ENEA
ITALIAN NATIONAL AGENCY FOR
NEW TECHNOLOGIES, ENERGY AND
SUSTAINABLE ECONOMIC DEVELOPMENT

Symbiosis Users Network – SUN

PROCEEDINGS

Sostenere la transizione delle aree industriali e delle brown areas italiane in parchi eco industriali e l'implementazione della simbiosi industriale come strumento di routine gestionale per le aziende

Supporting the transition of Italian industrial areas and brown areas into eco-industrial parks and the implementation of Industrial Symbiosis as a management routine tool for companies

Symbiosis Users Network – SUN
Proceedings of the eighth SUN Conference

November 6th 2024

Edited by Tiziana Beltrani and Marco La Monica

SUN Symbiosis Users Network

Supporting the transition of Italian industrial areas and brown areas onto eco-industrial parks and the implementation of Industrial Symbiosis as a management routine tool for companies

Symbiosis Users Network – SUN

Proceedings of the eighth SUN Conference

November 6th, 2024

Edited by Tiziana Beltrani and Marco La Monica

2025 ENEA

National Agency for New Technologies, Energy and Sustainable Economic Development

978-88-8286-525-2

Cover design: Flavio Miglietta

Ecomondo 2024, Rimini – Un momento del convegno SUN, 6 novembre 2024

Introduzione

La trasformazione delle aree industriali e delle *brown-areas* italiane in Eco-Distretti Circolari (EDC) o Parchi Eco-Industriali (PEI), anche attraverso l'implementazione della simbiosi industriale, rappresenta una sfida complessa ma fondamentale per il futuro sostenibile del Paese. Il quadro politico e normativo, sia a livello europeo che nazionale, offre un contesto favorevole e riconosce l'importanza di questo approccio per il raggiungimento degli obiettivi di economia circolare e neutralità climatica. La simbiosi industriale si configura come uno strumento strategico per la costruzione di ecosistemi territoriali dove ottimizzare l'uso delle risorse, ridurre l'impatto ambientale e creare nuove opportunità economiche.

La transizione delle aree industriali e delle *brown-areas* in EDC o PEI rappresenta un passo cruciale in questa direzione. Queste realtà sono costituite da comunità di imprese e di servizi che collaborano per migliorare le proprie prestazioni ambientali ed economiche, condividendo risorse come energia, acqua, materiali, asset e servizi anche in collaborazione con il territorio in cui sono insediate La rigenerazione di *brown-areas* e la riconversione di aree industriali attraverso la realizzazione di PEI o EDC basati sui principi della simbiosi e della ecologia industriale accompagna la transizione delle aree produttive in poli di sviluppo sostenibile e circolare, favorendo al contempo gli investimenti, la creazione di posti di lavoro e la riduzione dell'impatto ambientale complessivo. Le dinamiche positive che si innescano in un parco eco-industriale consentono infatti di rendere il sistema produttivo maggiormente competitivo, più stabile dal punto di vista dei rischi ambientali e sociali connessi con le attività industriali, nonché più efficace dal punto di vista dell’approvvigionamento delle risorse e della gestione dei residui.

L'Unione Europea riconosce il potenziale della simbiosi industriale nel creare sinergie tra le aziende, trasformando sottoprodotti e scarti in risorse per altre imprese, con significativi vantaggi in termini di efficienza e sostenibilità. Per sostenere questa trasformazione, nel 2023 è stato lanciato il Piano Industriale del Green Deal e, all'inizio del 2025, è stato introdotto il Clean Industrial Deal.

In questo scenario, l'Italia, con la sua lunga tradizione industriale e la presenza di numerose aree dismesse, affronta sfide e opportunità uniche. La transizione delle aree industriali esistenti e la riqualificazione delle aree dismesse rappresenta un'occasione strategica per sviluppare un nuovo modello industriale, più innovativo e a minor impatto. In linea con le direttive europee e nazionali, questo approccio punta a privilegiare cicli produttivi brevi e a ridurre il consumo di suolo, promuovendo una transizione più attenta all’ambiente e al territorio. Il nostro Paese, infatti, ha recepito gli indirizzi europei e ha sviluppato una propria strategia per la transizione verso un'economia circolare. La Strategia Nazionale per l'Economia Circolare (SEC), adottata nel giugno 2022, definisce un percorso chiaro con obiettivi misurabili fino al 2035, ponendo particolare attenzione alla trasformazione dei modelli produttivi, alla gestione dei rifiuti e alla creazione di nuove filiere circolari. Il Cronoprogramma della SEC, adottato nel settembre 2022, stabilisce le misure prioritarie per l'attuazione della strategia, includendo il supporto alla simbiosi industriale e alla rigenerazione delle aree industriali nonché la adozione di modelli di eco-distretto circolare (o parchi eco-industriali), sottolineando l'importanza di un approccio integrato che coinvolga politiche, strumenti finanziari e la collaborazione tra imprese per realizzare una trasformazione significativa del tessuto produttivo italiano, con attenzione ai flussi di materiali e sottoprodotti tipici dei nostri territori.

In questo contesto, il convegno della rete italiana di simbiosi industriale SUN Symbiosis Users Network, tenutosi il 6 novembre 2024 a Ecomondo, ha affrontato un tema di grande attualità e rilevanza per il futuro sostenibile dell'Italia: la transizione delle aree industriali e delle *brown-areas* italiane verso modelli di parchi eco-industriali, anche con l'obiettivo di rendere la simbiosi industriale una prassi gestionale consolidata per le aziende. Durante il convegno è stato evidenziato il ruolo fondamentale degli strumenti e degli incentivi, sia economici che normativi, per facilitare il passaggio da modelli produttivi lineari a sistemi sostenibili e circolari. L'evento ha favorito il confronto tra ricercatori, policymaker, esperti del settore e rappresentanti delle imprese, promuovendo la collaborazione tra i diversi attori coinvolti nella transizione. Inoltre, sono state analizzate le migliori pratiche a livello europeo e nazionale e discusse le strategie più efficaci per implementare la simbiosi industriale come pratica di routine e per favorire la transizione delle aree industriali italiane in EDC dinamici e sostenibili.

Ing. Laura Cutaia

Presidente SUN, ENEA – Divisione Economia Circolare - Dipartimento "Sostenibilità circolarità e adattamento ai cambiamenti climatici dei Sistemi Produttivi e Territoriali"

Alessandra De Santis

Presidente Editrice Circolare, editrice di EconomiaCircolare.com

Introduction

The transformation of Italy's industrial areas and brown-areas into Circular Eco-Districts (EDCs) or Eco-Industrial Parks (EIPs)—including through the implementation of industrial symbiosis—represents a complex yet vital challenge for the country's sustainable future. Both European and national regulatory frameworks provide a favorable context and acknowledge the value of this approach in achieving circular economy and climate neutrality goals.

Industrial symbiosis stands out as a strategic enabler for the development of local ecosystems, where resource efficiency is maximized, environmental impact is minimized, and new economic opportunities are generated. Transitioning industrial areas and brown-areas into EDCs or EIPs is a crucial step in this direction. These ecosystems are built around communities of businesses and services that collaborate to enhance their environmental and economic performance by sharing resources—such as energy, water, materials, infrastructure, and services—in synergy with the surrounding territory.

The regeneration of brown-areas and the conversion of industrial areas into EDCs or EIPs based on the principles of industrial symbiosis and ecology support the evolution of production zones into hubs of sustainable and circular development. This process also drives investment, job creation, and overall reductions in environmental impact. The positive dynamics triggered within an eco-industrial park improve the competitiveness of the production system, enhance its resilience to environmental and social risks, and strengthen efficiency in resource supply and waste management.

The European Union recognizes the potential of industrial symbiosis to create synergies among companies, transforming by-products and waste into resources for other businesses—yielding significant gains in both efficiency and sustainability. To support this transition, the Green Deal was launched in 2023, followed in early 2025 by the Clean Industrial Deal.

In this evolving landscape, Italy—leveraging its longstanding industrial tradition and the presence of numerous disused sites—faces both unique challenges and significant opportunities. The transformation of existing industrial areas and the redevelopment of brown-areas offer a strategic opportunity to shape a new, more innovative, and lower-impact industrial model. In line with European and national directives, this model promotes shorter production cycles and reduced land consumption, supporting a transition that is more attentive to environmental and territorial sustainability.

Italy has aligned with EU policies and developed a national roadmap for the transition to a circular economy. The National Strategy for the Circular Economy (NSCE), adopted in June 2022, outlines a clear path with measurable targets through 2035, with a strong focus on transforming production systems, improving waste management, and developing new circular value chains. The NSCE Implementation Roadmap, adopted in September 2022, defines priority actions to support the strategy, including measures to promote industrial symbiosis, regenerate industrial sites, and adopt circular eco-district (or eco-industrial park) models. It underscores the importance of an integrated approach that combines policy, financial tools, and business collaboration to enable meaningful transformation of Italy's industrial base, with close attention to local material and by-product flows.

Within this context, the national conference of the Italian industrial symbiosis network SUN – Symbiosis Users Network, held on 6 November 2024 at Ecomondo, addressed a timely and highly relevant topic for Italy's sustainable future: the transition of industrial areas and brown-areas toward eco-industrial park models, with the goal of making industrial symbiosis a widespread and standard management practice for businesses.

The conference highlighted the key role of economic and regulatory instruments and incentives in enabling the shift from linear production models to sustainable, circular systems. It fostered dialogue among researchers, policymakers, industry experts, and business leaders, promoting collaboration across sectors. Best practices at both European and national levels were examined, and effective strategies were discussed to embed industrial symbiosis into routine business operations and support the transformation of Italian industrial areas into dynamic, sustainable EDCs.

Eng. Laura Cutaia

President of SUN, ENEA – Circular Economy Division – Department for Sustainability

Alessandra De Santis

President of Editrice Circolare, publisher of EconomiaCircolare.com

Mercoledì, 6 novembre 2024 ore 10.00 – 13.00 Sala Mimosa pad.B6

TITOLO: Sostenere la transizione delle aree industriali e delle brown aree italiane in parchi eco industriali e l'implementazione della simbiosi industriale come strumento di routine gestionale per le aziende

Organizzato da: CTS Ecomondo, ENEA e SUN (Symbiosis Users Network)

CALL FOR PAPERS

Strumenti ed incentivi economici e non economici giocano un ruolo cruciale nell'affiancare la transizione da modelli di produzione e consumo lineari verso quelli sostenibili e circolari. Il Cronoprogramma della Strategia Nazionale per l'Economia Circolare, in questa prospettiva, prevede il sostegno ai progetti di simbiosi industriale attraverso lo sviluppo di strumenti e/o schemi di incentivazione e propone, inoltre, il ricorso allo strumento delle reti di impresa con finalità circolari e la rigenerazione di aree industriali dismesse in eco-distretti circolari (parchi eco-industriali), anche attraverso la simbiosi industriale. A tal fine risulta anche fondamentale il coinvolgimento ed il confronto con e tra gli stakeholder come imprese, pubbliche amministrazioni, università e centri di ricerca, sistemi di istruzione/formazione, associazioni di categoria e terzo settore. In questo contesto, l'VIII edizione del Convegno della rete SUN rappresenta un'opportunità per porre l'attenzione sugli strumenti e sugli incentivi economici e non economici per la promozione della simbiosi industriale e la transizione delle aree industriali italiane verso il modello di eco-distretto circolare.

Presidenti di sessione

Alessandra De Santis, economiacircolare.com
Laura Cutaia, ENEA - SUN Symbiosis Users Network

Programma

10.00 – 10.10 Introduzione

10.10 – 11.00 Interventi ad invito

Carlo Zaghi, Direzione generale sostenibilità dei prodotti e dei consumi, Ministero dell'Ambiente e della Sicurezza Energetica

Roberto Tatò, Direzione generale per le politica industriale, la riconversione e la crisi industriale per le politiche industriale, l'innovazione, le PMI e il Made in Italy, Ministero delle imprese e del Made in Italy

Maria Teresa Monteduro, Direzione studi e ricerche economico fiscali, Ministero dell'Economie e delle Finanze

Floriana La Marca, Health and Digital Executive Agency

Michele Posocco, Favini

Giovanni Caniglia, Pelligra Holding

Giancarlo Bellina, Confindustria Siracusa e Brown2Green Sicily

Silvia Sbaffoni[1] e Eleonora Perotto[2] - [1]ENEA , [2]Polimi, SUN GdL4 Certificazione e standardizzazione della simbiosi industriale

11.00-12.20 Presentazioni da call for paper

Perché le imprese italiane (non) implementano la simbiosi industriale?

Luca Fraccascia[1 2], Lorenza Fallone[1], [1]Sapienza Università di Roma, [2]University of Twente

Analisi degli strumenti finanziari utili a favorire la riconversione delle aree produttive italiane in un quadro green e sostenibile.

Giovanni Moccia, Centro Studi Di Ricerche Economiche e Sociali Mondi Sostenibili

From textile waste to resource: exploring industrial symbiosis opportunities between the textile and the furniture sectors

Roberta Pellegrino[1], Rosa Maria Dangelico[1], Vito Albino[1], Lorenzo Ardito[1], Umberto Panniello[1], Ilaria Giannoccaro[1], Pierpaolo Pontrandolfo[1], Francesco Martellotta[1], Chiara Rubino[1], Stefania Liuzzi[1], Stefano Franco[1], Giovanni Miccolis[1], Giovanni Perrone[2], Paolo Roma[2], Alessia Busacca[2], Silvia Barbero[3], Eliana Ferrulli[3], [1]Politecnico di Bari, [2]Università di Palermo, [3]Politecnico di Torino

SYMBA - Securing local supply chains via the development of new Methods to assess the circularity and symbiosis of the Bio-bAsed industrial ecosystem enhancing the EU

Antonietta Pizza[1], Marco de la Feld[1], Antonella De Fenza[1], Tanja Meyer[2], [1]ENCO s.r.l., [2]BBEPP

FacilitAmbiente, la facilitazione a supporto delle simbiosi industriali

Elisabetta Mauri, Camera Di Commercio Di Milano Monza Brianza Lodi - Camera Arbitrale Di Milano

An Industrial symbiosis top-down approach to plan industrial districts based on the exploitation of waste heat from different production processes

Giuseppe Mancini[1], Antonella Luciano[2], Debora Fino[3], [1]Università di Catania, [2]ENEA, [3]Politecnico di Torino

Distretti energetici circolari: il modello concreto per trasformare i rifiuti in risorse

Giovanni Baldassarre, Edison Next

Trieste Net0: Strategie di decarbonizzazione dell'area industriale giuliana

Augusto Peruzzi[1], S. Primiceri[2], A. Di Paolo[1], F. Fileni[1], M. Martignani[3], G. Nenzioni[3], Daniela Filipaz[4], Luigi Borgogno[4], [1]Capgemini, [2]Coselag, [3]Hera Servizi Energia, [4]Justonearth

12.20-12.55 Pitch – Casi studio - Coordinatrice Tiziana Beltrani

Sustainable Urban Ecosystems: Advancing Waste Management, Circular Economy Practices, and Symbiotic Solutions in Eastern Amman's Industrial Cities

Haneen Hassouneh, SCDA - Non-Profit Organization

La circolarità della Valutazione Ambientale Strategica per l'attuazione di scelte sostenibili di pianificazione e sviluppo economico del territorio della Regione Basilicata

Maria Carmela Bruno, Fiorella Messina, Regione Basilicata

Circolarità per il rinverdimento dei compositi - Circularity for greening composite

Maria Savina Pianesi, Delta s.r.l.

