# CEN WORKSHOP AGREEMENT

# CWA 17354

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# Industrial Symbiosis: Core Elements and Implementation Approaches

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# European foreword

This Workshop has been proposed by 4 European projects working to advance the uptake of industrial symbiosis across Europe and globally. Contribution to standardization activities has been specified as one of the means for dissemination for the projects SHAREBOX (Secure Platform for the Flexible Management of Shared Process Resources) and EPOS (Enhanced energy and resource efficiency and Performance in process industry Operations via onsite and cross-sectorial Symbiosis) of the European Commission's Horizon 2020 programme, SPIRE Sustainable Process Industries PPP. Advancing policy to stimulate industrial symbiosis is an objective of Interreg Europe projects TRIS (Transition Regions towards Industrial Symbiosis) and SYMBI (Industrial Symbiosis for a Resource Efficient Economy).

CWA Industrial Symbiosis was developed in accordance with CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – The way to rapid agreement" and with the relevant provisions of CEN/CENELEC Internal Regulations – Part 2. It was agreed on 2018-10-22 in a Workshop by representatives of interested parties, approved and supported by CEN following a public call for participation made on 2018-01-24. It does not necessarily reflect the views of all stakeholders that might have an interest in its subject matter.

The final text of CWA Industrial Symbiosis was submitted to CEN for publication on 2018-11-12. It was developed and approved by:

International Synergies Limited

INEOS Group AG

University of Ghent

CEPI - Confederation of European Paper Industries

CEMBUREAU - the European Cement association

Motiva

University of Sussex

EIT RawMaterials

University of Cantabria

Ministry of Development, Turkey

Industrial Symbiosis Limited

ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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# Overview

The 2018 Amendment to the Waste Framework Directive (2008/98/EC) passed into law calls for member states to promote sustainable use of resources and industrial symbiosis. As industrial symbiosis is further integrated into the policies, reports and recommendations of the European Commission across multiple DGs and various member states at the national, regional and local scale, the variety of terminologies used in these documents can be confusing and sometimes misleading to those wishing to implement industrial symbiosis. Such confusion dilutes the effectiveness of the approach to deliver resource efficiency, greenhouse gas reduction and economic benefits.

Resource efficiency through industrial symbiosis offers economic opportunities for European industry. This CEN Workshop Agreement (CWA) is intended to help organisations, governments and individuals consider and implement industrial symbiosis. To support the effective adoption of industrial symbiosis by the public and private sector and to advance toward mainstream adoption, this CWA provides a consensus on the core elements of industrial symbiosis to enable its identification and on good practice approaches to industrial symbiosis implementation across Europe and beyond. These common elements and approaches can form the basis for policy, recommendations and widespread implementation.

Specifically, this CWA sets out the following:

1. Core elements of industrial symbiosis;
2. Drivers for industrial symbiosis;
3. Approaches to industrial symbiosis;
4. Industrial symbiosis implementation: good practice.

Industrial symbiosis is the use by one company or sector of underutilised resources broadly defined (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) from another, with the result of keeping resources in productive use for longer. Core elements of industrial symbiosis are the aspects that enable its identification. Elements considered core to industrial symbiosis are:

- Returning underutilised resources (often called waste) to productive use;
- Information about opportunities (e.g., data on other organisations' resources, or new technologies) is required to be able to advance a synergy;
- Business conditions incentivising industrial symbiosis, which may be through market conditions or through policies and regulations; and

Four common approaches to industrial symbiosis (that are not mutually exclusive) vary depending on where the onus for identifying and advancing opportunities lies:

1. Self-organised: a bottom-up approach resulting from direct interaction among industrial actors, without external coordination. Expertise resides within the organisations with resources and opportunities; organisations identify, assess and advance opportunities themselves.
2. Facilitated: wherein a third-party intermediary coordinates the activity, working with organisations to identify opportunities and help bring them to fruition. Facilitators (sometimes referred to as practitioners) work with the companies to identify, assess and advance opportunities; often the onus is on the facilitators to progress opportunities. Facilitator business models vary from commercial brokers to public investment networks and any combination thereof.
3. ICT-supported: industrial symbiosis activity is supported by an ICT system to capture and manage data on resource availability and potential synergies. The onus lies with the software users, be they companies, other organisations or facilitators.

4. Strategic or planned: a top-down approach where networks are formed following a central plan or vision that includes attracting new businesses to regeneration sites or purpose-built developments. The onus lies with the central body (often public sector) implementing the plan or vision.

