Strategies for Sustainability

Roberta Salomone · Andrea Cecchin · Pauline Deutz · Andrea Raggi · Laura Cutaia *Editors*

Industrial Symbiosis for the Circular Economy

Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach

Springer

Chapter 3
Resources Audit as an Effective Tool for the Implementation of Industrial Symbiosis Paths for the Transition Towards Circular Economy

Laura Cutaia, Tiziana Beltrani, Valentina Fantin, Erika Mancuso, Silvia Sbaffoni and Marco La Monica

Abstract The optimisation and the resources saving can represent an economic lever and support companies' competitiveness. In Italy, the national government has established a strong policy for energy saving, energy efficiency and for incentives to energy production from renewable sources, whereas polices and tools for improving resource efficiency have not been developed yet. The purpose of this work is to present an operational methodology, developed by ENEA, for the audit of resources at the company level, with the aim to boost resource efficiency, thus obtaining both economic and environmental advantages. This methodology operates both internally, by means of an efficiency increase and processes optimisation, and externally, by means of the cooperation with other companies and stakeholders at territorial level (industrial symbiosis). The proposed resources audit is based firstly on the analysis of input and output resources used and produced by a company and then on the investigation of possible options to reduce their consumption or under-utilization (waste disposal, etc.).

L. Cutaia (✉) · T. Beltrani · E. Mancuso · S. Sbaffoni · M. La Monica
Resource Valorisation Laboratory (RISE), ENEA—Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Via Anguillarese 301, Rome, Italy
e-mail: laura.cutaia@enea.it

T. Beltrani
e-mail: tiziana.beltrani@enea.it

E. Mancuso
e-mail: erika.mancuso@enea.it

S. Sbaffoni
e-mail: silvia.sbaffoni@enea.it

M. La Monica
e-mail: marco.lamonica@enea.it

V. Fantin
Resource Valorisation Laboratory (RISE), ENEA—Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Via Martiri di Monte Sole 4, Bologna, Italy
e-mail: valentina.fantin@enea.it

R. Salomone et al. (eds.), *Industrial Symbiosis for the Circular Economy*, Strategies for Sustainability, https://doi.org/10.1007/978-3-030-36660-5_3

Keywords Industrial symbiosis · Life cycle assessment · Operative handbooks · <origin, destination> string · Resource audit · Resource efficiency

3.1 Introduction

The 2030 Agenda for Sustainable Development of the United Nations Environment Program (UNEP 2015), with its 17 objectives (SDG—Sustainable Development Goals) aims to eradicate poverty, conserve land resources, protect ecosystems for the welfare of present and future generations. Among these objectives, the number 12 is related to consumption and sustainable production, i.e. to do more with less, thus increasing productivity, reducing both the use of resources and environmental impacts throughout the entire life cycle of products and, consequently, improving quality of life. It is important to point out that, according to the UN, the world population will reach 9.7 billion in 2050 (UN 2015), with an increase of 33% compared to 2015, resulting in economic growth that will lead to an increase in environmental pressures and demand for material resources (Krausmann et al. 2009; UNEP 2012). In order to limit the impacts arising from the exploitation of resources and to increase human well-being, a decoupling among economic activity, environmental impacts and natural resource use are necessary (UNEP 2011).