Enhancing industrial symbiosis as a business model in POREM's value chain: assessing its potential economic impact in Italy

Francesca Ceruti[1], Marco La Monica[2], Alice Dall'Ara[3], Alessandra Strafella[2], [1]Università di Brescia, [2]ENEA, [3]ADA S.R.L.S

Governing the Industrial parks: different Governance models to sustainable and circular Industrial parks

Massimo Di Domenico, Antonio Ballarin Denti, Mita Lapi, Fondazione Lombardia per l'Ambiente – FLA

Sportello circolarità

Paolo Maffè[1], Marina Stroppa[1], Giovanni Rossitti[1], Enrico Boccaleri[2], [1]Confindustria Novara Vercelli Valsesia, [2]Università del Piemonte Orientale

Use of Biochar in Metallurgical Sector: Potentials for Industrial Symbiosis and Transition to Circular Eco-Districts in Lombardy

Reza Vahidzadeh, Marta Domini, Giorgio Bertanza, Università degli Studi di Brescia

12.55-13.00 Chiusura lavori

Sessione poster – Coordinatore Marco La Monica

SUN - P1 *Promoting Industrial Symbiosis and Sustainable Agricultural Practices Using Algae*
Inese Skapste, Latvia University of Life Sciences and Technologies, Latvia

SUN - P2 *Per un Ecosistema dei Centri di Preparazione per il Riutilizzo in Italia*
Luca Pomili, Luca Pomili, Pomili Demolizioni Speciali Srl

SUN - P3 *WaStudy: la 4° edizione dell'osservatorio italiano del mercato dei rifiuti speciali*
Alberto Marazzato, Marazzato Soluzioni Ambientali Srl

SUN - P4 *Trasformazione del paesaggio industriale: revisione della letteratura sulle NBS in Europa e Italia*
Maria Elena Bini, Sara Pennellini, Alessandra Fiorucci, Alessandra Bonoli, Università di Bologna

SUN - P5 *Decarbonization of the Taranto steelmaking area: reduction of environmental and climate impacts*
Francesco Cardellicchio, CNR

SUN - P6 *Mapping the Horizon projects concerning the development of incentives for industrial symbiosis*
Mariarita Paciolla[1], Anna Rita Ceddia[2], Marco La Monica[2], [1]CDCA - Centro di Documentazione sui Conflitti Ambientali, [2]ENEA

SUN - P7 *Towards a standardized approach: UNI PdR for Biodiversity Credits*
Simone Mazzola[1], Salvatore Faugno[2], Simona Alberti[1,3], Francesca Barbero[3], Luca Pietro Casacci[3], Marino Quaranta[4], Monica Riva[5], Daria Maso[5], Pietro Spataro[6], Giorgio Pelassa[7], AA.VV[8], [1]3Bee srl, [2]Università Federico II di Napoli, [3]Università di Torino, [4]Crea di Bologna, [5]Bureau Veritas, [6]Climate Standard, [7]Regione Piemonte, [8]UNI - Ente Italiano di Normazione

SUN - P8 *I.F. - Second Life Furniture*
Michela Reale RINNOVATIVE S.r.l.

SUN - P9 *Approcci e strumenti per l'analisi e la modellizzazione di scenari circolari nelle filiere locali: il Progetto "MAX-SHEEP"*
Raffaella Taddeo[1], Enrico Vagnoni[2], Rosa Di Capua[3], Veronica Casolani[1], Alberto Simboli[2], Andrea Raggi[2], Valentino Tascione[1], Alessandra Piga[2], Sara Bortolu[2], Bruno Notarnicola[3], Pietro Alexander Renzulli[3], [1]Università degli Studi "G. d'Annunzio" di Chieti-Pescara, [2]CNR, [3]Università degli Studi di Bari Aldo Moro

SUN - P10 *Strumenti e incentivi per la promozione della riconversione delle aree produttive Italiane in parchi eco-industriali e per la diffusione della Simbiosi Industriale*
Giolitti Gianfranco, Edison Regea S.r.l.

SUN - P11 Application of multi-criteria decision analysis approach for evaluating the sustainability of landfills waste in Sicily
Agata Matarazzo, Salvatore Ingenito, Massimo Riccardo Costanzo, Antonio Zerbo, Università Di Catania

SUN - P12 *Linking agri-food good practices of circular economy with technology readiness levels*
Agata Matarazzo, Salvatore Ingenito, Massimo Riccardo Costanzo, Carla Serrano, Università Di Catania

SUN - P13 *Environmental performance and economic feasibility assessment of a Sicilian composting process as an example of transition from linear to circular production models*
Salvatore Ingenito[1], Massimo Riccardo Costanzo[1], Giuseppe Guagliardi[2], Angelo Lapiana[2], Agata Matarazzo[1], [1]Università di Catania, [2]Progitec S.r.l.

SUN - P14 *Il lavoro del futuro nella città del futuro.*
Armillotta G., Berardi M., Gnudi M., Lettieri F., Romano F., Randstad Research

SUN - P15 *Generatori ad idrogeno: una soluzione di backup a impatto zero per i data center*
ABDESSAMAD SAIDI[1], ANDREA PIVATELLO[2]. [1]Innio Jenbacher GmbH & CO OG - Jenbach – Austria, [2]Jenbacher srl – Verona, Italy

SUN - P16 *Generazione di energia basata sull'idrogeno. Una soluzione di backup a impatto zero per gli hub di Ammoniaca Verde*
ABDESSAMAD SAIDI[1], ANDREA PIVATELLO[2]. [1]Innio Jenbacher GmbH & CO OG - Jenbach – Austria, [2]Jenbacher srl – Verona, Italy

SUN - P17 Slow Fiber

Dario Casalini, President and Founder of Slow Fiber network

SUN - P18 *Il festival art for earth per una smart e green community*
Marinella Montanari. Affiliata con Jobel APS e Jobel North America

SUN - P19 *BeeGreen: Innovazione e sostenibilità per le aziende di produzione*
Giosef Perricci, UPNOVA GROUP SRL

Wednesday, 6 November 2024 10.00 – 13.00 Sala Mimosa Hall B6

TITLE: Supporting the transition of Italian industrial areas and brown areas into eco-industrial parks and the implementation of Industrial Symbiosis as a management routine tool for companies

Organized by: CTS Ecomondo, ENEA and SUN (Symbiosis Users Network).

CALL FOR PAPERS

Economic and non-economic tools and incentives play a crucial role in accompanying the transition from linear production and consumption models to sustainable and circular ones. The so called "Cronoprogramma" of the Italian National Strategy for Circular Economy, in this perspective, envisages the support of industrial symbiosis projects through the development of tools and/or incentive schemes and proposes, in addition, the use of business networks with circular purposes and the regeneration of brownfields into circular eco-districts (eco-industrial parks), including through industrial symbiosis. To this end, involvement and discussion with and among stakeholders such as businesses, public administrations, universities and research organizations, education/training systems, trade associations and the third sector is also essential. The 8th SUN Network Conference is an opportunity to focus attention on economic and non-economic tools and incentives for the promotion of industrial symbiosis and the transition of Italian industrial areas towards the circular eco-district model.

Session chairs

Alessandra De Santis, economiacircolare.com
Laura Cutaia, ENEA – SUN Symbiosis Users Network

Programme

10.00 – 10.10 Introduction by the Chairs

10.10 – 11.00 Invited speakers

Carlo Zaghi, Ministry of rnvironment and Energy Security

Roberto Tatò, Ministry of enterprises and made in Italy

Maria Teresa Monteduro, Ministry of economy and finance

Floriana La Marca, Health and Digital Executive Agency

Michele Posocco, Favini

Giovanni Caniglia, Pelligra Holding

Giancarlo Bellina, Confindustria Siracusa e Brown2Green Sicily

Silvia Sbaffoni, ENEA - – SUN Symbiosis Users Network

11.00-12.20 Speeches selected from the Call for Papers

Perché le imprese italiane (non) implementano la simbiosi industriale?

Luca Fraccascia[1 2], Lorenza Fallone[1], [1]Sapienza Università di Roma, [2]University of Twente

Analisi degli strumenti finanziari utili a favorire la riconversione delle aree produttive italiane in un quadro green e sostenibile.

Giovanni Moccia, Centro Studi Di Ricerche Economiche e Sociali Mondi Sostenibili

From textile waste to resource: exploring industrial symbiosis opportunities between the textile and the furniture sectors

Roberta Pellegrino[1], Rosa Maria Dangelico[1], Vito Albino[1], Lorenzo Ardito[1], Umberto Panniello[1], Ilaria Giannoccaro[1], Pierpaolo Pontrandolfo[1], Francesco Martellotta[1], Chiara Rubino[1], Stefania Liuzzi[1], Stefano Franco[1], Giovanni Miccolis[1], Giovanni Perrone[2], Paolo Roma[2], Alessia Busacca[2], Silvia Barbero[3], Eliana Ferrulli[3], [1]Politecnico di Bari, [2]Università di Palermo, [3]Politecnico di Torino

SYMBA - Securing local supply chains via the development of new Methods to assess the circularity and symbiosis of the Bio-bAsed industrial ecosystem enhancing the EU

Antonietta Pizza[1], Marco de la Feld[1], Antonella De Fenza[1], Tanja Meyer[2], [1]ENCO s.r.l., [2]BBEPP

FacilitAmbiente, la facilitazione a supporto delle simbiosi industriali

Elisabetta Mauri, Camera Di Commercio Di Milano Monza Brianza Lodi - Camera Arbitrale Di Milano

An Industrial symbiosis top-down approach to plan industrial districts based on the exploitation of waste heat from different production processes

Giuseppe Mancini[1], Antonella Luciano[2], Debora Fino[3], [1]Università di Catania, [2]ENEA, [3]Politecnico di Torino

Distretti energetici circolari: il modello concreto per trasformare i rifiuti in risorse

Giovanni Baldassarre, Edison Next

Trieste Net0: Strategie di decarbonizzazione dell'area industriale giuliana

Augusto Peruzzi[1], S. Primiceri[2], A. Di Paolo[1], F. Fileni[1], M. Martignani[3], G. Nenzioni[3], Daniela Filipaz[4], Luigi Borgogno[4], [1]Capgemini, [2]Coselag, [3]Hera Servizi Energia, [4]Justonearth

12.20-12.55 Pitch – Case study – Chair Tiziana Beltrani

Sustainable Urban Ecosystems: Advancing Waste Management, Circular Economy Practices, and Symbiotic Solutions in Eastern Amman's Industrial Cities

Haneen Hassouneh, SCDA - Non-Profit Organization

La circolarità della Valutazione Ambientale Strategica per l'attuazione di scelte sostenibili di pianificazione e sviluppo economico del territorio della Regione Basilicata

Maria Carmela Bruno, Fiorella Messina, Regione Basilicata

Circolarità per il rinverdimento dei compositi - Circularity for greening composite

Maria Savina Pianesi, Delta s.r.l.

Enhancing industrial symbiosis as a business model in POREM's value chain: assessing its potential economic impact in Italy

Francesca Ceruti[1], Marco La Monica[2], Alice Dall'Ara[3], Alessandra Strafella[2], [1]Università di Brescia, [2]ENEA, [3]ADA S.R.L.S

Governing the Industrial parks: different Governance models to sustainable and circular Industrial parks

Massimo Di Domenico, Antonio Ballarin Denti, Mita Lapi, Fondazione Lombardia per l'Ambiente – FLA

Sportello circolarità

Paolo Maffè[1], Marina Stroppa[1], Giovanni Rossitti[1], Enrico Boccaleri[2], [1]Confindustria Novara Vercelli Valsesia, [2]Università del Piemonte Orientale

Use of Biochar in Metallurgical Sector: Potentials for Industrial Symbiosis and Transition to Circular Eco-Districts in Lombardy

Reza Vahidzadeh, Marta Domini, Giorgio Bertanza, Università degli Studi di Brescia

12.55-13.00 Conclusion

Sessione poster – Chair Marco La Monica

SUN - P1 *Promoting Industrial Symbiosis and Sustainable Agricultural Practices Using Algae*
Inese Skapste, Latvia University of Life Sciences and Technologies, Latvia

SUN - P2 *Per un Ecosistema dei Centri di Preparazione per il Riutilizzo in Italia*
Luca Pomili, Luca Pomili, Pomili Demolizioni Speciali Srl

SUN - P3 *WaStudy: la 4° edizione dell'osservatorio italiano del mercato dei rifiuti speciali*
Alberto Marazzato, Marazzato Soluzioni Ambientali Srl

SUN - P4 *Trasformazione del paesaggio industriale: revisione della letteratura sulle NBS in Europa e Italia*
Maria Elena Bini, Sara Pennellini, Alessandra Fiorucci, Alessandra Bonoli, Università di Bologna

SUN - P5 *Decarbonization of the Taranto steelmaking area: reduction of environmental and climate impacts*
Francesco Cardellicchio, CNR

SUN - P6 *Mapping the Horizon projects concerning the development of incentives for industrial symbiosis*

Mariarita Paciolla[1], Anna Rita Ceddia[2], Marco La Monica[2], [1]CDCA - Centro di Documentazione sui Conflitti Ambientali, [2]ENEA

SUN - P7 *Towards a standardized approach: UNI PdR for Biodiversity Credits*
Simone Mazzola[1], Salvatore Faugno[2], Simona Alberti[1,3], Francesca Barbero[3], Luca Pietro Casacci[3], Marino Quaranta[4], Monica Riva[5], Daria Maso[5], Pietro Spataro[6], Giorgio Pelassa[7], AA.VV[8], [1]3Bee srl, [2]Università Federico II di Napoli, [3]Università di Torino, [4]Crea di Bologna, [5]Bureau Veritas, [6]Climate Standard, [7]Regione Piemonte, [8]UNI - Ente Italiano di Normazione

SUN - P8 *I.F. - Second Life Furniture*
Michela Reale RINNOVATIVE S.r.l.

SUN - P9 *Approcci e strumenti per l'analisi e la modellizzazione di scenari circolari nelle filiere locali: il Progetto "MAX-SHEEP"*
Raffaella Taddeo[1], Enrico Vagnoni[2], Rosa Di Capua[3], Veronica Casolani[1], Alberto Simboli[2], Andrea Raggi[2], Valentino Tascione[1], Alessandra Piga[2], Sara Bortolu[2], Bruno Notarnicola[3], Pietro Alexander Renzulli[3], [1]Università degli Studi "G. d'Annunzio" di Chieti-Pescara, [2]CNR, [3]Università degli Studi di Bari Aldo Moro

SUN - P10 *Strumenti e incentivi per la promozione della riconversione delle aree produttive Italiane in parchi eco-industriali e per la diffusione della Simbiosi Industriale*
Giolitti Gianfranco, Edison Regea S.r.l.

SUN - P11 Application of multi-criteria decision analysis approach for evaluating the sustainability of landfills waste in Sicily
Agata Matarazzo, Salvatore Ingenito, Massimo Riccardo Costanzo, Antonio Zerbo, Università Di Catania

SUN - P12 *Linking agri-food good practices of circular economy with technology readiness levels*
Agata Matarazzo, Salvatore Ingenito, Massimo Riccardo Costanzo, Carla Serrano, Università Di Catania

SUN - P13 *Environmental performance and economic feasibility assessment of a Sicilian composting process as an example of transition from linear to circular production models*
Salvatore Ingenito[1], Massimo Riccardo Costanzo[1], Giuseppe Guagliardi[2], Angelo Lapiana[2], Agata Matarazzo[1], [1]Università di Catania, [2]Progitec S.r.l.