Good practice implementation in any approach requires the following steps:

1. Fully characterising the resources available: thinking broadly about resources (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials); and reassessing waste for value as a resource.
2. Identifying and assessing opportunities to return underutilised resources to productive use: statistically, most (not all) reuse opportunities are outside one's own sector, so cross-sector knowledge may be required.

Matching the available resource with the appropriate opportunity, addressing technical, economic, and legal requirements. Intermediate transformation steps may also be required.

# 1 Scope

Industrial symbiosis is the use by one company or sector of underutilised resources broadly defined (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) from another, with the result of keeping resources in productive use for longer. It presents a systems approach to a more sustainable and integrated industrial economy that identifies business opportunities to improve resource utilisation and productivity. The objectives of this CEN Workshop Agreement (CWA) are to support the mainstream adoption of good practice approaches proven through implementation by advancing the mutual understanding of actors (public, private, third sector, and community) currently using the term industrial symbiosis in different ways. This CWA is intended to help the above actors consider and implement industrial symbiosis.

# 2 Normative references

The following **standards-related references** are central to this document:

- BS 8001: 2017 “Guidelines to a Circular Economy” and references therein
  https://www.bsigroup.com/en-GB/standards/benefits-of-using-standards/becoming-more-sustainable-with-standards/BS8001-Circular-Economy/

- IWA 27: 2017 “Guiding principle and framework for the sharing economy”
  https://www.iso.org/standard/72643.html

The following **related references (reports, policies)** are central to this document:

There are multiple directives that mention industrial symbiosis and its relationship to resource efficiency within the European Union, although few are specific to industrial symbiosis as a focus; rather, industrial symbiosis is included as support to their primary aims. Some of the most relevant documents are listed below:

- Official Journal of the European Union, Legislation L150, Volume 61, 14th June 2018 amendments to: Directive 1999/31/EC Landfill of Waste; Directive 2008/98/EC on Waste; and Directive 94/62/EC Packaging and Packaging of Waste.
  https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2018%3A150%3ATOC

- DG GROW, Cooperation fostering industrial symbiosis: market potential, good practice and policy actions (2018)
  http://publications.europa.eu/publication/manifestation_identifier/PUB_ET0517150ENN

- European Environment Agency: Circular Economy in Europe (2016)
  https://www.eea.europa.eu/publications/circular-economy-in-europe

- European Resource Efficiency Platform: Short-term recommendations (2014)
  http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf

- European Commission Communication: GREEN ACTION PLAN FOR SMEs, Enabling SMEs to turn environmental challenges into business opportunities (2014)
  https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0440&from=EN

- European Commission Communication: A Stronger European Industry for Growth and Economic Recovery, Industrial Policy Communication Update (2012) recommendation
  https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0582&from=EN

- DG Regions: Connecting Smart and Sustainable Growth through Smart Specialisation (2012) http://ec.europa.eu/regional_policy/en/information/publications/guides/2012/connecting-smart-and-sustainable-growth-through-smart-specialisation-a-practical-guide-for-erdf-managing-authorities

- European Commission: Roadmap to a Resource Efficient Europe (2011) http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN

- DG Enterprise: Sustainable Industry: Going for Growth & Resource Efficiency (2011) https://ec.europa.eu/docsroom/documents/5188/attachments/1/translations/en/renditions/pdf

- ETAP 10th Eco-Innovation Forum (2011) http://ec.europa.eu/environment/archives/ecoinnovation2011/1st_forum/

- European Waste Framework Directive 'Being Wise with Waste' – Best Practice (2009) http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf

A review of how the term 'industrial symbiosis' is used in the European institutions' documentation (legislative and beyond) has produced the following examples:

— **Council of the European Union:** Since 2013, there have been many references but only 2 occasions whereby there is an attempt to describe the term: one as a *'new business model'*, and one as *a 'user-driven innovation business model'*.