A transition from a linear economy towards a circular economy can be an effective strategy to achieve this goal (Ellen MacArthur Foundation 2012, 2013, 2014, 2015). In the last centuries the global economy's evolution has been dominated by a linear model of production and consumption, the so-called '*take-make-dispose*' model where companies extract materials, apply energy to them to manufacture a product, and sell the product to a final consumer, who then discards it when it no longer works or no longer serves the user's purpose. The circular economy represents a radical paradigm shift from the linear economy model and also supports the development of new sustainable business models, with the final aim to increase both the potential for closed-loop productive systems and the resource efficiency in a territory. Industrial ecology and industrial symbiosis are effective approaches towards this direction, since they promote more sustainable use of resources and can lead to several economic, environmental and social advantages (Cutaia and Morabito 2012; Garner and Keoleian 1995) by means of a more efficient use of energy inputs and materials as well as through the waste reduction at source and the implementation of closing the loop, i.e. linkages where the waste of a production line becomes the valuable input of another one (Ayres and Ayres 2002; Jelinski et al. 1992; Desrochers and Leppälä 2010). Within industrial ecology, industrial symbiosis is one of the most relevant tools for implementing circular economy at territorial level. For this reason, it is included in several EU policy documents (European Commission 2011, 2012, 2015; European Union 2018). Industrial symbiosis can be defined as an integrated system to share resources (i.e. materials, water, by-products, scraps, services, skills, tools, databases, etc.) among different companies where an output of a company can be shared with another company, which will utilize it as an input for its production process (Chertow 2000; Lombardi and Laybourn 2012).

It is important to highlight that drawing on industrial ecology, industrial symbiosis incorporates many elements which emphasise the cycling and reuse of materials in a broader systems perspective: embedded energy and materials, life cycle perspective, cascading, loop closing and tracking material flows. In particular, a material tracking for symbiosis identifies and quantifies all significant material inputs and outputs of each firm in the industrial system in order to suggest opportunities for sharing materials among firms as well as for more efficient resource use in the industrial ecosystem. There are also several useful industrial symbiosis tools in order to plan new symbioses or to increase existing matches: industrial inventories, input/output matching, stakeholder processes and materials budgeting. In particular, the latter is a materials tracking system which is used to map energy and material flows through a chosen system and can be a basic building block of an industrial symbiosis analysis because it based on three key concepts: (i) reservoirs; (ii) flux; (iii) sources and sinks (Chertow 2004).

In this context, the purpose of this work is to develop an operational methodology for the audit of resources at company level based on the analysis of input and output resources used and produced by a company and on the investigation of possible ways to reduce their consumption or under-utilization (waste disposal, etc.) in order to facilitate a transition to circular economy, using both industrial ecology and industrial symbiosis approaches.

3.2 Resources Audit: The ENEA Methodology

On the basis of the experience gained in the last years by means of different research projects at both national and European level, ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development) has developed an innovative methodology (Fig. 3.1) for carrying out company's resource audit, in order to support the implementation of circular economy actions and to increase resource efficiency and industrial symbiosis (Cutaia et al. 2014). This methodology can be particularly effective to support Small and Medium Enterprises (SMEs), which seldom have the necessary knowledge and expertise, in the transition towards circular economy models. The resources audit has been developed on the basis of an analogy with the energy audit, a well-known methodology which is mandatory in Italy (Decreto Legislativo 18 luglio 2016, n. 141) and which, over the time, has pushed Italian companies to become more and more energy-efficient (ENEA 2017).

The audit of resources is focused on the inventory, understanding and optimisation of input and output resources used and/or produced by a single entity (such as a company or a part of it): the main aim of the audit is to save company's resources by means of their optimisation and savings at internal and external level. Both these options, in addition to the resource savings, can lead to environmental and economic