SUN - P14 *Il lavoro del futuro nella città del futuro.*
Armillotta G., Berardi M., Gnudi M., Lettieri F., Romano F., Randstad Research

SUN - P15 *Generatori ad idrogeno: una soluzione di backup a impatto zero per i data center*
ABDESSAMAD SAIDI[1], ANDREA PIVATELLO[2]. [1]Innio Jenbacher GmbH & CO OG - Jenbach – Austria, [2]Jenbacher srl – Verona, Italy

SUN - P16 *Generazione di energia basata sull'idrogeno. Una soluzione di backup a impatto zero per gli hub di Ammoniaca Verde*
ABDESSAMAD SAIDI[1], ANDREA PIVATELLO[2]. [1]Innio Jenbacher GmbH & CO OG - Jenbach – Austria, [2]Jenbacher srl – Verona, Italy

SUN - P17 Slow Fiber
Dario Casalini, President and Founder of Slow Fiber network

SUN - P18 *Il festival art for earth per una smart e green community*
Marinella Montanari. Affiliata con Jobel APS e Jobel North America

SUN - P19 *BeeGreen: Innovazione e sostenibilità per le aziende di produzione*
Giosef Perricci, UPNOVA GROUP SRL

INTERVENTI AD INVITO

Dario D’Angelo – Ministero dell’Ambiente e della Sicurezza Energetica

Il Ministero dell'Ambiente e della Sicurezza Energetica (MASE) è attivamente impegnato nello sviluppo di politiche ambientali volte a promuovere la simbiosi industriale (SI) e l'economia circolare (EC) in Italia. Questo impegno si traduce in diverse iniziative e strumenti, tra cui un accordo di collaborazione con ENEA e l'implementazione di una metapiattaforma digitale per facilitare la SI.

È noto che l'EC è un modello di produzione e consumo che mira a estendere il ciclo di vita dei prodotti, riducendo al minimo i rifiuti mantenendo le risorse in circolo. Questo si realizza attraverso un ciclo virtuoso che parte dalla progettazione (pensando già al riutilizzo e al riciclo), prosegue con la produzione e rimanifattura (ottimizzando i processi e riducendo gli scarti), include la distribuzione (favorendo la condivisione), e si estende all'uso, manutenzione e riparazione (per allungare la vita dei beni). Infine, prevede una raccolta efficiente e il riciclo, trasformando i rifiuti in nuove preziose risorse. L'idea centrale è semplice: meno "rifiuti residui" e più "materie prime" che continuano a generare valore.

Per superare i "fallimenti del mercato", il MASE sta introducendo una serie di strumenti diversificati. Ci sono le regole chiare del "Command & Control", che stabiliscono comportamenti obbligatori. Poi, abbiamo strumenti di mercato, come le certificazioni e i sussidi, che offrono incentivi economici alle pratiche sostenibili. Non mancano approcci innovativi come la "Behavioral Economics", con tecniche di "Nudge" che mirano a guidare le scelte di imprese e consumatori verso soluzioni più ecologiche. E, naturalmente, strumenti fiscali come crediti d'imposta per chi adotta prodotti alternativi alla plastica monouso o utilizza materiali recuperati.

L'impegno del MASE è tangibile e si manifesta in diverse iniziative chiave: Il progetto "Advanced Policy Instruments to Accelerate the Circular Economy in Italy", finanziato dalla DG Reform dell'UE, mira a sviluppare strumenti politici all'avanguardia. L'istituzione di un Tavolo Ecodesign, per promuovere la progettazione di prodotti intrinsecamente sostenibili. Sono stati definiti e implementati i Criteri Ambientali Minimi (CAM) per settori cruciali come l'arredamento, l'edilizia, la gestione dei rifiuti e gli eventi culturali. È stato lanciato "Made 21 Green in Italy", uno schema nazionale volontario per valutare e comunicare l'impronta ambientale dei prodotti. L'accordo di collaborazione con ENEA, siglato a fine 2022, è un pilastro per lo sviluppo della SI. Non ultimo, l'iniziativa "Mangiaplastica" (D.M. n. 360 del 02/09/2021) e il credito d'imposta per incentivare fiscalmente prodotti alternativi alle plastiche monouso e per l'utilizzo di materiali recuperati.

Nonostante questi sforzi, la SI incontra ancora ostacoli significativi. A volte, sono le normative stesse a rallentare i progetti collaborativi tra aziende. A livello economico, si avverte la scarsità di investimenti in nuove tecnologie e infrastrutture necessarie per il recupero degli scarti. Vi sono anche lacune tecnologiche, con una carenza di strumenti adeguati alla valorizzazione dei rifiuti. A ciò si aggiunge una mancanza di informazioni sulla disponibilità di scarti potenzialmente riutilizzabili e, non da ultimo, una scarsa consapevolezza culturale sui benefici ambientali ed economici della SI.

Per superare queste sfide, l'accordo tra MASE ed ENEA è un vero e proprio motore, articolato in dieci Working Packages (WP). L'obiettivo è costruire un'infrastruttura solida per la SI in Italia. Le attività principali includono:

- La creazione di una metapiattaforma digitale per la SI, uno strumento flessibile e collaborativo per connettere domanda e offerta di risorse.
- L'applicazione della SI per rigenerare le "brown areas" (aree industriali dismesse) e dar vita a veri e propri eco-distretti circolari.
- L'analisi e la definizione di meccanismi incentivanti per la SI.
- La definizione di strumenti di standardizzazione e certificazione per la SI.
- Il monitoraggio degli impatti generati dalla SI.
- Lo sviluppo di competenze e formazione nel campo della SI.

La metapiattaforma digitale, in particolare, si prefigge di essere il cuore pulsante di questo sistema. I suoi obiettivi sono chiari: facilitare l'incontro tra domanda e offerta di risorse, monitorare lo stato di avanzamento della SI in Italia e informare sui suoi molteplici impatti economici, ambientali e sociali. Attualmente, esistono già diverse piattaforme in Italia con l'obiettivo di individuare e implementare percorsi di SI. La metapiattaforma cercherà di mettere a sistema e integrare le funzionalità di queste piattaforme esistenti per massimizzare il loro potenziale.

Sarà uno strumento dinamico e cooperativo, alimentato direttamente dagli utenti che, iscrivendosi, forniranno informazioni specifiche sulle loro risorse. Gli utenti potranno consultare esempi e buone pratiche di simbiosi che hanno già portato a risultati positivi a livello nazionale. Inoltre, sarà possibile individuare aziende interessate a condividere esperienze e risorse. La banca dati delle risorse sarà popolata da gestori di piattaforme, consulenti e aziende, con schede dettagliate sull'origine, l'uso e la gestione delle risorse. È importante sottolineare che tutte le informazioni raccolte riporteranno la fonte e verranno validate da un gruppo di esperti prima di essere rese pubbliche.

Un altro fronte cruciale è la rigenerazione delle "brown areas". Le città europee post-industriali soffrono l'espansione urbana incontrollata, che non solo spreca territorio ma ha anche impatti negativi sull'ambiente, la società e l'economia. Molte città hanno visto un decentramento e una perdita significativa di residenti e industrie. Questo ha portato a un aumento delle aree dismesse, le cosiddette "vacant land" o "brownfield". L'accordo MASE-ENEA prevede di analizzare queste aree esistenti in Italia per valutarne la possibile riconversione in chiave circolare, proprio tramite la SI. Verranno create schede operative e di confronto su casi emblematici di brown area già rigenerate, poiché queste aree dismesse sono considerate il terreno privilegiato per le trasformazioni urbane contemporanee.

Infine, i prossimi sviluppi prevedono la stesura della prima bozza del Programma Nazionale per la SI, che sarà poi sottoposta a consultazione con tutte le parti interessate. Questo programma ambizioso includerà la definizione di strumenti normativi e tecnico-normativi, nonché di certificazioni per la SI, strumenti economici per implementare la SI su tutto il territorio italiano e un piano per lo sviluppo di competenze e formazione nel settore.

In sintesi, l'Italia, attraverso il MASE e la sinergia con ENEA, sta costruendo un percorso chiaro e articolato per superare le sfide e abbracciare pienamente i benefici di un'EC e della SI.

Maria Teresa Monteduro – Ministero dell'economia e delle Finanze

Nel contesto della trasformazione dei processi produttivi, il modello della simbiosi industriale, che coinvolge vari attori, pubblici e privati, a livello centrale e territoriale, riveste un ruolo di primissimo rilievo.

La condivisione di risorse e materiali di scarto tra aziende può ridurre significativamente i costi operativi. L'utilizzo di sottoprodotti di un'azienda come materie prime per un'altra riduce, ad esempio, la necessità di acquistare nuove risorse. La simbiosi industriale promuove un uso più efficiente delle risorse, minimizzando gli sprechi, ottimizzando i processi produttivi e generando una maggiore produttività e una riduzione dei costi di produzione. Le collaborazioni tra aziende all'interno di un sistema di simbiosi industriale possono inoltre stimolare l'innovazione e lo sviluppo di nuove tecnologie sostenibili.

In questo quadro, la leva fiscale è uno strumento potente per sostenere la transizione verso modelli di produzione circolare, promuovendo pratiche sostenibili e incentivando comportamenti virtuosi tra le imprese. Se ben progettati e implementati, gli incentivi possono generare benefici economici, sociali e ambientali significativi, contribuendo a una crescita sostenibile e inclusiva.

Tuttavia, le politiche fiscali, da sole, non bastano ad attivare meccanismi virtuosi. Per essere efficaci, necessitano di interventi di adeguamento culturale, normativo, tecnologico, industriale e logistico. Diverse barriere ostacolano infatti ancora oggi la piena diffusione di modelli trasformativi delle realtà aziendali. Vi sono barriere culturali che originano dalla scarsa conoscenza dei benefici del cambiamento organizzativo e dalla resistenza a implementare nuove *routine* o a condividere informazioni aziendali. Ad esempio, in materia di gestione e trattamento dei rifiuti, sforzi significativi sono continuamente necessari per aggiornare e semplificare le normative adattandole a fenomeni in continua evoluzione. Le imprese devono inoltre gestire i disallineamenti tra domanda e offerta in termini di quantità e qualità degli scarti. Infine, sotto il profilo economico, le imprese devono sostenere costi e investimenti significativi per adeguarsi a nuovi modelli produttivi.

Quale ruolo può assumere la leva fiscale per accelerare i processi di simbiosi industriale e favorire la collaborazione tra aziende per un uso più efficiente delle risorse?

Un primo aspetto riguarda la correzione delle esternalità negative, ovvero degli effetti collaterali delle attività economiche che non sono riflessi nei costi di mercato. Tasse ambientali possono penalizzare le attività inquinanti, mentre incentivi fiscali possono premiare le pratiche sostenibili. Per favorire lo sviluppo della simbiosi industriale, la riduzione dei rifiuti e l'uso efficiente delle risorse possono ad esempio essere incentivati attraverso agevolazioni fiscali. Incentivi fiscali o detrazioni alle imprese che riducono il consumo energetico attraverso l'uso di tecnologie avanzate possono essere utilizzati per promuovere l'efficienza energetica, altro elemento chiave della simbiosi industriale.

Un ulteriore aspetto è legato alla circostanza che le agevolazioni fiscali possono stimolare l'innovazione e l'adozione di tecnologie verdi. Ad esempio, crediti d'imposta per la ricerca e sviluppo (R&D) incoraggiano gli investimenti in soluzioni innovative per il riutilizzo dei materiali e la riduzione degli sprechi, migliorando la sostenibilità economica delle scelte aziendali. Le imprese che adottano pratiche sostenibili e modelli di produzione circolari possono migliorare la loro competitività sul mercato globale, rispondendo anche alle crescenti richieste dei consumatori per prodotti e servizi ecologici. Per adottare modelli di produzione circolari le imprese possono necessitare di nuove competenze e professionalità e impiegare lavoro qualificato, con conseguenze positive in termini di creazione di posti di lavoro di qualità.

La transizione verso modelli di produzione sostenibili richiede, inoltre, cambiamenti sistemici e investimenti in nuove tecnologie e infrastrutture. Incentivi fiscali mirati possono ridurre il rischio finanziario per le aziende, incoraggiandole a sperimentare e adottare soluzioni innovative e circolari e sostenere gli investimenti nelle infrastrutture necessarie per la simbiosi industriale.

Infine, la politica fiscale può essere utilizzata per ridurre le disparità regionali, indirizzando incentivi specifici verso le aree meno sviluppate, al fine di promuovere uno sviluppo economico più equilibrato e inclusivo.

In sintesi, sebbene gli incentivi fiscali alla simbiosi industriale comportino costi iniziali significativi, le loro implicazioni a lungo termine possono essere altamente positive, contribuendo *i)* alla sostenibilità ambientale attraverso la creazione di un modello di sviluppo che riduce la dipendenza dalle risorse naturali; *ii)* alla resilienza delle imprese alle fluttuazioni dei prezzi delle materie prime e alle pressioni normative legate alla transizione ecosostenibile; *iii)* alla crescita economica inclusiva, promuovendo la collaborazione tra aziende di diverse dimensioni e settori.

Nel disegnare gli incentivi è, tuttavia, essenziale privilegiare un approccio equilibrato che consideri costi e benefici dal punto di vista economico e sociale, garantendo un utilizzo delle risorse pubbliche orientato al lungo termine. Un elemento importante del *design* di un incentivo è la sua capacità di modificare efficacemente il comportamento degli agenti economici, sostenendo la transizione verso un'economia circolare. E' importante che gli incentivi inducano investimenti aggiuntivi o incoraggino comportamenti virtuosi che non si verificherebbero in assenza delle misure agevolative (cd addizionalità). L'introduzione di incentivi fiscali può inizialmente far diminuire le entrate fiscali riducendo le risorse destinate al finanziamento di altre spese pubbliche. Se si registrano aumenti della produttività, attraverso la riduzione dei costi operativi e il miglioramento dei processi produttivi, si possono tuttavia generare benefici economici a lungo termine, un aumento delle entrate generata dall'espansione delle basi imponibili e uno stimolo alla crescita economica.

Per perseguire questi obiettivi, è quindi necessario analizzare i mercati e i processi produttivi che le politiche possono promuovere, comprendere i fattori che determinano le scelte aziendali e introdurre incentivi che abbiano maggiori probabilità di favorire una risposta comportamentale positiva. Per massimizzarne l'efficacia è inoltre essenziale indirizzare gli incentivi verso quei soggetti che, in assenza di politiche agevolative, non sarebbero in grado di contribuire in modo significativo a un'economia circolare vitale. La selettività di questo approccio (*targeting*) assicura che le risorse siano allocate in modo ottimale attraverso la leva fiscale. Una selettività accurata garantisce anche che ogni euro speso abbia il massimo impatto per stimolare comportamenti e pratiche sostenibili dei beneficiari, evitando di sostenere costi per sovvenzionare aziende che avrebbero comunque implementato pratiche virtuose. Il supporto ai soggetti chiave, a sua volta, promuove una rete più robusta e interconnessa di produttori, riducendo la dipendenza dalle risorse vergini e limitando la produzione di rifiuti.

L'approccio selettivo e mirato degli incentivi fiscali può essere quindi estremamente efficace nel promuovere la simbiosi industriale e, di conseguenza, un'economia circolare più sostenibile. Indirizzare le risorse verso soggetti che necessitano realmente del supporto assicura che gli incentivi fiscali siano utilizzati nel modo più efficiente ed efficace possibile, favorendo una migliore transizione verso modelli di produzione più sostenibili e circolari.