— **European Parliament:** There have been many references to industrial symbiosis since 2013. It is referred to as *'turning one industry's by-product into another industry's raw material.'* From the European Parliamentary Research Service, *'Industrial symbiosis engages different organisations in a network to foster eco-innovation and long-term culture change. It provides mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs, and improved business and technical processes'* citing Lombardi and Laybourn (2012a).[1]

— **European Commission –** Findings are divided into the various Directorate-Generals:

  - **DG Environment:** There are several mentions of the term industrial symbiosis. Referring to NISP®, a facilitated industrial symbiosis activity: "*It is a business opportunity programme that develops mutually profitable links between traditionally separate companies from all industrial sectors and of all sizes so that previously unused or discarded resources such as energy, water and/or materials from one company can be recovered, reprocessed and re-used by other companies in the industrial member network.*" Further links to global agendas are made here: *" …with respect to industrial symbiosis, knowledge transfer and the shift towards a circular and green economy, particular attention should be given to resource efficient, environmentally-sound performance of businesses, including the value chains, and on the harmonisation of the methodology for measuring their ecological footprint."*

  - **DG Grow:** also cites Lombardi and Laybourn (2012a)[2] in its 2018 report[3] to encourage broader uptake of industrial symbiosis for economic benefit.

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[1] Lombardi DR and P Laybourn (2012a) Redefining Industrial Symbiosis: Crossing Academic-practitioner Boundaries. **Journal of Industrial Ecology** 12(1): 28-37

[2] *Ibid*

[3] Domenech et al. (2018). Cooperation fostering Industrial Symbiosis, Report prepared for DG Grow. Available at: https://publications.europa.eu/en/publication-detail/-/publication/174996c9-3947-11e8-b5fe-01aa75ed71a1/language-en

- **DG Regio:** There is an indirect definition in one of its publications, *'The Industrial Symbiosis Network helps to identify opportunities to recover and reprocess waste products from one industry that can then be re-used by other businesses. This, in turn, reduces the amount of waste going to land fill, cuts carbon emissions and creates greener jobs. In essence, it is a brokerage initiative to increase business opportunities and contribute to the sustainable growth of the region.'*
- **DG Research** describes industrial symbiosis in the text of the H2020 2014 call on waste: *'Industrial symbiosis, whereby different actors derive mutual benefit from sharing utilities and waste materials, requires large-scale systemic innovation with the aim of turning waste from one industry into useful feedstock for another one.'*
- **DG Secretary General** was responsible for coordinating the policy work that went into the circular economy package. Industrial symbiosis is communicated as: *'turning one industry's by-product into another industry's raw material'.* On a separate occasion industrial symbiosis is referred to as *'an innovative industrial process'.*

# 3 Terms, definitions and abbreviation

## 3.1 Terms and definitions

**3.1.1**

**alternative fuel**

any fuel with a potential for long-term non-renewable fuel substitution

REFERENCE: Adapted from Communication from the Commission of 24 January 2013 entitled 'Clean Power for Transport: A European alternative fuels strategy', available at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A52013PC0017.

**3.1.2**

**by-product**

substance or object, resulting from a production process, the primary aim of which is not the production of that item fulfilling the following points:

(a) further use of the substance or object is certain;

(b) the substance or object can be used directly without any further processing other than normal industrial practice;

(c) the substance or object is produced as an integral part of a production process;

(d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

REFERENCE: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

**3.1.3**

**cascading use**

in general, means a sequence of use phases with declining product value. Cascading allows the use of resources (materials and water) to be extended. For instance, using biomass as a production material first, then recycling it (several times) before finally recovering the energy content from the resulting waste at the end of its lifecycle. Such cascading systems may provide general advantages for climate change mitigation and ease land use pressure

**3.1.4**

**circular economy**

where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, making an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy

REFERENCE: Closing the loop - An EU action plan for the Circular Economy. COM/2015/0614 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

**3.1.5**

**eco-innovation**

refers to innovation that results in reduced environmental impact, no matter whether or not that effect is intended. Eco-innovation is not limited to innovation in products, processes, marketing methods and organisational methods, but also includes innovation in social and institutional structures. Eco-innovation is seen as key to achieving the transition to a sustainable economy

REFERENCE: OECD, 2009. Eco-innovation in Industry: Enabling Green Growth. Available at: https://read.oecd-ilibrary.org/environment/eco-innovation-in-industry_9789264077225-en

**3.1.6**

**emission**

the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources from an installation into the air, water or land

REFERENCE: The Environmental Permitting (England and Wales) Regulations 2010 https://www.legislation.gov.uk/ukdsi/2010/9780111491423/body?view=plain

**3.1.7**

**energy efficiency**

refers to the ratio of output of performance, service, goods or energy, to input of energy

REFERENCE: Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1539262877283&uri=CELEX:32012L0027

**3.1.8**

**industrial ecology**

the study of the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal.