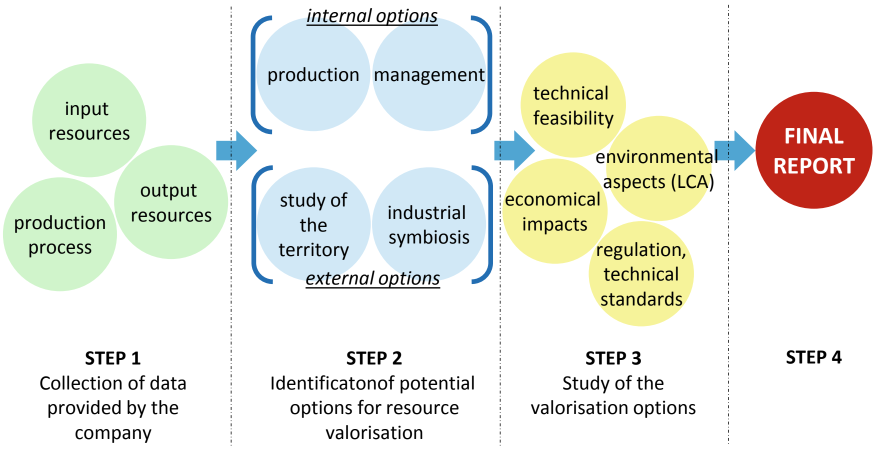

Fig. 3.1 Scheme of the ENEA's methodology

benefits. While internal optimisation requires only the company's effort, the 'external' optimisation needs collaboration with other stakeholders who can contribute to the alternative supply of input resources and/or destination of output resources.

The first step of the methodology is the collection of data on the input and output resources, which are provided by the company itself. For this purpose, a data collection spreadsheet developed by ENEA is used. Strong proactive cooperation of the involved company is required for a successful data collection.

The resources audit is mainly based on the availability of the following information:

- Data on the input and output resources. For each resource (material, energy, expertise, service, etc.) and for each production process, the following information must be collected: description of the resource, quantity, type of production (continuous, batch), resource category (e.g. for materials if by-product or waste), resource classification (European Waste Code—EWC if waste, 'PRODuction COMmunautaire'—ProdCom code if product, Nomenclature statistique des activités économiques dans la Communauté européenne—NACE code if service);
- Description of the production processes adopted by the company, with a focus on the resources used in each step;
- Other companies in the surrounding area potentially interested in sharing resources (as outputs destination and/or inputs suppliers, whereas the considered area depends on the economic and technical feasibility of resources sharing). This information is the result of a thorough study of the territory potential combined with the input and output data provided.

According to this methodology, sustainable and innovative production and management options as well as circular business models are identified, with the final goals of implementing both industrial symbiosis and resource efficiency (i.e. reduction of both waste production and resource use).

The environmental impacts and the potential advantages related to more efficient resource use and resource management can be estimated by means of life cycle based methods and tools, such as ISO Life Cycle Assessment (LCA) method, which can help in identifying the main environmental burdens of the current resource use at company level and the possible benefits obtained by the implementation of industrial symbiosis paths.

A final report on the results coming from the resources audit is produced for the involved company where also main information on relevant stakeholders is reported. This document focuses on the resource management system as well as on the strategies and options for increasing resource efficiency, including the related environmental impacts and possible environmental and economic benefits.

3.2.1 Data Collection on Resources and on the Production Process

The first step of the methodology is the identification of the following key aspects:

1. The processes taking place at the production plant;
2. The system boundaries referred to process(es);
3. The input resources (e.g. raw materials, water, energy, etc.) and the outputs (e.g. products, by-products, emissions, waste, services, capacities, etc.), referred to the entire production plant as well as to the single process;
4. The type (e.g. renewable or non-renewable; virgin or recycled; etc.) and amount of inputs used by the process and outputs generated. As an example of input resources, raw materials used by an organisation can be non-renewable materials, such as minerals, metals, oil, gas, or coal; or renewable materials, such as wood or water. Both renewable and non-renewable materials can consist of virgin or recycled input materials. The type and amount of materials the organisation uses can indicate its dependence on natural resources, and the impacts it has on their availability. The organisation's contribution to resource conservation can be indicated by its approach to recycling, reusing and reclaiming materials, products and packaging;
5. Actions already taken to address the actual and potential negative environmental impacts identified in the production process, and whether these actions are intended to prevent, mitigate, or remediate the impacts;
6. The list of indicators which can provide information on the placement of the company regarding the resource efficiency and the transition towards circular economy. These indicators can inform about the organisation's economic, environmental and social performance. Furthermore, the indicators refer to what can be measured and—consequently—monitored and managed, guiding ENEA and the organisation through the process of resource audit. These indicators are established in the so-called material aspects.