Anche nel contesto internazionale, gli esempi del Regno Unito, della Danimarca, della Corea del Sud e del Giappone evidenziano come incentivi fiscali mirati possano stimolare la collaborazione tra aziende, promuovere l'adozione di tecnologie sostenibili e migliorare l'efficienza nell'uso delle risorse. Il *National Industrial Symbiosis Programme* (NISP) nel Regno Unito ha beneficiato di finanziamenti governativi e incentivi fiscali, facilitando lo scambio di materiali di scarto e riducendo le emissioni di CO_2. In Danimarca, il distretto industriale di *Kalundborg* ha ricevuto incentivi per investire in infrastrutture condivise, creando una rete di scambio di risorse che ha migliorato l'efficienza e ridotto l'impatto ambientale. In Corea del Sud, le politiche fiscali hanno sostenuto i parchi eco-industriali, offrendo agevolazioni alle aziende che adottano pratiche di simbiosi industriale. Allo stesso modo, in Giappone, il governo ha introdotto incentivi fiscali per le aziende partecipanti a progetti di simbiosi industriale, come il *Kitakyushu Eco-Town*, stimolando la collaborazione e l'innovazione tecnologica.

Quali misure agevolative possono essere disegnate a supporto dell'economia circolare nel nostro paese?

Una possibile opzione è l'introduzione di agevolazioni per l'acquisto di *input* derivati da scarti o rifiuti di altre industrie. Misure di questo tipo rischierebbero di essere inefficaci e inefficienti nella misura in cui riconoscano incentivi a imprese che già acquistano *input* da rifiuti e scarti, poiché questi risultano già più convenienti rispetto alle materie prime o vergini e/o non incentivano comportamenti virtuosi aggiuntivi, includendo tra i beneficiari imprese che già operano in simbiosi, senza generare addizionalità.

In alternativa, si può agire sul processo di trasformazione industriale. Riconoscere agevolazioni alle imprese che intendono investire per processare e lavorare scarti e rifiuti, trasformandoli in *input* utili al processo produttivo, favorirebbe gli investimenti necessari a rimuovere barriere tecnologiche all'ingresso, consentendo la partecipazione di nuovi soggetti in grado di contribuire attivamente al raggiungimento degli obiettivi di economia circolare e massimizzando un utilizzo efficiente ed efficace delle risorse.

Nell'esperienza italiana, il legislatore ha scelto di percorrere la seconda strada, inserendo la simbiosi industriale tra le attività agevolabili con il credito d'imposta per ricerca, sviluppo, innovazione e *design*, introdotto con la legge di bilancio 2020 e successivamente modificato con la legge di bilancio 2022. La misura riconosce a tutte le imprese, indipendentemente dalla forma giuridica, dimensione e settore economico un credito d'imposta sugli investimenti in ricerca e sviluppo, transizione ecologica, innovazione tecnologica 4.0 e altre attività innovative, con aliquote differenziate a seconda del tipo di attività agevolabile. Gli investimenti in progetti di simbiosi industriale rientrano tra le attività di innovazione tecnologica, per le quali è prevista un'aliquota del 5%, con un limite massimo annuale di 4 milioni di euro di credito. Tra le spese agevolabili figurano quelle per il personale, quote di ammortamento e canoni di locazione per beni materiali e software, nonché spese per servizi di consulenza. La misura è fruibile per i periodi d'imposta 2024 e 2025.Il decreto attuativo del 26 maggio 2020, emanato dal Ministero delle Imprese e del Made in Italy, include, tra le attività di innovazione tecnologica finalizzate al raggiungimento degli obiettivi di transizione ecologica, i lavori svolti nell'ambito di progetti relativi alla trasformazione dei processi aziendali secondo i principi dell'economia circolare e cita espressamente la simbiosi industriale.

Si tratta di un primo tentativo di implementare strumenti fiscali per sostenere la simbiosi industriale, in risposta alle molteplici sfide che dovranno essere affrontate per assicurare il successo di una strategia complessiva. Assieme a incentivi fiscali mirati, è essenziale assicurare il coordinamento tra le parti interessate, la creazione di reti di collaborazione, l'uso di piattaforme digitali per il *matching* delle risorse e un quadro flessibile che faciliti lo scambio di materiali tra le aziende e superi le barriere normative esistenti. I costi iniziali elevati dei progetti e la necessità di consapevolezza e formazione rappresentano ulteriori ostacoli. Infine, il monitoraggio continuo e la valutazione dell'efficacia degli strumenti fiscali e dei progetti di simbiosi industriale consentono di ottimizzare le pratiche e massimizzare i benefici ambientali ed economici ma sono anche caratterizzati da un notevole grado di complessità.

In una prospettiva più ampia, un'efficace gestione della simbiosi industriale può contribuire a ridurre il costo delle politiche climatiche. La simbiosi industriale, analogamente ad altri processi di trasformazione industriale orientati alla transizione, necessita di un *mix* di strumenti per accelerare il progresso tecnologico nei settori ad alto valore aggiunto, con un conseguente beneficio anche in termini di riduzione del costo delle politiche climatiche. La creazione di sinergie e l'utilizzo di tutti gli strumenti disponibili in modo completo e complementare consentirebbe di conseguire un risultato vantaggioso per tutti gli *stakeholders*, con la possibilità per le aziende di abbattere i costi privati e per i *policy maker* di raggiungere gli obiettivi ambientali in modo efficiente.

Alla luce delle sfide e delle opportunità che ci attendono, il convegno odierno è un'importante occasione di confronto e dibattito per promuovere iniziative volte a favorire la collaborazione tra industrie e contribuire a creare un ambiente favorevole alla simbiosi industriale. Il confronto tra rappresentanti della pubblica amministrazione, delle imprese e dell'università è fondamentale per acquisire una visione completa e articolata di questi temi. Condividere esperienze, idee e soluzioni innovative è la strada da percorrere verso un futuro più sostenibile e circolare per l'industria italiana.

Floriana La Marca – Health and Digital Executive Agency

HaDEA, l'Agenzia Esecutiva della Commissione Europea per la Salute e il Digitale si occupa della gestione dei programmi e delle iniziative di ricerca e innovazione (R&I) dell'Unione Europea. In particolare, l'Unità B3 – Industry, gestisce i progetti del segmento Industry del Cluster 4 di Horizon Europe, dedicato appunto al digitale, all'industria e allo spazio. HaDEA lavora a stretto contatto con alcune DG, tra cui DG GROW e R&I che si occupano invece di attività di policy-making, di legislazione e strategia.

Nata in aprile 2021, HaDEA risponde all'ambizione della Commissione Europea di contribuire a ricostruire un'Europa post-COVID-19 più verde, più digitale, più resiliente e più adeguata alle sfide attuali e future.

La simbiosi industriale nei programmi di finanziamenti europei

Tra le priorità dei programmi di finanziamenti europei vi è la costituzione degli hub per la circolarità (Hub for Circularity - H4C) come uno strumento chiave per far progredire la ricerca e l'innovazione del settore industriale europeo verso gli obiettivi del Green Deal. Gli H4C hanno come obiettivo l'attuazione di una serie di tecnologie di simbiosi industriale-urbana e circolarità su larga scala, da dimostrare in impianti primi nel loro genere, di dimensioni (quasi) commerciali, che attuano la simbiosi industriale e/o la simbiosi industriale urbana, integrando infrastrutture e reti energetiche. Partendo da un cluster industriale esistente o da aree urbane fortemente industrializzate, il loro obiettivo è di raggiungere e dimostrare collettivamente su larga scala un cambio di passo verso la circolarità nell'uso delle risorse (materie prime, energia e acqua), coinvolgendo tutte le parti interessate (industria, PMI, autorità locali, istituti di istruzione e società civile). Le industrie coinvolte dovrebbero promuovere l'efficienza delle risorse, il recupero del calore, l'integrazione di energie rinnovabili, l'uso dell'idrogeno come vettore energetico e/o sostenere l'utilizzo della CO2 catturato (Carbon Capture and Utilization – CCU) e pianificare gli aspetti logistici della cattura del carbonio con stoccaggio permanente (Carbon Capture and Storage – CCS).

È un nuovo modo di reimmaginare l'intera catena del valore in modo intersettoriale e collaborativo sfruttando sinergie e collegamenti nell'ecosistema locale per ottimizzare le risorse in arrivo, compresi gli investimenti. Si tratta di costruire su creatività, strumenti digitali, intelligenza artificiale e tecnologie innovative per l'attuazione di percorsi ottimali in termini di costo e nuove catene del valore per l'ingegnerizzazione di un'economia circolare a impatto zero.

Con gli H4C, il modello di business orientato all'offerta si evolve in un approccio più lungimirante basato sulla domanda, che faciliti lo sviluppo della simbiosi industriale in diversi settori industriali.

Altra priorità è il beneficio per i cittadini che vivono in prossimità di agglomerati fortemente industrializzati di un ambiente più sano grazie alla simbiosi industriale, riducendo le emissioni attraverso fonti energetiche circolari e rinnovabili.

Gli H4C costituiranno un trampolino di lancio verso la neutralità climatica e la circolarità nell'industria. Si tratta di ecosistemi industriali economici autosufficienti per la promozione della simbiosi industriale-urbana (*industrial–urban symbiosis – I-US*) su vasta scala e dell'economia circolare.

In questo contesto, la Comunità europea di pratica (*European Community of Practice – ECoP*) si baserà su H4C e I–US, inizialmente supportando le dimostrazioni H4C finanziate nell'ambito di Horizon Europe. Il progetto H4C ECoP, finanziato dall'UE, svilupperà la rete delle ECoP e delle parti interessate mediante una piattaforma di informazioni e conoscenze per consentire agli interlocutori di agire. La piattaforma H4C sosterrà la condivisione delle conoscenze tra regioni/città e le loro industrie, fornendo gli strumenti per l'approccio da adottare su larga scala in tutta Europa.

Un altro risultato atteso è quello di fornire raccomandazioni per ottimizzare le condizioni quadro regionali, mettendo in evidenza ostacoli e politiche appropriate orientate all'innovazione, nonché di utilizzare metodologie consolidate per la valutazione delle attività e degli scambi di simbiosi industriali, come ad esempio i *Symbiosis Readiness Levels (SRLs)* e consolidate migliori pratiche.

Un altro segmento dei finanziamenti europei per la simbiosi industriale è rappresentato dal partenariato *Processes4Planet (P4Planet)*, che mira a trasformare le industrie europee di trasformazione per raggiungere la circolarità e la neutralità climatica globale a livello UE entro il 2050, migliorando nel contempo la loro competitività globale. *P4Planet* è un partenariato pubblico-privato europeo co-programmato, istituito tra A.SPIRE – come ente privato – e la Commissione Europea nel contesto del programma di finanziamento Horizon Europe, nell'ambito del Cluster 4 (Digitale, Industria e Spazio).

Il cambiamento sistemico necessario per la transizione verso una società climatica e circolare richiede qualcosa di più che l'innovazione tecnologica. Lo spirito del partenariato *P4Planet* è quello di promuovere un approccio socioeconomico sistemico olistico. Il partenariato ha un'importanza strategica per l'industria europea, che grazie al suo vantaggio tecnico globale può generare un impatto sulla crescita economica e sulla creazione di nuovi posti di lavoro altamente qualificati.

Alcuni esempi di progetti finanziati dell'Unione Europea

Il progetto *INITIATE* promuove l'attuazione dell'economia circolare e della simbiosi industriale riutilizzando i gas residui dell'industria dell'acciaio come risorsa per la produzione più efficiente e meno dispendiosa di urea, con un'impronta di carbonio significativamente ridotta.

Il progetto *SYMSITES* mira a sviluppare nuove tecnologie e soluzioni basate sul concetto di simbiosi industriale e urbana (I-US) per la collaborazione locale e regionale tra diversi attori (cittadini, comuni e imprese) e settori, migliorando la sostenibilità nell'uso delle risorse industriali e sociali a partire dalle acque reflue e dai materiali di scarto.

Il progetto *MOBICCON-PRO* si prefigge di sviluppare, introdurre e dimostrare soluzioni circolari integrate e innovative per recuperare le risorse dai rifiuti da costruzione e demolizione (CDW) e ridurre così il consumo di materie prime, applicando in situ la separazione e la demolizione selettiva.

Il progetto *IS2H4C* si concentra sulla diffusione della simbiosi industriale sistemica attraverso tecnologie innovative quali la cattura del carbonio e l'elettrolisi. L'iniziativa è guidata dall'intento di migliorare l'efficienza delle risorse, mediante la produzione di energia rinnovabile, la prevenzione dei rifiuti e la promozione della simbiosi industriale-urbano-rurale. Il progetto mira a sviluppare le tecnologie sostenibili più innovative e l'integrazione delle infrastrutture in quattro centri dimostrativi ed è sostenuto da ricerche pionieristiche sull'innovazione sociale, governativa e commerciale per H4C.

Disclaimer

Le informazioni e i punti di vista espressi nel contributo sono propri dell'autore e non necessariamente riflettono l'opinione ufficiale di HaDEA - European Health and Digital Executive Agency.

Michele Posocco – Favini

Favini è un'azienda leader a livello mondiale nella produzione di **carte speciali innovative**, realizzate con materie prime naturali come cellulosa, alghe, cuoio, denim, cotone, lana, frutta e noci. Accanto alle divisioni Release e cartotecnica, l'azienda si distingue per il suo impegno nella **sostenibilità** e nell'**upcycling**, trasformando materiali di scarto in risorse di valore per il packaging di brand del settore luxury e fashion.

La sostenibilità è un principio fondamentale che guida l'attività produttiva, la ricerca e lo sviluppo dell'azienda. Questo si traduce nel **monitoraggio dei consumi** di acqua, energia ed emissioni durante il processo produttivo, con l'obiettivo di ridurre l'impatto ambientale e migliorare l'efficienza.

La sostenibilità guida anche il **prodotto**: fin dagli anni '90 Favini si dedica alla creazione di ispirate ai principi dell'upcycling, trasformando materiali di scarto in risorse di valore. A partire dalle alghe della laguna di Venezia che minacciavano l'intero ecosistema, è nata **Alga Carta**. Ad oggi è stato esteso il concetto di Upcycling in diverse filiere, da quella agroalimentare, a quella tessile e conciaria dando vita alle collezioni **Crush, Refit e Remake**. Queste ultime due incorporano anche il principio di **simbiosi industriale**, le fibre tessili troppo corte per essere impiegate nel settore moda vengono integrate nell'impasto cartario, creando una carta di pregio con una resa materica unica.

Favini continua a innovare nel settore delle carte speciali, coniugando eccellenza, creatività e responsabilità ambientale.

Giancarlo Bellina – Confindustria Siracusa e Brown2Green Sicily

Oggi transizione ecologica e sviluppo sostenibile sono diventati due fattori chiave strategici per le imprese del settore energetico che scelgono di essere parte attiva nella costruzione di una società più attenta a migliorare la qualità di vita.

B2G Sicily, acronimo di Brown to Green, si ispira a questi valori per creare una storia di sviluppo e di crescita nel territorio in cui opera, attraverso la realizzazione di nuovi progetti di decarbonizzazione e di green economy che valorizzano l'asset esistente e il know-how delle persone.

Nata a ottobre 2023 dalla cessione dell'intero capitale sociale di Erg Power S.r.l. ad Achernar Energy S.p.a. (oggi B2G Italy S.p.a.), B2G Sicily è un'impresa leader nell'attività di produzione, distribuzione e vendita di energia elettrica e utilities.

La società assume una posizione strategica nell'area industriale in cui opera perché gestisce la centrale a Ciclo Combinato CCGT (Combined Cycle Gas Turbine) a gas naturale, ad alto rendimento cogenerativo e a basso impatto ambientale, entrata in esercizio commerciale nell'aprile 2010.

La centrale ha una potenza nominale installata di 480 MW che la rende essenziale per il bilanciamento e la sicurezza della rete elettrica nazionale, con una produzione media annua pari a 2,4 TWh di energia elettrica, di 1,2 milioni di tonnellate di vapore e di 4.5 milioni di metri cubi di acqua demineralizzata.

