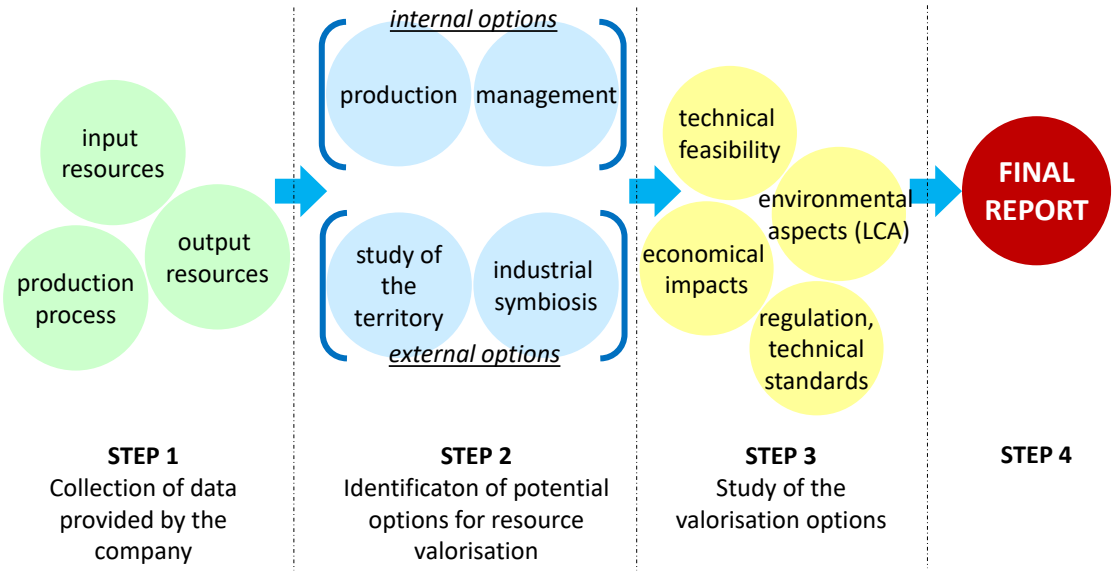

Figure 1: Methodological steps of for resources audit (Cutaia et al, 2020)

The first step of the resource audit is the collection of data on the production process, and on its inputs and outputs. This includes the description of the production processes taking place at the production plant, the definition of system boundaries, the quantification and characterisation of flows of resources entering and leaving the production processes, and of environmental emissions and waste. A list of the indicators taken into consideration for the resource audit is reported in Table 1. This step implies the involvement of the company who is asked to provide the abovementioned data. To facilitate this activity and support companies in the data collection, ENEA has developed a specific format (Figure 2).

Table 1: Indicators considered in the resource audit methodology (Cutaia et al., 2020)

	Aspects					
	Organisation profile	**Materials**	**Energy**	**Water**	**Emissions**	**Effluents and Waste**
INDICATORS	- Name - Primary brands, products, services - Location - Headquarters - Number and names of countries where it operates or has significant operations - Nature of ownership and legal form - Markets served - Scale (employees, operations) - Supply chain - Quantity of products or services provided	- Materials used - Percentage of materials used that are recycled input materials	- Energy consumption outside of the organisation - Energy consumption within the organisation - Energy intensity - Reduction of energy consumption - Reductions in energy requirements of products and services	- Total water withdrawal by source - Water sources significantly affected by withdrawal of water - Percentage and total volume of water recycled and reused	- Direct-greenhouse gas (GHG) emissions - Energy indirect GHG emissions - GHG emissions intensity - Reduction of GHG emissions - Emissions of ozone depleting substances (ODS)	- Total water discharge by quality and destination - Total weight of waste by type and disposal method - Weight of transported, imported, exported, or treated waste - Percentage of transported waste shipped internationally

Non-renewable materials

Material type	Source (ext./int.)	Resources (commercial name)	Quantity (t)	Quantity (m^3)

Recycled materials

Recycled input materials used	Quantity (t)	Quantity (m^3)

Other materials used*

Material type	Source (ext./int.)	Resources (commercial name)	Quantity (t)	Quantity (m^3)

TOTAL input materials used (t, m^3)

TOTAL recycled input materials used (t, m^3)

**all forms of materials and components that are part of the final product*

TOTAL WEIGHT OF WASTE BY TYPE AND DISPOSAL METHOD					WEIGHT OF TRASPORTED, IMPORTED, EXPORTED, OR TREATED WASTE DEEMED HAZARDOUS UNDER THE TERMS OF THE BASEL CONVENTION ANNEX I, II, III, AND VIII, AND PERCENTAGE OF TRASPORTED WASTE SHIPPED INTERNATIONALLY			
Description of waste	Waste type	Phisical state	Destination of waste	Total weight waste(kg)	Description of waste	Type of waste	Destination of waste	Total weight hazardous waste (kg)

(*)= to specify the frequency of the controls, dates last control laboratory that effects the controls

TOTAL WATER DISCHARGE BY QUALITY AND DESTINATATION

Type of water discharges (*)	Destination	Declared?	Treated?	Treatment process	Whether it was reused by another organization	Total water discharge (m^3/year)	Possible changes to reduce the quantities of water discharges during future productive cycles

(*)= escluding collected rainwater and domestic sewage

TOTAL WATER DISCHARGE	

Figure 2: Examples of the data collection format developed by ENEA (Cutaia et al., 2020)

The second step of the resource audit consists in the identification of potential options for resource valorisation either internally to the organisation or externally.