The methodology defines the following material aspects, each one with its specific indicators (Table 3.1):

- Organisation profile, in terms of location, size, production process, product, services, etc.
- Materials. The indicators established in this aspect describe the organisation's contribution to the conservation of the global resource and its efforts to reduce the material intensity. Figure 3.2 shows formats used for the data collection on input recycled and virgin materials used by the company;
- Energy. Any changes in the balance of energy sources can indicate the organisation's efforts to minimise its environmental impacts. Energy consumption has also a direct effect on operational costs;
- Water. Reporting the total volume of water withdrawn by source contributes to understand the overall scale of potential impacts and risks associated with the organisation's water use;
- Emissions. Reductions, or performance beyond compliance, can enhance relations with affected communities and workers, and the ability to maintain or expand operations. The volume of emissions has also direct cost implications, due to the emission trading systems;
- Effluents and waste. By progressively improving the quality of discharged water or reducing water volumes, the organisation has the potential to reduce its impact on the surrounding environment. Data on waste generation over several years indicates the level of progress of the organisation towards waste reduction efforts and the potential improvements in process efficiency and productivity. The reduction of both effluents and waste contributes directly to decrease costs for materials, processing, and disposal. Figure 3.3 presents the tables for data collection on waste and effluents;
- Products and services. For some sectors, the impacts of products and services during their use phase and at the end of their useful life can be equal or higher than those of the production phase. The significance of such impacts is determined by both customer behaviour and the design of the product or service;
- Transport. The environmental impacts of transportation systems have wide coverage, from global warming to local smog and noise. Impact assessment of transport is part of a comprehensive environmental management strategy.

Although the ENEA's methodology has been developed to be replicable and applicable to almost all companies, specific circumstances such as the business model, sector, geographic, cultural and legal operating context, ownership structure, and the size and nature of impacts affect how the organisation identifies the aforesaid material aspects and indicators.

Table 3.1 Indicators taken into consideration by the resource audit methodology

	Aspects			
	Organisation profile	Materials	Energy	Water
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
	Aspects			
	Emissions	Effluents and Waste	Products and services	Transport
Indicators	– 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	– Extent of impact mitigation of environmental impacts of products and services – Percentage of products sold and their packaging materials	– Significant environmental impacts of transporting products and other goods and materials for the organisation's operations – Significant environmental impacts of transporting members of the workforce

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

Fig. 3.2 Materials used which are recycled as input materials (percentage)

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	

Fig. 3.3 Effluents and waste

3.2.2 Searching for Industrial Symbiosis Matches

Companies in the surrounding area can be potentially interested in sharing resources (as destination of output resources or as supplier of input resources) for the implementation of industrial symbiosis matches and the creation of new cooperative and circular business models. It is noteworthy that these pieces of information are the result of the analysis of the industrial symbiosis potential coming from company's available input/output data and their alternative supply/destination scenarios, related

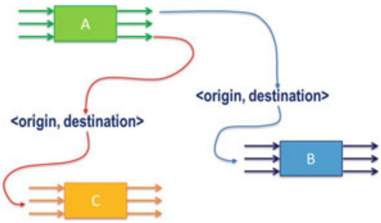

Fig. 3.4 Connection between output(s) and input(s) according to the logic of <origin-destination> strings

to the real options (e.g. companies able to use scraps as input materials) available in the area (whereas its extent depends on the case-by-case economic and technical feasibility proposed match).

Moreover, ENEA—as resources audit 'consultant'—plays a crucial role in helping the company in finding potential options for alternative scenarios for the supply of input resources and the destination of output resources. The connection between an available resource and its possible destination as input for another production process can be represented by <origin, destination> strings (Fig. 3.4).

The connection algorithm of the <origin, destination> string is based on the logic 'one-to-many', with the aim to find possible relations between the main characteristics of output from one company and its potential use as input resource for another company. Following the opposite direction, the same algorithm allows the practitioner or the industrial symbiosis facilitator to verify which resource, used or produced by different companies, satisfies the quality specifications necessary for its use, as input resource, for a certain company (Cutaia et al. 2015).