Il funzionamento e la gestione della centrale sono garantiti da 144 persone, tra cui tecnici e ingegneri altamente specializzati nell' Operation & Maintenance degli impianti, nella vendita dell'energia elettrica al mercato (Energy Management) e nello sviluppo industriale di nuovi investimenti.

B2G Sicily è proprietaria di una Rete Interna di Utenza (RIU) grazie alla quale si configura oltre che come produttore, anche come distributore di energia elettrica nel sito industriale di Priolo e gestisce, inoltre, impianti per la produzione di vapore e, in misura minore, di altre utilities.

B2G Sicily intende contribuire con un ruolo chiave alla transizione ecologica ed energetica attraverso il suo modello di business che si concentra sulla creazione di un futuro più sostenibile, con un impegno specifico nell'utilizzo responsabile delle risorse naturali, un miglioramento continuo delle prestazioni e dell'efficienza degli impianti e un'analisi oculata del contesto per generare valore per le comunità locali.

Animata da un forte senso di responsabilità e consapevolezza in tema di sostenibilità, la società ha elaborato un ambizioso piano ESG (Environmental, Social e Governance), contribuendo alla stesura del Rapporto di Sostenibilità del Polo Industriale di Siracusa.

Infatti, nel solco della continuità, Confindustria Siracusa, attraverso le sue aziende associate, continua a essere protagonista e a fianco delle istituzioni, dei territori e delle comunità per promuovere iniziative e progetti sostenibili, che possano generare speranza e fiducia in un futuro migliore.

Alla luce di quanto sopra, il terzo Rapporto di Sostenibilità del Polo Industriale di Siracusa è una testimonianza concreta di rendicontazione, agli stakeholders interni ed esterni, delle attività che le piccole, medie e grandi aziende hanno avviato nell'ambito della lotta ai cambiamenti climatici, della promozione di uno sviluppo sostenibile e del passaggio da un'economia lineare all'economia circolare; una conferma dell'impegno concreto che Confindustria Siracusa e le sue aziende associate hanno preso su una delle sfide epocali più rilevanti della nostra civiltà.

Eleonora Perotto e Silvia Sbaffoni – GdL4 SUN

Certificazione e standardizzazione della simbiosi industriale: le linee guida SUN – Symbiosis User Network

Le organizzazioni sono chiamate ad affrontare quotidianamente nuove sfide rispetto alle quali il tema della sostenibilità, sia essa declinata in termini ambientali, sociali, economici e/o di *governance*, gioca un ruolo cruciale.

In particolare, la transizione verso un'economia più circolare, indispensabile ai fini della decarbonizzazione (*European Commision, 2015*), vene agevolata dall'adozione di diverse strategie, tra le quali si annovera la Simbiosi Industriale (S.I.).

La Simbiosi Industriale vede quale obiettivo principale il fare in modo che le risorse sottoutilizzate (o non utilizzate) da parte di una organizzazione, possano esserlo da parte di un'altra (o altre) grazie all'adozione di un approccio sistemico, instaurando un meccanismo collaborativo di reciproco vantaggio, con ricadute positive soprattutto a scala territoriale.

In considerazione delle grandi potenzialità della S.I., nel 2017 è stata istituita la rete SUN, Symbiosis Users Network, promossa da ENEA, che raccoglie oggi il contributo di circa 40 organizzazioni afferenti al mondo della ricerca, dell'università, delle imprese, della pubblica amministrazione e della società civile, con la finalità di promuovere il confronto sui temi legati alla S.I. e favorirne un'applicazione estesa e sistematica sul territorio nazionale.

La rete, in relazione alle tematiche di maggiore rilevanza identificate dai suoi membri, si è strutturata in diversi Gruppi di Lavoro (GdL), uno dei quali, il GdL 4, attualmente coordinato da ENEA, CNR e Politecnico di Milano, dedicato al tema "*certificazione e standard per la simbiosi industriale*".

In seno a tale GdL, si è valutato che un manuale volto a supportare le organizzazioni nell'identificazione e successiva applicazione di specifici e pertinenti standard tecnico-gestionali potesse costituire un utile strumento di promozione della Simbiosi Industriale; esistono infatti standard che consentono di implementare modelli di business, ad alta replicabilità, basati su riferimenti comuni, condivisi e caratterizzati da sistemi di misurazione delle prestazioni affidabili, capaci di promuovere il trasferimento tecnologico e la diffusione dell'innovazione. In particolare, sono molteplici gli standard utilizzabili durante le fasi progettuali o nei processi operativi e gestionali delle organizzazioni che possono fornire un quadro condiviso atto a sistematizzare procedure, prassi e attività, dimostrandone al contempo la sostenibilità (i requisiti presenti negli standard possono infatti spesso essere verificati da un organismo di parte terza parte). La standardizzazione, anche grazie alla messa in campo di un linguaggio comune, contribuisce infatti a gestire in modo più efficiente ed efficace i flussi di risorse (anche immateriali) in ingresso e uscita ad una determinata attività di uno o più specifici processi.

Il documento prodotto dal GdL, risultato di un impegno collettivo e appassionato, ha dunque quale obiettivo quello di offrire un quadro ampio ed organico concernente la ricognizione (e relativa analisi) sia delle iniziative di standardizzazione in corso, che degli standard esistenti e applicabili all'implementazione della Simbiosi Industriale a livello nazionale, europeo ed internazionale. Il manuale fornisce, di fatto, una guida alle varie tipologie di stakeholder per un uso sistematico e ragionato degli standard identificati come potenzialmente utili ai fini di una migliore promozione della S.I. in relazione al contesto e alle peculiarità delle organizzazioni.

Nel seguito si riporta la struttura del volume (tabella 1) e una sintesi dei contenuti principali, esito di un lavoro caratterizzato da quattro fasi fondamentali: *i)* analisi dell'evoluzione del concetto di simbiosi industriale e della sua applicazione in rapporto alla standardizzazione; *ii)* identificazione dei principali standard a supporto dell'economia circolare e della sostenibilità delle organizzazioni; *iii)* identificazione degli aspetti riconducibili alla simbiosi industriale; *iv)* esame del framework applicativo della standardizzazione e degli sviluppi attesi.

Tabella 1: Struttura del documento e note sintetiche

Indice	***Note sintetiche***
Prefazione	*A cura del Technical Project Manager di UNI e della Presidentessa della Rete SUN.*
Introduzione e scopo	*Il manuale vuole essere una guida per le diverse tipologie di stakeholder per un uso sistematico e ragionato degli standard identificati come utili ai fini di una migliore promozione della simbiosi industriale in relazione al contesto e alle peculiarità delle organizzazioni.*
Termini e definizioni	*Riportate oltre 150 definizioni (scelte a partire dai termini utilizzati negli standard analizzati).*
Acronimi	*Riportate otre 50 voci*
Simbiosi industriale: contesto ed elementi cardine	*Analisi del concetto di simbiosi industriale, collocazione rispetto ad altri modelli di policy per l'economia circolare, relazione con gli strumenti di standardizzazione e proposta di una nuova definizione di simbiosi industriale.*

Esempi di simbiosi industriale	*Esempi di simbiosi industriale a livello italiano, europeo e internazionale.*
Mappatura e analisi degli standard per la simbiosi industriale	*Analisi degli standard rispetto a molteplici criteri (dall'ambito geografico all'ente di normazione) con contestuale definizione di un approccio metodologico per la consultazione degli standard rispetto a specifiche categorie tematiche, ai principali stakeholder di riferimento, nonché agli SDGs.*
Gli standard di riferimento	*Redatte 63 schede analitiche.*
Sinossi analisi standard	*È stato analizzato il ruolo della standardizzazione nella simbiosi industriale in considerazione delle attuali tendenze evolutive. Sono state quindi esposte le principali evidenze risultanti dall'analisi degli standard e i trend per il futuro.*
Autori	*23 afferenti a 9 diversi enti (centri di ricerca e università).*

Il concetto di simbiosi industriale

La Simbiosi Industriale, realtà fortemente complessa e multidimensionale, ha radici nel campo dell'ecologia industriale, disciplina che studia i sistemi produttivi come fossero ecosistemi naturali, in cui materiali ed energia vengono riutilizzati e riciclati grazie a cicli produttivi chiusi (*Edgeman et al. 2013*).

Nel corso di poco più di venti anni, il concetto di simbiosi industriale ha subito un'evoluzione significativa (*Renner, 1947; Chertow, 2000; Agarwal and Strachan, 2008; Lombardi and Laybourn, 2012; Domenech et al., 2018; EU Committee, 2018*), rappresentata in figura 1, e pur tuttavia ancora oggi non si presta ancora ad essere formalizzato e "congelato" in una definizione univoca, motivo per cui è stata proposta, insieme ad un modello rappresentativo (figura 2), una definizione di S.I. che gli autori hanno inteso condividere al fine di raccogliere al meglio i termini ed i concetti più utilizzati all'interno del manuale, per evitare possibili fraintendimenti e facilitarne la lettura:

La Simbiosi Industriale è una forma di interazione sinergica tra attori all'interno di un'area geografica ed economica finalizzata alla gestione efficiente di risorse materiali e immateriali, che tramite relazioni, informazioni e innovazioni tecnologiche consente di ottenere benefici organizzativi, economici, ambientali e sociali sia a livello puntuale sia a livello sistemico.

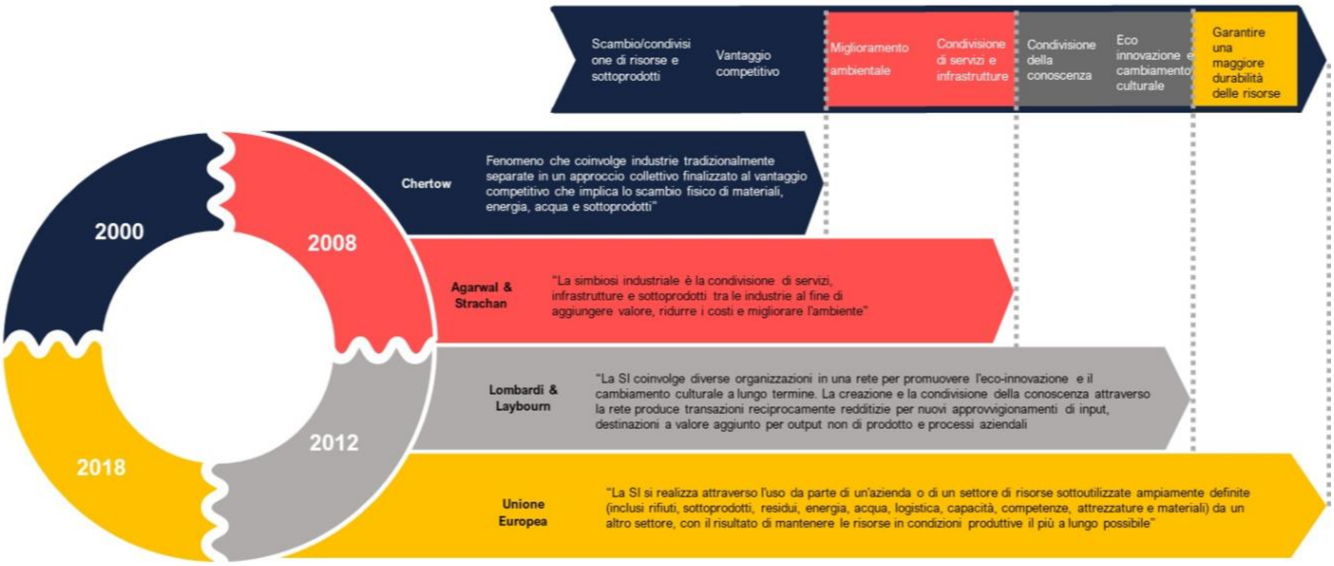

Figura 1 - Evoluzione del concetto di Simbiosi Industriale nel tempo (elaborazione degli autori).

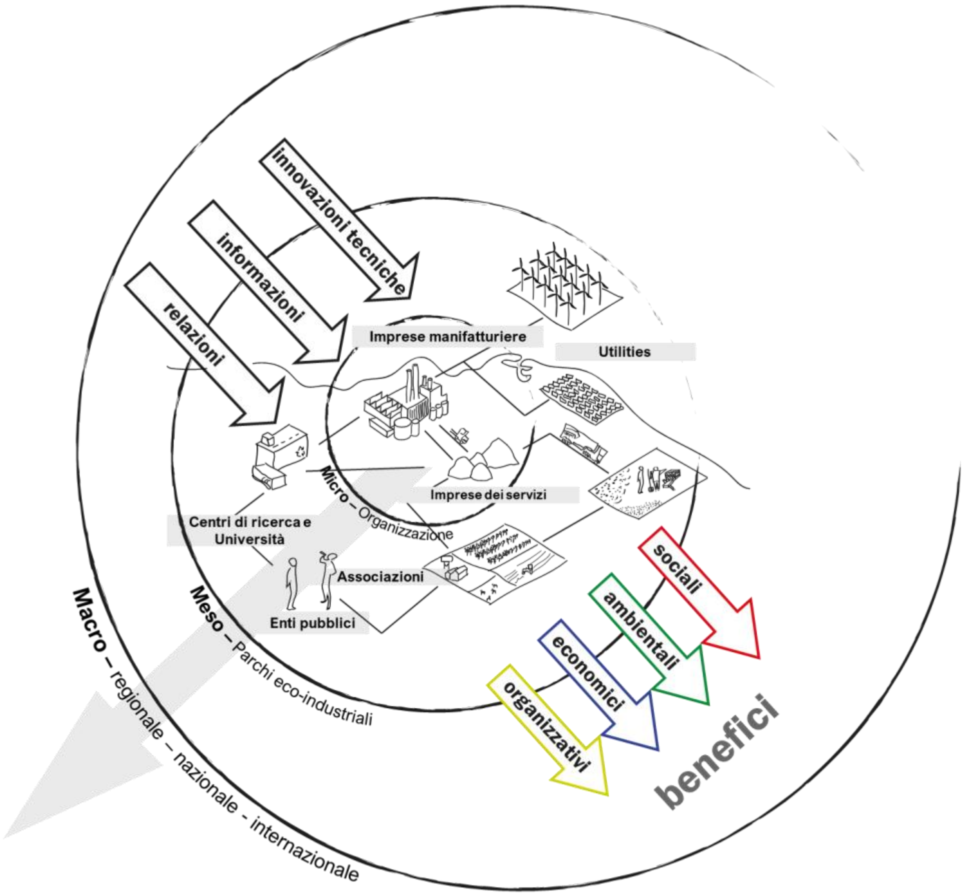

Figura 2. Rappresentazione grafica della definizione di SI (elaborazione a cura degli autori).

Esempi di simbiosi industriale

A fronte delle molteplici esperienze di simbiosi industriale, il manuale ha analizzato alcuni casi rappresentativi a livello italiano, europeo e mondiale, al fine di identificarne le peculiarità, ma anche le caratteristiche comuni, i drivers e le barriere che ne hanno caratterizzato lo sviluppo.

Nel dettaglio, per l’Italia sono stati approfonditi i progetti di S.I. promossi da ENEA e il progetto CLOSED che ha interessato i distretti industriali di Prato, Lucca e Pistoia. Per l’Europa è stato analizzato il progetto pilota “Manresa en Simbiosi” in Catalogna, primo progetto di S.I. della regione che promuove l’economia circolare nel settore delle imprese del Bages. A livello internazionale, si è scelto di approfondire il caso di S.I. di Kwinana, in Australia, selezionato in quanto risulta uno dei casi studio più completi per numero e tipologie di scambi simbiotici.