REFERENCE: Graedel T.E. and B.R. Allenby (1995) Industrial Ecology. Englewood Cliffs, NJ: Prentice Hall. 412 pp.

**3.1.9**

**matchmaking**

the process of identifying organisations with the potential to establish a synergy

**3.1.10**

**material stream**

refers to the aspects of a stream as a substance mainly in terms of mass or volumetric flows

**3.1.11**

**production residue**

refers to a material that is not deliberately produced in a production process but may or may not be a waste

REFERENCE: Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste. http://ec.europa.eu/environment/waste/framework/pdf/guidance_doc.pdf)

**3.1.12**

**raw material**

the basic input material to make a product in an industrial facility

**3.1.13**

**recycling**

any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations

REFERENCE: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

**3.1.14**

**resources**

defined by UNEP and OECD as the naturally occurring assets that provide use benefits through the provision of raw materials and energy used in economic activity (or that may provide such benefits one day) and that are subject primarily to quantitative depletion through human use. They are subdivided into four categories: mineral and energy resources, soil resources, water resources and biological resources. Resources for a business are more inclusive than just materials and equipment, including also (for example) human resources. This CWA uses 'resources' to have this breadth of interpretation

**3.1.15**

**resource efficiency**

about ensuring that natural resources are produced, processed and consumed in a more sustainable way, reducing the environmental impact from the consumption and production of products over their full life cycles. By producing more wellbeing with less material consumption, resource efficiency enhances the means to meet human needs while respecting the ecological carrying capacity of the earth

REFERENCE: UNEP, ABC of SCP. http://www.uneptie.org/scp/marrakech/pdf/ABC%20of%20SCP%20-%20Clarifying%20Concepts%20on%20SCP.pdf

**3.1.16**

**SPIRE**

refers to the Public-Private Partnership in the European process industries sectors of ceramics, cement, non-ferrous metals, chemicals, minerals, steel, water and engineering

REFERENCE: https://www.spire2030.eu/

**3.1.17**

**synergy**

the creation of an integrated whole that has a greater value than the addition of its parts. Industrial symbiosis ‘synergies’ are transactions where one organisation acquires underutilised resources (by-products, waste, materials, energy, water, equipment or other resources that are not the primary output of the production process) from the organisation generating them, and integrates them as inputs into their own production process. Synergies are predominantly bilateral (organisation to organisation) or multi-lateral (between many organisations) but can also be within a single organisation

**3.1.18**

**waste**

any substance or object which the holder discards or intends or is required to discard

REFERENCE: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

**3.1.19**

**Sustainable Development Goals** (SDGs)

otherwise known as the Global Goals, are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. These 17 Goals build on the successes of the Millennium Development Goals, while including new areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, among other priorities. The goals are interconnected – often the key to success on one will involve tackling issues more commonly associated with another

REFERENCE: UNDP, http://www.undp.org/content/undp/en/home/sustainable-development-goals.html

## 3.2 Abbreviations

| | |
|---|---|
| CSR | Corporate Social Responsibility |
| CWA | CEN Workshop Agreement |
| OECD | Organisation for Economic Co-operation and Development |
| SCP | Sustainable Consumption and Production |
| SDG | Sustainable Development Goals |
| UNEP | United Nations Environment Programme |

# 4 Core Elements of Industrial Symbiosis

Industrial symbiosis presents a systems approach to a more sustainable and integrated industrial economy which identifies business opportunities to improve resource utilisation. Industrial symbiosis 'synergies' are transactions where one organisation acquires underutilised resources (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials that are not the primary output of the production process) from the organisation generating them, and integrates them as inputs into their own production process.

The concept of industrial symbiosis in the academic literature is traced back to the seminal article by Frosch and Gallopoulos in Scientific American (1989)[4] where the authors envisioned "industrial ecosystems" in which "the consumption of energy and materials is optimized and the effluents of one process serve as the raw material for another process." Several industrial sectors have incorporated similar principles into standard operating procedures for many years, including cement and chemicals.

Core elements of industrial symbiosis are the aspects that enable its identification. Elements considered core to industrial symbiosis are:

- Returning underutilised resources (often called waste) to productive use. Transactions (synergies) involving material, energy and water tend to be at the core of industrial symbiosis, but non-material resources such as expertise, capacity and logistics can be equally valuable.
- Information about opportunities (e.g., data on other organisations' resources or new technologies) is required to be able to advance a synergy.
- Business conditions incentivising industrial symbiosis, which may be through market conditions (cost reduction, risk reduction, improved competitiveness) or through policies and regulations that specify definitions (for example, waste versus by-product) and responsibilities.