In addition to the description of the identified possible synergy, the <origin-destination> string mainly contains:

- Resource's information: resource's description by means of EWC Code or other appropriate codes (ATECO/NACE or PRODCOM if the resource is not a waste); resource's origin and composition;
- Possible resource's destinations using ATECO/NACE codes and information about its properties;
- Relevant regulations (at European, national and local level) and/or technical standards which rule the resource use as input for a specific production process;
- Other useful information;
- Keywords.

In order to define the potential destination of a resource (or alternative supply options) and, consequently, to implement industrial symbiosis paths, a comprehensive analysis of the production process and of the company's resource management system is required, along with the study of the following items:

- Resources flow, in terms of quality and quantity;
- Resources life cycle;
- Production and management of waste, by-products and scraps.

3.2.3 Operative Handbooks

As a result, the most substantial resource streams, in terms of quantity and costs for companies, are analysed in order to design symbiotic paths involving at least two companies.

Preliminary selection of companies that can, in a technologically proved and sustainable way, reuse these residues in their production processes is performed. A strong collaboration with the companies really interested to implement actual matches is thus required. The companies are promptly informed, through timely reports, on the progression of the study, with a short-targeted information leaflet on the potential use of the highlighted resources in their production process (Luciano et al. 2016).

All the information related to this path is contained in an operative handbook which supports companies towards a more efficient use of resources and in all steps of synergies' implementation: they include European, national and regional regulations, guidelines, technical standards, logistic and economical aspects, to be taken into consideration step-by-step along the path from origin company to the destination one, for the given resource stream.

A first draft of this handbook is prepared to provide many potential technical solutions for the reuse of waste and by-product materials, water, and energy between neighbouring industries. Then, this first draft is presented to the involved companies, but also to various stakeholders (e.g. local institutions, authorities and professional associations) to focus on operational aspects, potential barriers or critical issues which should be overcome. During the consultation phase, all the parties involved in the process of industrial symbiosis discuss on various issues related to the identified synergies. The proposed solution is validated and the operative handbook is definitely finalised after receiving all the observations and comments from the actors involved.

The evaluation of economic impacts of the options presented in the handbook is achieved through a comparison between two scenarios based on a profitability analysis for the companies involved:

- The Business As Usual (BAU) scenario, which takes into account costs and revenues of the current production process and resource management of the companies involved;
- The optimisation or 'symbiosis' scenario, which considers costs and revenues deriving from the synergies proposed according to an industrial symbiosis approach or from the improvements in resource management.

The economic data used to build these scenarios derive from interviews with the companies involved and from additional research aiming at estimating missing data.

Despite being recommended at the European level, the Italian law system makes it very difficult to guarantee a path of industrial symbiosis, since it is completely alternative to traditional waste management. In case of scraps sharing, the qualification of scraps as 'by-product' instead as 'waste' is needed in order to implement an industrial symbiosis match. Differently, waste sharing among companies is not permitted. Since the qualification of ‘by-product’ is very restrictive and its application can be very tricky, the operative handbook can support effectively the waste management, in terms of resource sharing. In other words, an industrial symbiosis path must always be supported by legal, administrative and technical information and requirements specifically focused on the analysed stream and its destination.

Operative handbooks are an interesting exercise to investigate new technologies and unknown solutions which could encourage companies to experiment new opportunities for eco-innovation and resource efficiency.

3.2.4 LCA

In the methodology, the environmental impacts and the potential advantages related to more efficient resource use and resource management is estimated by means of life cycle based methods and tools, such as ISO LCA method (ISO 2006a, b), based on Life Cycle Thinking (LCT) approach, which can identify the main environmental burdens of the current resource use at company level and the possible benefits obtained by the implementation of industrial symbiosis paths.

In fact, the holistic approach of LCA method can efficiently support the evaluation of the environmental performance of symbiotic systems because it includes the whole supply chain (Zhang et al. 2017).