Oltre all’esposizione dei casi è stata effettuata una comparazione tra gli stessi (mediante tabelle sinottiche di immediata lettura) prendendo in considerazione vantaggi e limiti/barriere/criticità da un punto di vista economico, ambientale e sociale, sia durante l’implementazione che durante la gestione della S.I.

Per approfondimenti si rimanda al manuale e alla pertinente bibliografia (*Côté and Cohen-Rosenthal, 1998; Dinelli et al., 2003; Van Beers D. et al., 2007; Van Beers D., 2008; Tarantini et al, 2009; AIRBA, 2010; Cariani, 2013; Cutaia et al., 2015; Farel et al, 2016; Notarnicola et al., 2016; Mazzoni, 2020*).

Mappatura e analisi degli standard per la simbiosi industriale

Nel periodo 2022-2023, a valle di un preliminare lavoro di ricognizione dei possibili standard e documenti di riferimento internazionali ad applicazione volontaria ritenuti utili ai fini della redazione del presente manuale, sono stati selezionati dagli autori 63 documenti (pubblicati principalmente dopo il 2010 da enti quali ISO, CEN, UNI e ASTM, nonché da istituzioni nazionali e associazioni industriali), oggetto di una successiva analisi, effettuata in considerazione delle specifiche competenze, nonché delle peculiarità dei pertinenti ambiti lavorativi. La maggior parte dei documenti è disponibile in lingua inglese, ma molti sono stati tradotti in italiano per facilitarne l'applicazione a livello nazionale. Inoltre, gli standard selezionati sono sia certificabili (prevedono audit e verifiche di conformità) che non (offrono linee guida volontarie).

Il criterio di riferimento per la scelta dei documenti ritenuti utili per la standardizzazione della Simbiosi Industriale è stato quello di identificare standard capaci di supportare lo sviluppo e il monitoraggio di relazioni simbiotiche tra le imprese in ottica "economia circolare", con particolare attenzione *i)* alla condivisione delle risorse (energia compresa), *ii)* alla riduzione dei rifiuti e delle emissioni nell'ambiente, *iii)* alla promozione di una generale sostenibilità ambientale. I documenti sono stati inoltre selezionati considerando la loro potenziale utilità per le organizzazioni ai fini della raccolta, utilizzo e condivisione delle informazioni sui loro processi produttivi e sull'uso delle risorse, per facilitare una migliore comprensione e comunicazione tra tutti i portatori di interesse. Gli standard scelti si ritiene che siano anche abbastanza "flessibili" per adattarsi a diversi modelli organizzativi e pratiche operative.

I documenti sono stati analizzati dapprima in relazione alle loro caratteristiche generali (ente di normazione, lingua, ambito geografico di applicazione, verificabilità/certificabilità, …) e successivamente entrando nel dettaglio dei loro contenuti dopo aver stabilito specifici criteri di analisi e classificazione, confluiti nell'apposito format utilizzato per la redazione delle singole schede analitiche (tabella 2). In particolare, al fine di permettere una rapida ed efficace consultazione delle linee guida, sono state identificate otto categorie tematiche che ricorrono nei documenti analizzati. Tali categorie sono da considerarsi etichette utili per l'identificazione rapida dei documenti e degli standard, da parte del lettore, pur nella consapevolezza che trattandosi di un contesto integrato non esiste una linea netta di demarcazione che le distingua. A tale riguardo, in figura 3 viene evidenziata la natura integrata della struttura con cui sono state scelte le categorie (fortemente correlate le une alle altre). Si precisa che la categoria delle risorse immateriali, ancorché presente nella suddetta figura, non è stata puntualmente mappata all'interno dei singoli standard in quanto considerata intrinsecamente presente per sua stessa definizione. In figura 4 è riportata inoltre l'occorrenza delle categorie tematiche.

Gli standard sono stati inoltre analizzati rispetto ai principali stakeholder (interni ed esterni) delle organizzazioni (figura 5a e 5b) e agli Obiettivi di Sviluppo Sostenibile (SDGs) delle Nazioni Unite (figura 6).

Tabella 2. Format schede per l'analisi di dettaglio degli standard

Campo Scheda	Contenuto
Tipo Documento	Viene indicato se lo standard è certificabile o meno.
Versioni e revisioni	Vengono riportate le edizioni dello standard; anno prima introduzione e anno di ultima revisione e/o aggiornamento.
Categorie	Vengono esplicitate le categorie tematiche dello standard.
Link al documento	Viene riportato, se disponibile, un link ad una pagina internet per la consultazione pubblica e del documento.
Descrizione	Vengono brevemente descritte le caratteristiche salienti del documento e il suo contenuto (ad esempio è riportato il focus, il soggetto o il settore industriale, il campo di applicazione, l'obiettivo e lo scopo).
Elementi chiave	Vengono riportati gli elementi chiave rispetto alla categoria o allo scopo di utilizzo del documento e dello standard.
Riferimenti alla Simbiosi Industriale	Viene evidenziato, se presente, il riferimento esplicito alla S.I. In caso negativo viene riportata una sintesi dei riferimenti ad aspetti correlati (ad es. Economia Circolare).
Riferimenti ad altri standard	Vengono riportati i riferimenti ad altri standard/documenti a cui si fa riferimento per verificare il collegamento con il framework di standardizzazione esistente.
Indicatori	Viene indicata la presenza di indicatori, esplicitando, quando presenti, la tipologia (quantitativo, qualitativo, misto).
Aspetti di comunicazione	Vengono sinteticamente descritti gli aspetti di comunicazione.
Aspetti di collaborazione	Vengono sinteticamente descritti gli aspetti relativi alla collaborazione tra le varie organizzazioni.
Attori coinvolti	Vengono descritti i portatori di interesse coinvolti nei processi.

Risultati attesi	Vengono sinteticamente descritti i risultati ottenuti concretamente dagli attori coinvolti nei processi.
SDGs di riferimento	Vengono indicati gli SDGs di riferimento.
Note	Vengono riportate altre informazioni, quali ad esempio la disponibilità alla consultazione gratuita o a pagamento e la lingua di pubblicazione.

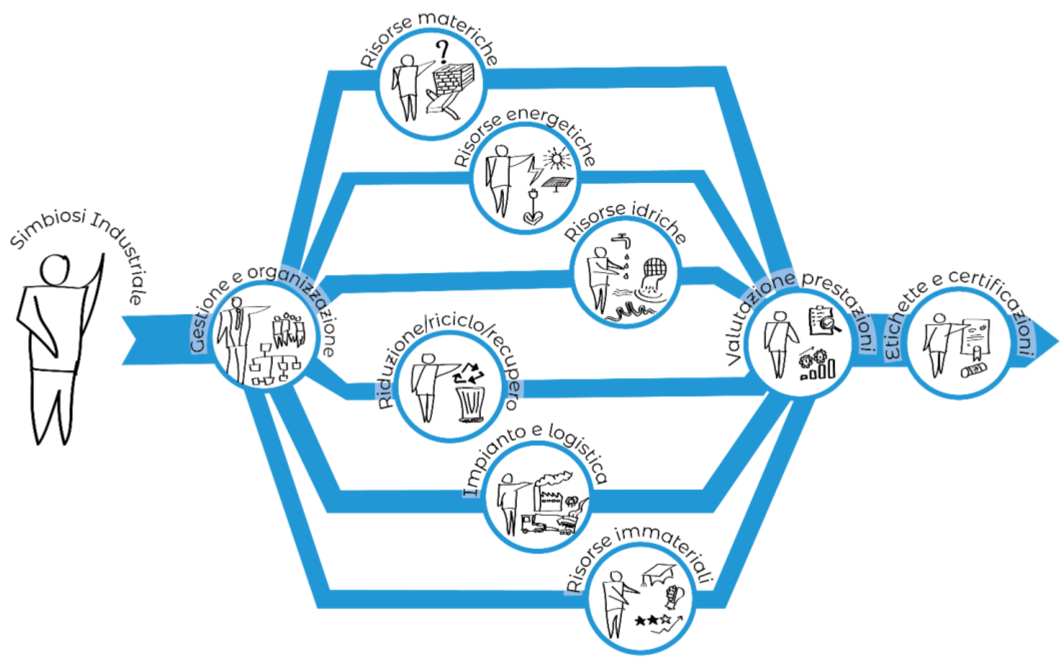

Figura 3. Categorie tematiche (elaborazione a cura degli autori)

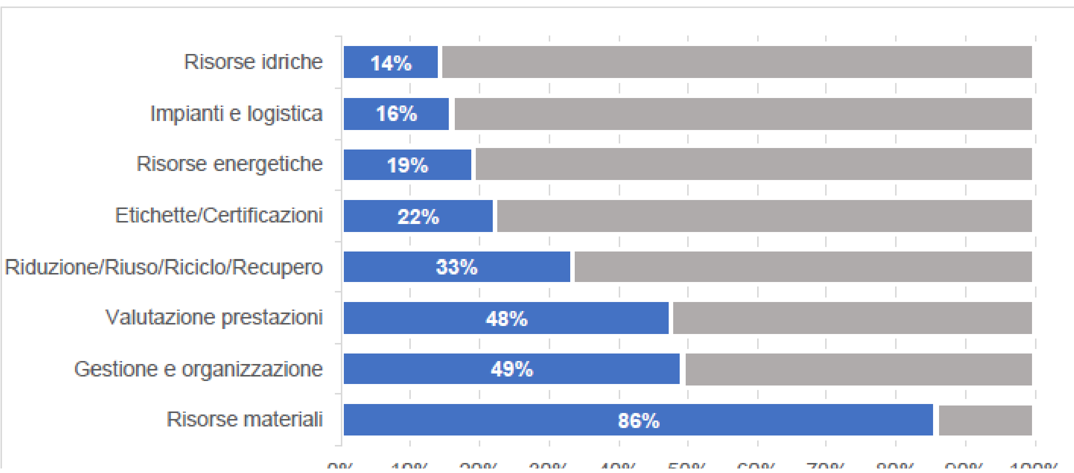

Figura 4. Categorie tematiche e loro occorrenza per i documenti e gli standard analizzati