Optional dimensions that may occur in some synergies and not in others:

- Collaboration through networks: A diverse network of organisations of all sectors and sizes contributes to success, as most opportunities lie outside one's own sector. Sectors including Government, third sector, research and the community each can contribute to industrial symbiosis, bringing new ideas and stimulating further activity. A formal network is not required for an actor to pursue industrial symbiosis (e.g., in the self-organised approach).
- Innovation: Often an industrial symbiosis opportunity entails innovative diversification of the business-as-usual supply chain.

Shared services: Sharing may reduce the environmental impact of the services, which is in line with the goal of industrial symbiosis, but if those services are not derived from previously underutilised resources (such as another organisation's wastewater being converted to input) then it may not be aligned with the core elements of industrial symbiosis described above.

# 5 Drivers for Industrial Symbiosis

Over the last decade and more, industrial symbiosis has been taken up on every continent, successfully crossing cultures and economies. Industrial symbiosis has proven successful not only in diverting waste from landfill or incineration, but also in closing the resources loop and moving waste up the value chain. The industrial symbiosis approach delivers benefits across the 3 pillars of sustainability (economic, social and environmental) and supports the delivery of a more circular economy. The European Resource Efficiency Platform championed industrial symbiosis as a mechanism for reducing carbon, preserving critical resources and securing business sustainability. It is recognised as a driver and accelerator of innovation. Recently, industrial symbiosis has gained increasing attention as a mainstream approach for

[4] Frosch, R.A. and Gallopoulos, N.E. (1989) Strategies for Manufacturing. **Scientific American**, 261: 144-152.

helping to deliver the circular economy[5] through the reduction of waste, emissions and primary resources consumption as priorities. The following five drivers were identified and explored at the International Working Conference on Applied Industrial Symbiosis (2012)[6] and reinforced in the 2018 report commissioned by DG GROW "Cooperation for Industrial Symbiosis"[7].

Economic/business impact: Generally industrial symbiosis is motivated by economic impacts delivered through mutually beneficial transactions that reduce cost or risk, generate revenue, or otherwise solve a business problem for the parties. Organisations engage in industrial symbiosis when the business case for doing so is clear – current and historical economic returns have been demonstrated in many countries. The increasing attention to sustainability and resource security issues further drives business engagement, as can a CSR agenda. At the 2015 G7 Alliance for Resource Efficiency Workshop on Industrial Symbiosis[8], UNEP mapped industrial symbiosis to the delivery of six SDGs:

- Decent Work and Economic Growth (8)
- Industry Innovation and Infrastructure (9)
- Sustainable Cities (11)
- Responsible Consumption and Production (12)
- Climate Action (13)
- Partnerships (17).

Eco-innovation: The OECD (2012) cited industrial symbiosis as a form of systemic eco-innovation 'vital for future green growth', recognising its role as a catalyst for demand-led business innovation, helping to bring novel and innovative products, processes and technologies to market. DG Secretary General also refers to industrial symbiosis as an 'innovative industrial process'.

Regional economic development: Regional economic development that draws on existing key industrial activity and resource streams can lower the carbon footprint of development, while strengthening local economies through improved material and energy security. Some regional and local governmental bodies are implementing industrial symbiosis to attract and retain businesses in their region – as in Birmingham UK, where an industrial symbiosis approach has been integrated into the economic development plan to reinvigorate the Tyseley Environmental Enterprise District. In the 10th Development Plan of Turkey, environmental protection and sustainable use of resources are among the priority goals: industrial symbiosis is defined as a strategic tool to achieve these goals in many national policy documents such as Priority Transformation Programme for Enhancing Productivity in Manufacturing, SME Strategy and Action Plan (2015-2018), National Efficiency Strategy and Action Plan (2015-2018) and National Cleaner Production/Eco-efficiency Strategy (2014-2017). It is also defined as a tool for reaching eco-efficiency and regional competitiveness objectives in regional policy documents, explicit in 19 out of 26 regional development plans prepared by Turkish regional development agencies.

Resource security: Risks associated with critical resource supply may be managed in part through managing demand, and in part through resource recovery at end of life, increasing supply. An industrial symbiosis approach is an effective means to move resources up the waste hierarchy: it reduces the use of virgin materials and water through substitution, identifies novel reuse and recycling opportunities for existing waste and by-products, diverts materials from the waste stream and prevents waste generation.