In the context of industrial symbiosis, LCA can support the quantitative analysis of by-product sharing (Zhang et al. 2017) or of symbiosis networks (Mattila et al. 2012) and can allow both to choose the solution with the lowest environmental impacts and evaluate if symbiosis paths contribute to the improvement of the environmental performance of the whole system.

More in detail, the application of this method can contribute to verify the hypotheses formulated in the business planning phase, highlighting, for example, any negative consequences due to a particular configuration. In addition, LCA can help to identify improvement opportunities by the evaluation of the possible alternatives and limits of the current scheme and then it could provide new ideas for the design phase (Chiavetta et al. 2017).

In the context of the methodology for the resource audit at a company level, LCA can, therefore, represent a complementary effective tool which can be applied in combination with the audit, to comprehensively evaluate the resource use and the possible advantages of the identified symbiosis paths.

During the resource audit, an LCA study is performed on the possible symbiosis paths identified for the tracked resources, with the aim to evaluate to what extent the valorisation of the waste resource leads to a decrease of the potential environmental impacts of the traditional waste destination. For example, an LCA study can be carried out to compare the environmental impacts of the waste disposal by landfill or incineration and those of the reuse of the waste resource as secondary raw material in other production processes. In this way, the environmental savings can be highlighted, which can be also coupled with economic savings, thus contributing to the design of circular business options. It is important to point out that strong cooperation with the managers of the company involved in the resource audit is required for the execution of the LCA study, in particular for the relevant data collection. In addition, the LCA practitioner has to work in a team consisting of resource audit experts, who have a deep knowledge of legislation and technology expertise, in order to identify and exploit all possible valorisation of waste resources to be tested through the LCA method.

3.3 Conclusions

The ENEA's methodology for the resources audit is based on an in-depth analytical data collection covering all the flows of resources at company level, including material resources, energy, logistics, etc., and on fruitful cooperation with other companies. Starting from the data collection, the options for boosting resource efficiency are identified.

The main steps of the methodology are collection of data provided by the company (resources, production processes); identification of potential options for resource valorisation at both internal and external level; study of the valorisation options (technical feasibility, regulation, technical standards, environmental and economic impacts). The operative handbooks provide important information on quantities, analytical characteristics of resources' streams as well as standards and needs of potential destinations. Therefore, by means of the <origin, destination> strings, the operative handbooks focus on the potential for optimisation of some specific waste streams or underutilized resources, identifying specific destination sectors where these resources can be reutilized as input materials or can be shared with other companies (e.g. transport services).

The methodology is being tested in some specific applications with the aim to validate it and operatively assess its replicability and the economic and environmental benefits which can be achieved.

References

Ayres RU, Ayres LW (2002) A handbook of industrial ecology. Edward Elgar, Cheltenham

Chertow MR (2000) Industrial symbiosis: literature and taxonomy. Annu Rev Energy Environ 25(1):313–337

Chertow MR (2004) Industrial symbiosis. In: Cleveland CJ (ed) Encyclopedia of energy. Elsevier, San Diego

Chiavetta C, Fantin V, Cascone C (2017) L'Economia Circolare nel settore agroalimentare e il Life Cycle Assessement come strumento a supporto: il progetto FOOD CROSSING DISTRICT. ENEA technical report, USER-PG64-003, June 2017

Cutaia L, Morabito R (2012) Sostenibilità dei sistemi produttivi. Strumenti e tecnologie verso la green economy. ISBN 978-88-8286-258-9

Cutaia L, Morabito R, Barberio G, Mancuso E, Brunori C, Spezzano P, Mione A, Mungiguerra C, Li Rosi O, Cappello F (2014) The project for the implementation of the industrial symbiosis platform in sicily: the progress after the first year of operation. In: Pathways to environmental sustainability. Methodologies and experiences, XXIII, ISBN 978-3-319-03825-4 and ISBN 978-3-319-03826-1

Cutaia L, Luciano A, Barberio G, Sbaffoni S, Mancuso E, Scagliarino C, La Monica M (2015) The experience of the first industrial symbiosis platform in Italy. Environ Eng Manage J 14(7):1521–1533