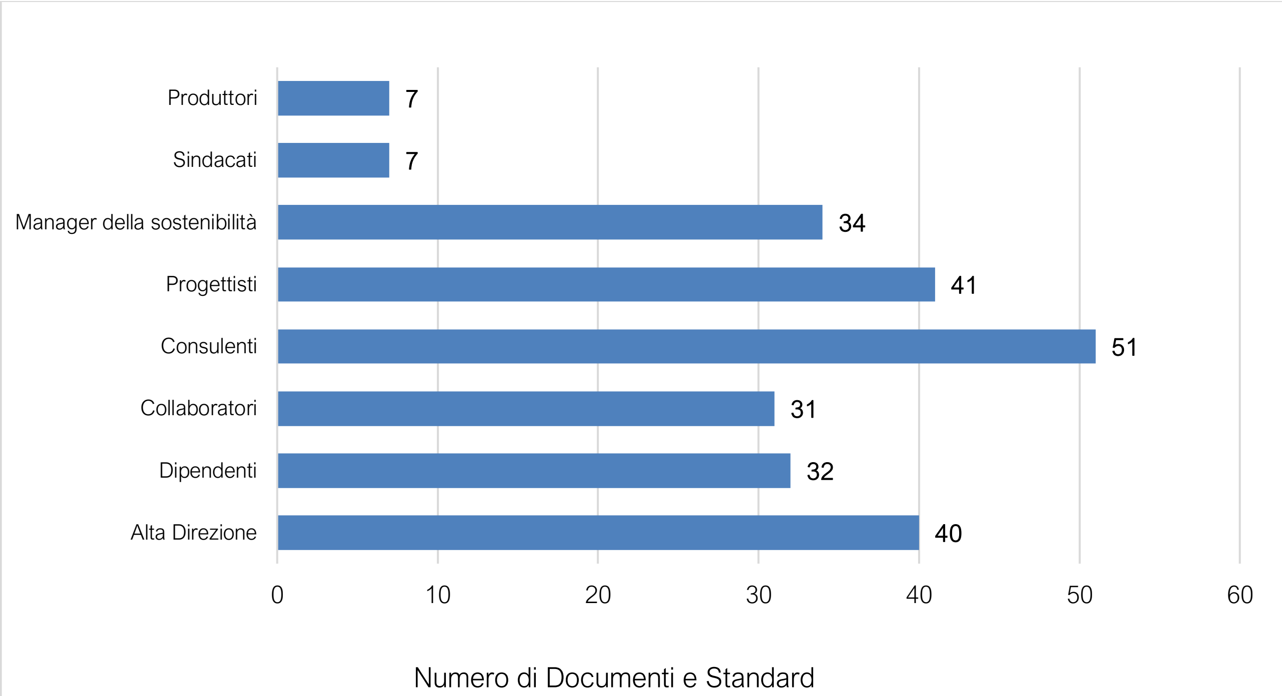

Figura 5°. Potenziale interesse degli stakeholder "interni" all'organizzazione

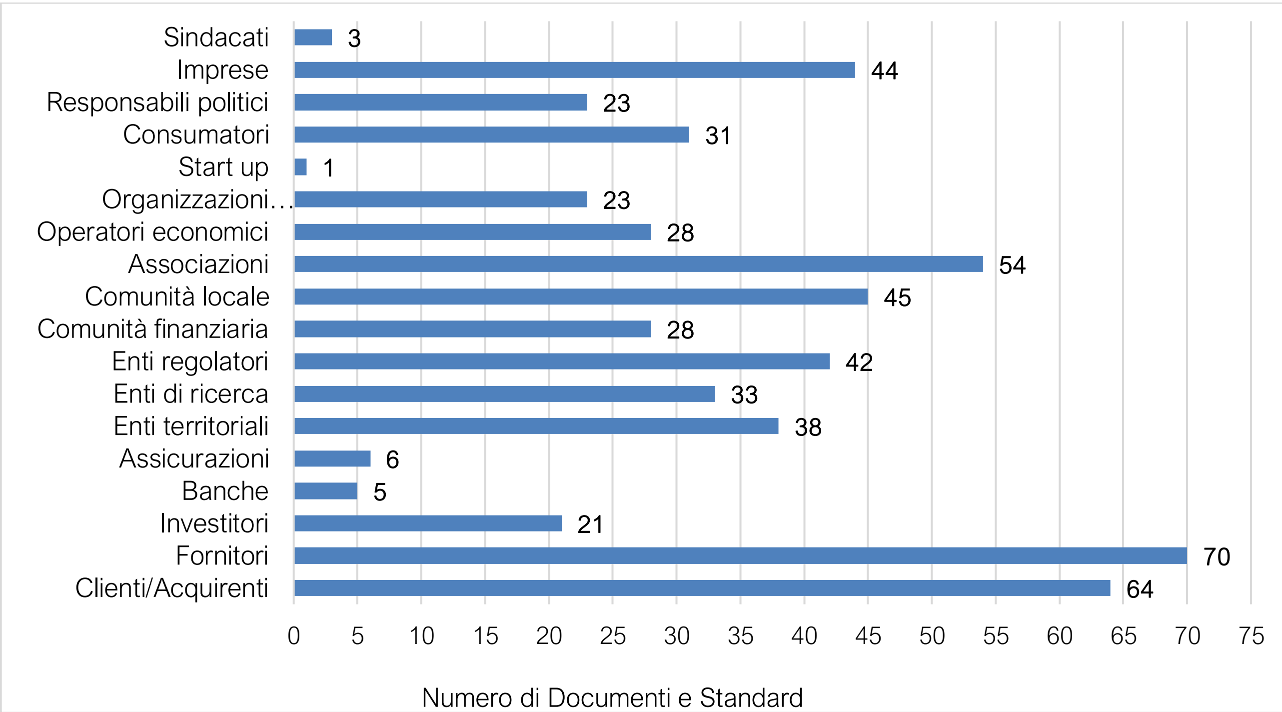

Figura 5b. Potenziale interesse degli stakeholder esterni all'organizzazione

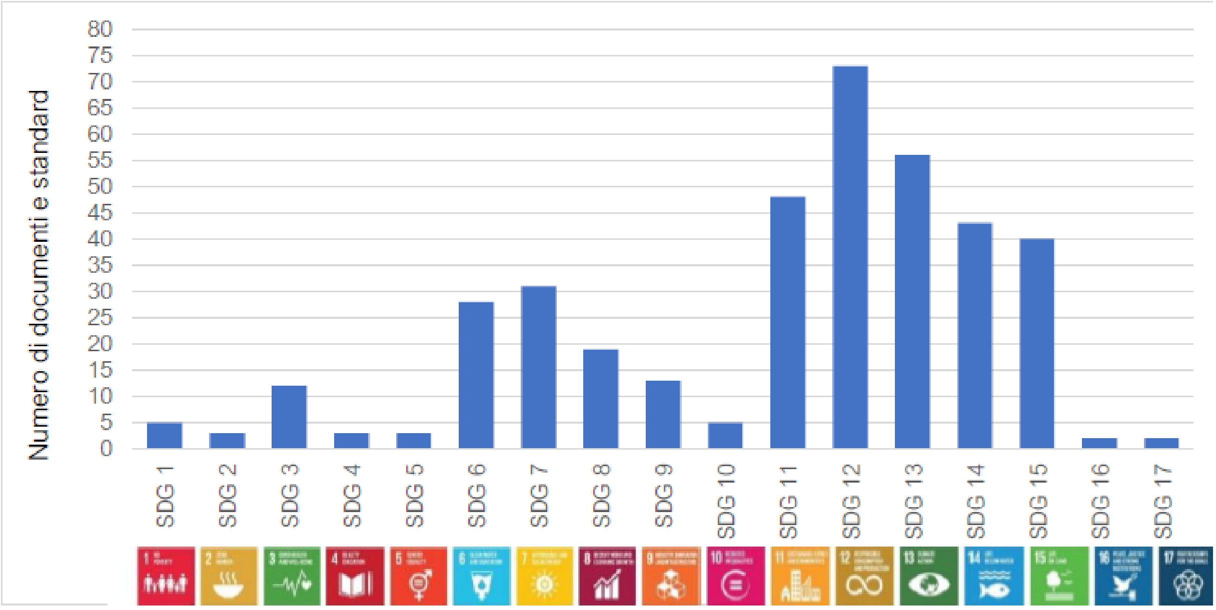

Figura 6. Correlazione tra gli SDG e i documenti e gli standard

Infine, è stata fatta un'analisi relativa alla presenza di indicatori potenzialmente utili ai fini della misurazione della simbiosi industriale e quindi della valutazione dell'efficacia delle strategie adottate (figura 7).

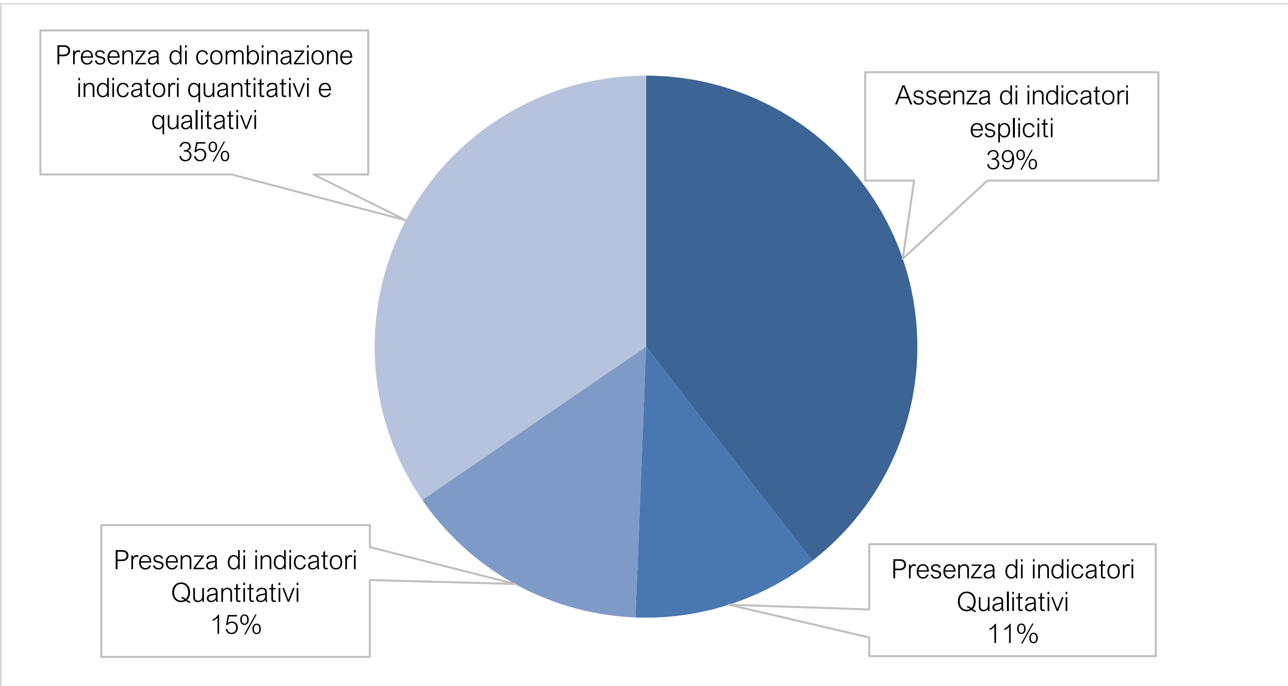

Figura 7 - Presenza di indicatori all'interno dei documenti e degli standard esaminati (attribuzione basata sul testo contenuto negli standard esaminati)

A valle delle suddette analisi, per facilitare la consultazione delle schede di sintesi di ciascuno standard, nel documento sono state riportate specifiche indicazioni su come consultare le linee guida in base ad una serie di "profili" utente identificati dagli autori: base, intermedio, avanzato o esperto (figura 8).

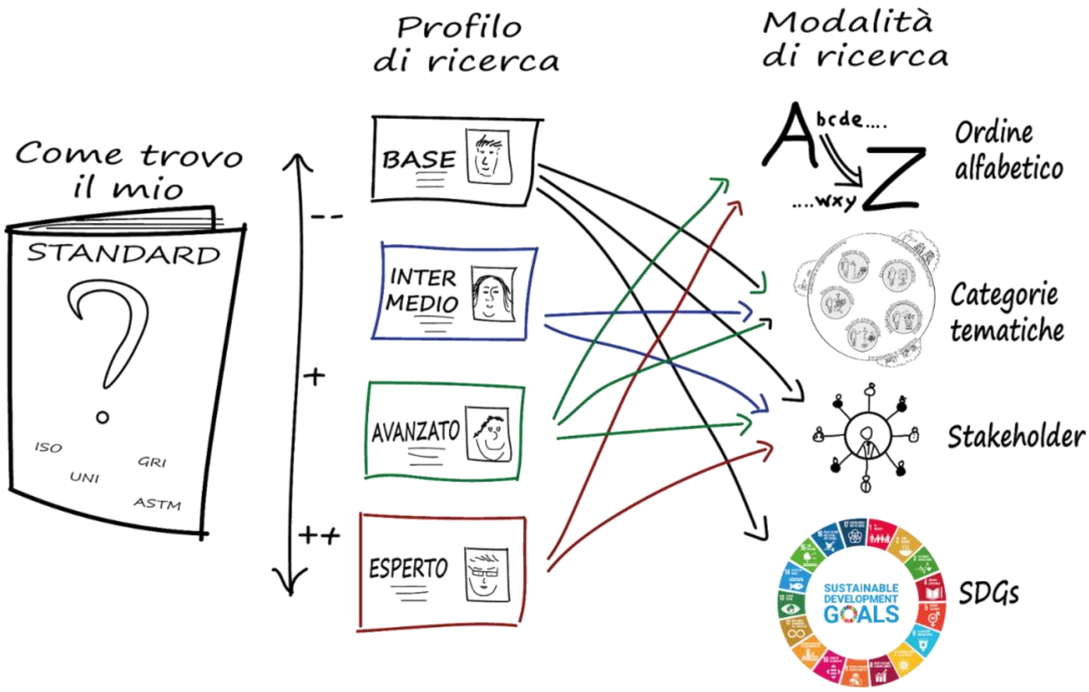

Figura 8. Modalità di ricerca dei documenti e degli standard

Prospettive future

La standardizzazione nella simbiosi industriale assume un ruolo sempre più rilevante in considerazione delle seguenti tendenze *i)* crescita del ruolo dell'economia circolare, *ii)* tracciabilità dei prodotti, *iii)* limitazione delle materie prime, *iv)* contenimento dei rischi delle filiere circolari, *v)* evoluzione normativa di supporto.

L'analisi degli standard esistenti all'interno delle linee guida evidenzia alcuni *macrotrend* a livello internazionale: *i)* proliferazione degli standard, *ii)* segmentazione degli aspetti tracciati (gli standard che trattano in maniera completa la S.I. n termini di organizzazione sono pochi e tendono ad essere focalizzati su aspetti molto specifici quali ad esemio energia, acqua, rifiuti); *iii)* forte evoluzione dei sistemi di tracciatura, *iv)* mancanza di indicatori "ad hoc", *v)* mancanza di aspetti di collaborazione e comunicazione, *vi)* focus su materiali ed energia e non su altre risorse.

Inoltre, gli autori ravvisano margini di sviluppo potenziale per la standardizzazione nell'ambito della Simbiosi Industriale, con particolare riferimento a: *i)* informatizzazione e modularizzazione dei dati, *ii)* crescita degli aspetti collaborativi, *iii)* crescita dell'importanza degli standard per le policy locali, *iv)* allineamento tra standard e normative locali, *v)* concezione di standard "ad hoc" (ad esempio la recente UNI TS 11820 sembra fornire strumenti più idonei alle organizzazioni in virtù della capacità di cogliere i diversi aspetti della simbiosi), *vi) ramp up* dei sistemi di gestione per la circolarità (l'implementazione della S.I. richiede nuove competenze professionali, quali esperti della gestione dei flussi di materiali, economia circolare e analisi dei dati ambientali, o figure gestionali specializzate come il "*sustainability manager*"; sarà fondamentale il rafforzamento della formazione su questi temi).

Infine, una delle prospettive più promettenti per il futuro della Simbiosi Industriale si ritiene che sia il suo contributo al raggiungimento degli Obiettivi di Sviluppo Sostenibile (SDGs): la S.I. è strettamente legata agli SDGs 9 (Industria, Innovazione e Infrastrutture), 12 (Consumo e Produzione Responsabili) e 13 (Azione per il Clima), ma può avere impatti positivi anche su altri obiettivi, come la riduzione della povertà (SDG 1) e il miglioramento delle condizioni di lavoro (SDG 8). Per massimizzare questi benefici, sarà essenziale un maggiore coinvolgimento di tutti gli stakeholder, inclusi enti pubblici, aziende, centri di ricerca, università e cittadini, in un'ottica di collaborazione sistemica.

In conclusione, il futuro della Simbiosi Industriale dipenderà dalla capacità di integrare innovazione tecnologica, standardizzazione e politiche pubbliche in un modello di sviluppo sostenibile e circolare. La creazione di nuovi strumenti digitali, la formazione di professionisti specializzati e il rafforzamento delle normative a livello internazionale saranno fattori determinanti per rendere la SI una pratica consolidata e diffusa su scala globale. Se questi elementi verranno adeguatamente sviluppati, la simbiosi industriale potrà diventare un pilastro fondamentale della transizione verso un'economia più circolare, efficiente e resiliente.

Bibliografia

Agarwal A. and Strachan P. (2008). *Is industrial symbiosis only a concept for developed countries?* The Journal for Waste & Resource Management Professionals, 42.

AIRBA (2010). Convegno *Il riuso delle acque reflue. Realizzazioni e prospettive – Il riuso industriale: l'esperienza del Distretto Pratese*. Prato, febbraio 2010.

Cariani R. (2013). *Eco-aree produttive. Guida all'eco-innovazione, alle politiche per la sostenibilità e ai progetti operativi nelle Aree Produttive Ecologicamente Attrezzate (APEA)*. Milano: Edizioni Ambiente.

Chertow M.R. (2000). *Industrial symbiosis: Literature and taxonomy*. Annual Review of Energy and Environment, 25, 313-337.

Côté R.P. and Cohen-Rosenthal E. (1998). *Designing eco-industrial parks: a synthesis of some experiences*. Journal of Cleaner Production, 6(3–4), pp. 181-188.

Cutaia L., Luciano L., Barberio G., Sbaffoni S., Mancuso E., Scagliarino C., La Monica M. (2015). *The experience of the first industrial symbiosis platform in Italy*. Environmental Engineering and Management Journal, Vol. 14(7), pp. 1521-1533.

Dinelli D. Garro S., Giovannelli L., Querci P. (2003). *Progetto CLOSED Il modello DPSIR applicato ai Distretti di Prato, Lucca, Pistoia, Firenze.* ARPAT, Firenze, marzo 2003. Disponibile su: https://www.arpat.toscana.it/documentazione/catalogo-pubblicazioni-arpat/progetto-closed-il-modello-dpsir-applicato-ai-distretti-di-prato-lucca-pistoia.

Domenech T., Doranova A., Roman L., Smith M., Artola I. (2018). *Cooperation Fostering Industrial Symbiosis: Market potential, good practice and policy actions*. Publications Office of the European Union, Luxembourg, p. 9.

Edgeman R., Wu Z., Laasch O. (2013). *Operations management. In O. Laasch and R. Conaway, Eds., Principles of Responsible Management: Sustainability, Responsibility, Ethics*. Stamford, USA: Cengage Learning. A United Nations PRME Textbook, p. 299.

European Committee for Standardisation and European Committee for Electrotechnical Standardisation, (2018). *Industrial Symbiosis: Core elements and implementation approaches.* Workshop agreement CWA 17354, p. 5.

European Commission (2015). *Closing the Loop - An EU Action Plan for the Circular Economy*. Bruxelles. Disponibile su: https://ec.europa.eu/environment/circular-economy/.

Farel R., Charrière B., Thevenet C., Yune J.H. (2016). *Sustainable manufacturing through creation and governance of eco-industrial parks.* Journal of Manufacturing Science and Engineering, 138(10),

Lombardi D.R. and Laybourn P. (2012). R*edefining industrial symbiosis. Crossing Academic–Practitioner Boundaries.* Journal of Industrial Ecology, 16(1), 28–37.

Mazzoni F. (2020). *Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster*. Insights into, Regional Development, 2(3), pp. 661–676.

Notarnicola B., Tassielli G. Renzulli P.A. (2016). *Industrial symbiosis in the Taranto industrial district: current level, constraints and potential new synergies.* Journal of Cleaner Production, 122, pp. 133–143.

Tarantini M., et al. (2009). *Life Cycle Assessment of waste management systems in Italian industrial areas: Case study of 1st Macrolotto of Prato*, Energy, 34(5), pp. 613–622.

Renner G.T. (1947). *Geography of industrial localization*. Economic Geography, 23, 167-189

Van Beers D., Bossilkov A., Corder G., Van Berkel R. (2007). *Industrial symbiosis in the Australian minerals industry: the cases of Kwinana and Gladstone*. Journal of Industrial ecology, 11(1), 55-72

Van Beers D. (2008). *Capturing Regional Synergies in the Kwinana Industrial Area (Status Report)*. Centre of Excellence in Cleaner Production, Curtin University of Technology (Australia).