Energy security and climate change mitigation: Governments and companies around the world are focused on addressing energy concerns, both by improving efficiency (of generation, distribution, and processes), and by decarbonisation. Carbon footprint may also be reduced by cascading resources

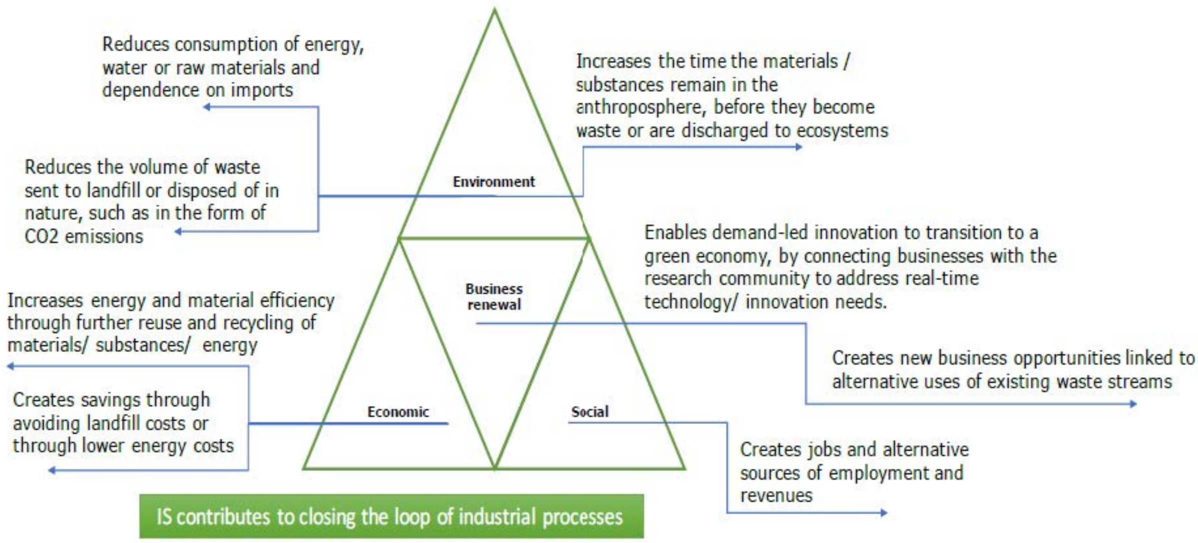
5 https://www.wrforum.org/event/world-circular-economy-forum-2017/

6 Lombardi D.R. and P. Laybourn (2012) *Outcomes of IWCAIS: Positive Action for Green Growth* Energy Delta Institute EDI Quarterly 4(3): 5-8. Available at: http://issuu.com/edi_quarterly/docs/edi2047_quarterly_3_okt_2012/1

7 *ibid*

8 https://www.international-synergies.com/projects/g7-workshop-on-industrial-symbiosis/

through multiple uses, keeping materials circulating in the economy and reducing the level of activity in extraction, refinement, transport and processing. Industrial symbiosis enables carbon reduction (including embedded carbon) through: efficiency improvements, novel fuel substitution, process innovation, heat recovery, avoided transport energy, and avoided virgin material extraction.




Long-term environmental and social impact of industrial symbiosis[9]

## 6 Approaches to Industrial Symbiosis NOTE

Four non-mutually exclusive approaches to industrial symbiosis have evolved. These are:

1. **Self-organised**: a bottom up approach resulting from direct interaction among industrial actors, without any external coordination, generally motivated by business concerns arising from context, including resource risk, pending legislation, and economic gains.

Self-organised Industrial Symbiosis Case study: Kalundborg, Denmark

The term industrial symbiosis has its origins in the Danish municipality of Kalundborg, the first recognized and best-known example of an industrial symbiosis network. Resource sharing by companies from different industries in Kalundborg, Denmark began because of the low availability of groundwater and the need for a surface water source which, once identified, became a key part of their resource network. The first synergies were in the 1970s, and additional synergies continued to develop into the 1980s.[10] The Kalundborg self-organization was initiated by the private sector to achieve goals including cost reduction, revenue enhancement, business expansion, and securing long-term access to water and energy.