The internal valorisation of resources can be obtained through an optimisation of the resource management system of the company.

The identification of possible resource valorisation routes in other sectors, instead, is preliminary to the creation of industrial symbiosis pathways. This phase of the methodology foresees that the company identifies potential options for the improvement of its resource efficiency in other productive sectors.

Once possible synergies are identified, there is the need to explore the actual potential for their implementation through the creation of an industrial symbiosis network. ENEA has developed a specific methodology for this purpose which is explained in depth in the work by Cutaia et al. (2018). The first organisational phase of the methodology for industrial symbiosis includes a detailed analysis of the territorial context, the definition of a georeferenced database of companies belonging to the same area, networking activities, and the organisation of workshops for companies where ENEA supports the identification of synergies. This is followed by an operational phase during which workshops take place. Data on input and output resources collected during the

workshop are analysed firstly during the workshops involving companies and, subsequently, are loaded in the ENEA industrial symbiosis platform, described in the following section, that allows to further explore potential synergies between companies.

The outcomes of this step are the definition of potential connections between companies that can be represented through <origin,destination> strings (Figure 3).

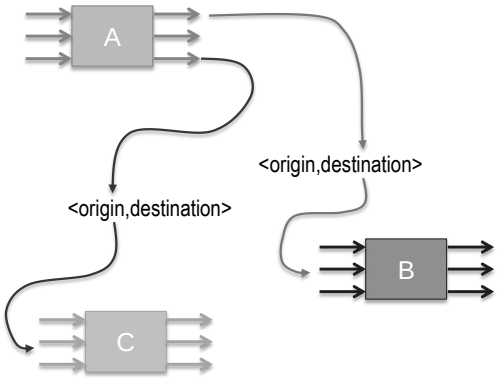

Figure 3: Example of <origin, destination> strings (Cutaia et al., 2020)

Once the potential routes for the valorisation of resources have been identified either internally to the organisation or through industrial symbiosis pathways involving different organisations, it is necessary to analyse the feasibility of identified solutions, focusing on the technical, economic, and legislative dimensions.

Moreover, it is recommended to assess the environmental performance of identified resource valorisation pathways to ensure that the environmental impacts of their implementation is minimised. Life Cycle Assessment (LCA) is a method aimed to quantify the environmental impacts of products and processes adopting a supply chain perspective and considering multiple environmental indicators. It allows an holistic assessment of the environmental burdens of the identified solutions since it is able to capture potential trade-offs, for example related to the "transfer" of impacts within life cycle stages or environmental compartments.

The outcomes of the resource audit are finally summarised in a report aimed to provide to the company the information to improve its overall resource efficiency. The document includes information on the resources management system and an overview of possible options to increase resource efficiency, either internally to the organisation or involving other companies. In addition it includes a summary of the feasibility analysis, the potential barriers that can be encountered in the implementation of industrial symbiosis, as well as a description of potential economic and environmental benefits.

SYMBIOSIS PLATFORM

In order to support the creation of cross-sectorial symbiosis pathways between companies belonging to the same geographical area, ENEA has developed an online platform called Symbiosis (http://www.industrialsymbiosis.it/piattaforma). The aim of this platform is to match the supply of resources of any kind, such as materials, energy, competences and services and facilitate the exchange between different companies.

Companies interested in using the platform are asked to register and to report and characterise their production of waste, by-products or other kinds of resources they would like to share or the receive from other companies.

The collection of this pieces of information supports the identification of possible synergies between the companies.

CONCLUSIONS

Circular economy can represent a win-win solution both for companies and for the environment. Indeed, it may be an opportunity for companies to increase their resource efficiency with positive effects on their business. At the same time, circular economy can contribute to reduce the extraction of raw materials, emissions of toxic pollutants in the environment and greenhouse gases.

However, to ensure economic and environmental benefits the implementation of circular economy should be properly designed.

ENEA has developed and tested in different projects operational methodologies and tools to support companies, especially small and medium enterprises, in the identification of pathways to increase their resource efficiency. The ENEA methodological approach focuses on the company and territorial dimensions. Building upon the positive experience with the energy audit, a methodological procedure for a resource audit for companies has been defined. The resources audit includes the analysis of the production process and related inputs and outputs, the identification of possible solutions to improve resource efficiency internally to the organisation or externally through the creation of industrial symbiosis pathways, a feasibility study and the analysis of potential economic and environmental benefits, and the elaboration of reports. Key to the success of the application of the methodology are the active involvement of companies that are asked to provide information on the input/output resources, and the support of ENEA in different steps of the definition of the strategical actions to improve the resource efficiency of companies.

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