Decreto Legislativo 18 luglio 2016, n. 141 (2016) Disposizioni integrative al decreto legislativo 4 luglio 2014, n. 102, di attuazione della direttiva 2012/27/UE sull'efficienza energetica, che modifica le direttive 2009/125/CE e 2010/30/UE e abroga le direttive 2004/8/CE e 2006/32/CE. (16G00153) (GU Serie Generale n.172 del 25-07-2016)

Desrochers P, Leppälä S (2010) Industrial symbiosis: old wine in recycled bottles? Some perspective from the history of economic and geographical thought. Int Reg Sci Rev 3(3):338–361

Ellen MacArthur Foundation (2012) Towards the circular economy, vol 1: Economic and business rationale for a circular economy. http://www.ellenmacarthurfoundation.org/publications

Ellen MacArthur Foundation (2013) Towards the circular economy, vol 2: Opportunities for the consumer goods sector. http://www.ellenmacarthurfoundation.org/publications

Ellen MacArthur Foundation (2014) Towards the circular economy, vol 3: Accelerating the scale-up across global supply chains. http://www.ellenmacarthurfoundation.org/publications

Ellen MacArthur Foundation (2015) Towards a circular economy: business rationale for an accelerated transition. http://www.ellenmacarthurfoundation.org/publications

ENEA (2017) Linee Guida per il Monitoraggio nel settore industriale per le diagnosi energetiche ex art. 8 del d.lgs. 102/2014

European Commission (2011) Roadmap to a resource efficient Europe, COM/2011/571 final

European Commission (2012) European Resource Efficiency Platform (EREP), Manifesto & Policy Recommendations. http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf

European Commission (2015) Action plan for the circular economy, COM/2015/0614 final

European Union (2018) Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (Text with EEA relevance). PE/11/2018/REV/2. OJ L 150, 14.6.2018, pp 109–140

Garner A, Keoleian GA (1995) Industrial ecology: an introduction. In: Pollution prevention and industrial ecology. National Pollution Prevention Center for Higher Education, University of Michigan, Ann Arbor

International Organisation for Standardisation (ISO) (2006a) ISO 14040—Environmental management—life cycle assessment—principles and framework, Geneva, Switzerland

International Organisation for Standardisation (ISO) (2006b) ISO 14044—Environmental management—life cycle assessment—requirements and guidelines, Geneva, Switzerland

Jelinski LW, Graedel TE, Laudise RA, Mccall DW, Patel CKN (1992) Industrial ecology: concepts and approaches. Proc Natl Acad Sci USA 89(3):793–797

Krausmann F, Gingrich S, Eisenmenger N, Erb KH, Haberl H, Fischer-Kowalski M (2009) Growth in global materials use, GDP and population during the 20th century. Ecol Econ 68(1):2696–2705

Lombardi DR, Laybourn P (2012) Redefining industrial symbiosis. J Ind Ecol 16(1):28–37

Luciano A, Barberio G, Mancuso E, Sbaffoni S, La Monica M, Scagliarino C, Cutaia L (2016) Potential improvement of the methodology for industrial symbiosis implementation at regional scale. Waste Biomass Valorization 7(4):1007–1015. https://doi.org/10.1007/s12649-016-9625-y

Mattila T, Lehtoranta S, Sokka L, Melanen M, Nissinen A (2012) Methodological aspects of applying life cycle assessment to industrial symbioses. J Ind Ecol 16:51–60

UN (2015) Department of Economic and Social Affairs Population Division, World Population Prospects the 2015 Revision

UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth. ISBN: 978-92-807-3167-5

UNEP (2012) Annual report 2012. ISBN: 978-92-807-3323-5 DCP/1646/NA
UNEP (2015) The 2030 Agenda for sustainable development of the United Nations Environment Program
Zhang Y, Duan S, Li J, Shao S, Wang W, Zhang S (2017) Life cycle assessment of industrial symbiosis in Songmudao chemical industrial park, Dalian, China. J Clean Prod 158:192–199