9 Domenech et al. (2018). Cooperation fostering Industrial Symbiosis, Report prepared for DG Grow, available at: https://publications.europa.eu/en/publication-detail/-/publication/174996c9-3947-11e8-b5fe-01aa75ed71a1/language-en

10 Ehrenfeld J. And N. Gertler. 1997. Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg. Journal of Industrial Ecology 1(1):67-79.

2. **Facilitated**: where a third-party intermediary coordinates the activity, working with organisations to identify opportunities and bring them to fruition. Industrial symbiosis practitioners play the critical role of facilitating and co-ordinating the contributions of the various stakeholders. By engaging with organisations from all sectors, the practitioner enables the flow of information across sectoral boundaries; practitioners often provide technical support to overcome technical or regulatory barriers associated with synergies.

   Facilitators come from the private sector (as in NISP England), the public sector (for example, City of Manresa, Spain; Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) Italy), academia (for example, Erasmus University Rotterdam, Netherlands), or the third sector (for example, GreenCape, South Africa). In all cases, the investment is in their time to build a network, gather information, and facilitate synergies to completion. At least for NISP England (2005-2010), the public investment returned a benefit cost ratio of between 32 and 53 to 1.[11] These activities can be directed to achieve specific targets: for example, if success is determined by achieving substantial landfill diversion, then target sectors are likely to include construction, cement, and foundries for the large volumes of materials mobilised. If instead the key metric is innovation, the coordination focuses on attracting entrepreneurs and innovators.

   Facilitated Industrial Symbiosis Case study: NISP®

   The most cited facilitated approach to industrial symbiosis in European policy is the NISP® methodology. First developed in the UK by International Synergies Ltd, it has since been replicated in over 20 countries on 5 continents. The NISP model involves expert facilitators (practitioners) gathering information from companies, making expert assessments, then identifying and facilitating synergy opportunities through to completion. The success of NISP has inspired many parties to implement industrial symbiosis across Europe: current activity largely comprises regional efforts supported by public-sector investment. This holistic approach has demonstrated *in practice* verified positive impacts including cost reduction, additional sales; reduction in materials, water and energy use; innovation, knowledge transfer and best practice sharing, capacity utilisation, and job creation.

3. **ICT-supported**: Part of the challenge of industrial symbiosis in practice is that most opportunities for a given organisation lie outside one's own sector. Decision-makers in industry today will have experience deriving primarily from a single industry; going outside one's own sector, and traditional supply chain, requires support. This market failure of information in relation to resource efficiency can be addressed through mechanisms that improve information flow between actors.

   The concept of ICT to support industrial waste reuse dates back to the 1970's when information exchanges were first established. More recently web-based waste exchanges have proliferated as the technology has developed. Passive online waste exchanges have had very limited uptake in Europe and around the world, which is attributed to their inability to meet the specific information needs of industrial users (including classification, contamination, distribution and timing issues) and the lack of mainstream buy-in to industrial symbiosis.

[11] Scott Wilson Business Consultancy and Manchester Economics. 2009. NISP Economic Evaluation Report. October.

<u>ICT-enabled Industrial Symbiosis Case study: SYNERGie®4.0</u>

International Synergies Limited SYNERGie®4.0 system bespoke to industrial symbiosis support. SYNERGie®4.0 delivers resource database, project management, impact reporting and customer relationship management functionalities, and is proven in practice hosting over 40,000 resources from over 20,000 companies worldwide. The most established ICT system supporting industrial symbiosis has been developed by practitioners to support their activity, and then extended to more general (non-expert) use.

4. **Strategic or planned**: a top-down approach where networks are formed following a central plan or strategic vision that includes attracting new businesses to regeneration sites or purpose-built developments. Industrial symbiosis in existing enterprise/commercial zones is based on existing resource flows, infrastructure and economic activity; the analysis identifies opportunities for strategic economic development that increases the productivity of existing resources, reduces carbon emissions, and attracts new investment and green business growth through industrial symbiosis. The approach has been applied to existing industrial parks and industrial areas of a city.

<u>Planned Industrial Symbiosis Case study: Sustainable Devens (USA)</u>

The Massachusetts economic development agency converted a former military base in Devens into a planned community and gave the Devens Enterprise Commission (DEC) the mission to integrate into its development and management the principles of sustainable development and industrial ecology (including industrial symbiosis).

Businesses operating in the Devens eco-industrial area are largely SMEs in the sectors of high tech, logistic, manufacturing, etc. The programme aims at fostering networking and environmental commitment among onsite and other local firms. DEC's environmental policy criteria include by-products and information exchanges, joint purchasing, recycling, sustainable building, reduced use of toxic chemicals, mutual aid to reach standards, etc.

Case study source: Massard et al (2014)

Information: http://www.devensec.com/sustain.html

These approaches are not mutually exclusive: Kalundborg was self-organised until 1996 when a coordinating organization, the Symbiosis Institute, was launched as part of Kalundborg's industrial development agency to accelerate the number and complexity of new synergies. NISP® in England was facilitated throughout its life but started without ICT support in its early days. ICT enabled approaches may or may not include facilitation. Strategic/planned approaches may involve facilitators and/or ICT support.

# 7 Industrial Symbiosis Implementation: Good Practice

## 7.1 Factors Enabling Good Practice

- Facilitation (through full time or substantial commitment) is necessary to advance synergies to completion.
- Public sector investment has led to macro-economic impact which contributes to the economy as a whole through multiplier effects and has proven value for money/return on investment.[12]
- A policy enabling context supportive of industrial symbiosis does not introduce legislative or regulatory barriers to industrial symbiosis, but rather incentivises it.
- Advancing synergies (with or without facilitation) requires an investment on the part of the organisations involved, in time if not capital. The communication of industrial symbiosis must be clearly focused on the benefits to be derived from the activity to gain the organisation's buy-in and investment.
- ICT (software) supports data management and impact tracking to overcome information barriers to industrial symbiosis.
- Industrial diversity in a region enhances the chance for industrial symbiosis[13] as most (not all) reuse opportunities are outside one's own sector.
- Various factors determine how far a resource will travel, including the market (price, cost), regulation and legislation: in England, documented NISP® synergies have moved textiles, metals, minerals and paper/card over 200 miles.[14] Steam and heat synergies are limited to local opportunities.
- A diverse network engaging business across all sectors and sizes, research and the government has proven to foster knowledge transfer and demand-led innovation by bringing together the companies with real problems, and the researchers able to address, and sometimes resolve, them. In the UK's NISP experience, over 70% of synergies have been shown to involve some form of innovation: 50% cross-sector knowledge transfer and best practice, and 20% new research and development deriving from close links with universities.
- A clear monitoring and evaluation framework established from the beginning of activity will provide the relevant information for assessing return on investment (for public sector, most common) and capturing the economic, environmental and social impacts.
- Targets and constraints drive activity: where desired outputs are defined in goal-directed approaches, then effort will first be directed to those sectors/materials that are most likely to deliver the priority outputs (be they environmental, economic or social, or any subset thereof).

[12] Scott Wilson Business Consultancy and Manchester Economics. 2009. NISP Economic Evaluation Report. October.

[13] Jensen P.D. (2016) The role of geospatial industrial diversity in the facilitation of regional industrial symbiosis. **Resources, Conservation and Recycling** 107 (Feb): 92-103. https://doi.org/10.1016/j.resconrec.2015.11.018

[14] Jensen P. D., Basson L., Hellawell E. E., Bailey M. R. and Leach M. (2011) Quantifying 'Geographic Proximity': Experiences from the United Kingdom's National Industrial Symbiosis Programme. **Resources, Conservation and Recycling** 55(7): 703-712. https://doi.org/10.1016/j.resconrec.2011.02.003

## 7.2 Actions Representing Good Practice

- Fully characterise the resources available: think broadly about resources (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials); and reassessing waste for value as a resource.
- Identify and assess opportunities to return underutilised resources to productive use: statistically, most (not all) reuse opportunities are outside one's own sector, so employ cross-sector knowledge as required.

Match the available resource with the appropriate opportunity, addressing technical, economic, and legal requirements. Intermediate transformation steps may also be required.

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Case study, Wood Waste as Fuel Substitute for Cement Manufacture:

https://circulareconomy.europa.eu/platform/en/good-practices/development-deconstruction-wood-waste-use-energy-recovery-cement-plants

Case study, Alternative Raw Material inputs to Cement Manufacture:

https://circulareconomy.europa.eu/platform/en/good-practices/cement-industry-protecting-natural-resources-reusing-alternative-materials

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## Appendix 2: Indicators

The following reports address the status of indicators for industrial symbiosis:

Domenech et al. (2018). Cooperation fostering Industrial Symbiosis, Report prepared for DG Grow, available at: https://publications.europa.eu/en/publication-detail/-/publication/174996c9-3947-11e8-b5fe-01aa75ed71a1/language-en

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## Appendix 3: Supplementary Guidance

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