INTERVENTI DA CALL FOR PAPER

The future of work in the city of the future: trends, and new professions

Federica Romano[1]*, Giovanni Armillotta[1], Maria Berardi[1], Martina Gnudi[1],
Francesca Lettieri[1]

[1] *Randstad Research, ITALY.*
(E-mail: federica.romano@randstad.it)
*Corresponding author

Abstract

In recent years, the relationship between work and housing choices has undergone significant changes in advanced countries. The quality of working, social, and housing life has become a priority due to technological innovations that have reshaped how we move, work, and interact. This shift is evident in remote working, which has revolutionized working and organizational conditions, influencing the design of living and workspaces as well as the boundaries between work, family, and social life. The technological revolution, such as using cell phones to plan trips, has transformed urban centers through digital and green transitions. However, challenges remain, such as environmental and social sustainability and the integration of elderly and immigrant populations into society.

Keywords: *City; mobility; sustainability; connectivity; jobs.*

Towards the definition of a transitional industrial designer

Italy exhibits a dichotomy between coastal and plain areas, rich in productive and residential activities, and hilly and mountainous regions, which are less densely populated. Metropolitan cities such as Milan and Rome feature high population concentrations, collectively hosting over 21.3 million inhabitants, equating to 36.2% of the total population. Smaller municipalities number around 5,500, representing 69% of Italian municipalities and covering up to 70% of the territory in several regions. Life in cities today is influenced by trends such as digitalization, increasing attention to sustainability, demographic changes, and mobility. Both living and working methods are evolving, with mutual influence. These shifts create diverse needs and shape urban centers and the jobs that will be required tomorrow.

Jobs in the city of the future

While large urban centers remain highly attractive, peripheral city areas have witnessed population growth post-pandemic. Conversely, inland areas suffer from depopulation and a lack of services. Various initiatives aim to reverse these trends and improve living quality to increase appeal. Quality of life is influenced by multiple factors and variables.

It can be measured through objective social indicators, crossing data on wealth, work, safety, demographics, environment, and culture, or through subjective evaluations by individuals (hedonic method). It varies between large and small cities, with ideal cities balancing congestion costs and the benefits of agglomerations [Fig. 1].

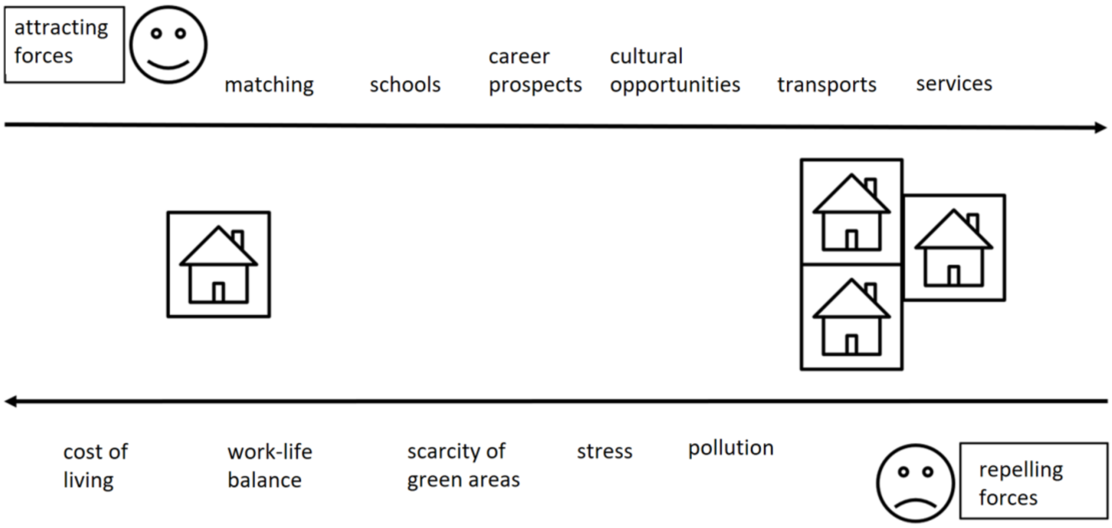

Figure 1. Figure Header (Source: *Randstad Research, 2024)*

The impact of remote work

The number of people working from home, at least part-time, has more than doubled in recent years—from about one million in 2019 to nearly three million in 2023. Remote work is primarily concentrated among skilled professions, which have a multiplier effect on low-skill jobs, such as those in catering. Remote work has changed the demand for housing in city centers and the geographical distribution of economic activities. Reduced transport costs make city outskirts more attractive, and highly qualified professionals tend to relocate to these areas, generating employment opportunities even for less-skilled workers. This phenomenon fosters the redistribution of economic activity and the creation of more flexible workspaces. To characterize future urban jobs, we analyzed city transformation trends through three major directives: mobility, sustainability, connectivity, and demographics.

Mobility and Future jobs

The "15-minute city" concept proposes an urban model where essential services are accessible within 15 minutes on foot or by bicycle. This approach is already present in many medium and small Italian cities, many of which have adopted projects promoting sustainable mobility and integrating public transport and shared mobility services. Future mobility roles will require integrating traditional industry skills with expertise in sustainability practices, such as emission types and reduction strategies. Psychological insights into human behavior and strategies to influence it will also be important. Additionally, professionals must analyze and manage large datasets to optimize mobility plans while minimizing environmental impact.

Examples of future mobility-related roles include:

- Coordinators between public transport and sharing services
- Integrated mobility developers for suburban areas
- Air taxi drivers
- Intermodal design experts
- Drone operators for remote deliveries.

Sustainability and Future jobs

National and international strategies promote the development of sustainable cities, with goals ranging from road safety to protecting green spaces. Numerous projects across the territory, aimed at encouraging a hybrid and intelligent use of available artificial spaces, highlight the importance of the green and digital transition. These initiatives promote the creation of green jobs and improve the quality of life for citizens. The future of work in sustainability requires highly skilled professionals capable of devising structured and long-term strategies. In the years ahead, training and education will be key to replacing the “comfortable” practice of compensatory measures with strategies that not only mitigate activity impacts but actively generate benefits for the planet. Key competencies include knowledge of sustainability principles, such as circular economy practices and life-cycle analysis. Important areas also include nature-based solutions, new materials, natural disaster prevention and management, biodiversity protection, ecosystem preservation, and mitigating urban heat islands. Sustainability professionals of the future are expected to engage actively, creatively, and collaboratively, promoting and sharing sustainability values comprehensively. Examples of future sustainability-related professions include:

- Non-energy resource diagnosis experts
- Environmental disaster prevention and management personnel
- Flying arborists
- Change managers

- Wellbeing designer.

Connectivity and Future jobs

Connectivity is crucial for the city of the future, integrating advanced technologies to enhance access to services and urban infrastructure management. Medium and large cities increasingly implement projects that incorporate artificial intelligence for routine urban operations, such as waste management, demonstrating how digital tools can increase recycling rates and urban circularity. The potential applications of these technologies are vast and positively affect transparency, legality, and safety. Future connectivity professionals will use this information to improve monitoring, analysis, and planning activities. STEM skills will be essential for developing new technology-based solutions, such as augmented reality devices. Moreover, integrating humanistic knowledge, such as philosophy, psychology, and anthropology, will be vital to cultivate critical thinking, judgment, and problem-solving abilities. As artificial intelligence technologies become more widespread and simplified, ethical considerations will grow. Professionals must learn to use these technologies wisely—not just the programmers but also end users. Examples of future professions in connectivity include:

- Cyber calamity forecasters
- Digital philosophers
- Smart grid managers
- Installers of contactless payment systems using palm recognition
- Edge computing experts for smart buildings.

Demography and Future jobs

The birth rate crisis and labor shortages have led to proactive recruitment of foreign workers of working age. Demographic challenges, such as an aging population and migration, require interventions to ensure integration, population well-being, and intergenerational harmony. The creation of collective living spaces and the adoption of technologies for personal assistance are crucial for addressing these challenges. Key competencies for future demographic trends include communication skills: empathy, active listening, and persuasion. The aging population and the potential for remote caregiving demand the development of strong interpersonal abilities. Familiarity with numerous technological aids, such as wearables, will also be essential. Addressing the integration of foreign individuals in accessing public services will require structured efforts, such as developing cultural mediation skills and improving foreign language proficiency. Examples of professions linked to demographic trends include:

- HR consultants for multigenerational workforces
- Wearable designers for personal assistance
- Bioinformatics engineers for personalized medical care
- Municipal cultural mediators
- Digital health specialists.

Conclusions

Technological, demographic, and environmental changes are significantly altering life habits in Italy and most advanced countries. Changes in habits bring about transformations in workplaces and social environments. Urban spaces and family life areas must therefore be reimagined to embrace major trends such as sustainability, digitalization, and the spread of remote working. At the same time, cities of the future will feature a growing proportion of elderly, solitary, and mobility-limited individuals. These changes will have a substantial impact on the labor market. Not only will new professions emerge, but the mix of skills required in existing jobs will also shift dramatically. The challenge lies in ensuring these transformative dynamics reduce, rather than exacerbate, gaps across generations and social groups.

References

[1] Randstad Research (2024). Il lavoro del futuro nella città del futuro. Trend, casi di studio e nuove professioni, 2024.

Analysing and modelling circular scenarios in local supply chains: approaches and tools within the "Max-Sheep" project

Raffaella Taddeo[1]*, Enrico Vagnoni[2], Rosa Di Capua[3], Veronica Casolani[1], Alberto Simboli[1], Andrea Raggi[1], Valentino Tascione[1], Alessandra Piga[2], Sara Bortolu[2], Bruno Notarnicola[3], Pietro Alexander Renzulli[3]

[1]*Università degli Studi "G. d'Annunzio" di Chieti-Pescara, Pescara, Italy*
[2]*Consiglio Nazionale delle Ricerche, Istituto per la Bioeconomia, Sassari*
[3]*Università degli Studi di Bari Aldo Moro, Taranto, Italy*
(E-mail: r.taddeo@unich.it)
*Corresponding author

Abstract

The transition towards circular and sustainable economic models (s.c. Circular Economy), requires the commitment of all the actors involved, at technological, social and political level. Although this paradigm is being established at the global level, the actions that characterize it often have local scale and impacts. To ensure that this transition process takes place in a balanced and measurable way, it is necessary to identify useful approaches and tools to define models for the implementation of potential solutions in different contexts, which may differ from a geographic, socio-economic, technological and product-related point of view. This article, through the description of the MAX-SHEEP research project, presents and discusses the results of an overview and systematization of the main tools potentially supporting the development of the different phases of an eco-industrial model of sheep supply chains.

Keywords: Industrial ecology; circ*ular Economy; sheep; supply chain.*

Introduction

The Circular Economy (CE) concept is rapidly gaining attention in the international debate, having been deemed as the necessary response to the fragility and unsustainability of current economic systems. Mainly based on reducing, reusing, repairing, refurbishing, and recycling solutions, it is intended to create a closed-loop system that decreases waste while increasing resource efficiency. The transition towards circular production and consumption models concern all actors in the economic world. In these terms, the CE can be considered a strategy and a development opportunity for local supply chains and territorial systems, as it is capable of proposing and fostering new -or renewed- paths of sustainable growth. The process behind will have to be supported by approaches and tools that enable the analysis of contexts, modelling and simulation of closed-loop/circular scenarios solutions at various levels of scale, such as products, processes, supply chains, local

systems [1-2]. Although the CE is now emerging as a new economic paradigm, the strategies implemented so far are mainly sectoral. Holistic approaches and tools, which consider broader aspects as well as system-level perspectives, have been relatively disregarded. From a systemic perspective, the literature and empirical evidence point to a number of important gaps, namely: i) knowledge and representation of the technological, structural and organisational characteristics of the contexts of interest; ii) identification of the most suitable circular approaches, tools and solutions for these contexts; iii) simulation of the effects on the contexts; iv) choice of metrics and indicators to support change decisions [3].
The present article presents the preliminary results of the research project "MAX-SHEEP: *Modelling and assessment of circular scenarios in local contexts. Applications in the sheep supply chain"* which aims to develop a dynamic model capable of supporting the implementation of circular solutions in local sheep supply chains. In particular, the results of a survey and systematisation of the main tools potentially able to support, in an integrated way, the development of the various phases of the model under study will be discussed.

Methods and findings

From a methodological point of view, the MAX-SHEEP research project uses approaches and analysis tools peculiar to Industrial Ecology. The local reference contexts are economic-productive systems, specifically supply chains, whose actors and processes are represented according to a "metabolic" perspective, i.e. in the set of material-energy flows and stocks that characterise them. The aim is to develop a dynamic model that allows these contexts to be represented in an eco-industrial perspective. Furthermore, the purpose is to assess the potential and possible impacts on sustainability (environmental, economic and social), also externally, i.e. at a territorial level, of circular solutions implemented in the linear system of reference. The project consists of five steps: i) analysis of the linear supply-chain; ii) identification of circular solutions; iii) modelling; iv) measurement; v) simulation. Its development necessarily requires the support of different types of tools of analysis, both typically used in Industrial Ecology studies and borrowed from other areas of research, with multiple functionalities and often overlapping fields of operation. In addition, to a reconnaissance of existing applications, the project aims to assess the possibilities of synergic use aimed at the dynamic representation of scenarios to support change decisions in a circular perspective. The main tools identified at this stage relate to approaches and tools for mapping and representing systems (e.g., Flow Chart); material flow analysis (e.g., Material Flow Analysis); methods to support the spatial representation of relationships (e.g., Social Network Analysis); tools for simulating circular scenarios (e.g., System Dynamics Modelling); and life cycle approaches used to assess the environmental, social and economic impacts of products, processes and organisations (e.g., Life Cycle Assessment). The search was conducted using a set of keywords combining the function of the tool with the software terminology (e.g. "software" AND "material flow analysis"). The search returned over 200 results. A total of 172 tools were analysed, following a refinement phase to exclude duplications and irrelevant results. These were grouped into 11 categories, divided into 4 main fields of application, as described in Table 1.

Table 1. The tools identified to support the project phases.

Fields of application	Tools	Description	Source
Economic-productive systems analysis and representation	Flow chart	*Graphic representation used to represent a sequence of operations. Report the temporal order of events or actions.*	[4]
	Sankey Diagram	*It provides a representation of material flows between processes, distinguishing between different sources and their different uses/applications.*	[5]
	MFA	*It quantifies how materials that feed modern society are used, reused and wasted.*	[6]
	IS	*It describes the physical exchange of materials, energy, water and by-products/wastes between companies and/or production sectors through an integrated approach aimed at obtaining mutual competitive benefits.*	[7]
Analysis and spatial representation of networks	GIS	*It facilitates the management, manipulation, analysis, modelling, representation and visualisation of georeferenced data to solve complex planning and resource management problems through a system of hardware, software and procedures.*	[8]
	SNA	*It maps and measures relationships between interacting units (such as organisations).*	[9]
Scenario development	ABM	*It studies the development of dynamic patterns. A way of describing a system of behavioural elements. It allows new agents to be added and behaviour, learning, evolution and complexity to be modified by modifying the rules of interaction.*	[10]
	SDM	*It represents the structure of complex systems through feedback loops, both material and informational, consisting of stocks, flows and auxiliary variables to explore the causes and consequences of dynamic trends causing concern and to design policies to improve systems performance.*	[11]
	Scenario simulation	*It assesses the uncertainty of future developments based on current conditions.*	[12]
Impact assessment	CF, WF	*Measuring, respectively, the greenhouse gas emission that contributes to global warming and the consumption and contamination of freshwater resources.*	[13]
	LCA, SLCA, LCC	*LCA: assesses the potential environmental impacts of a product system throughout its life cycle. S-LCA: assesses the social and socio-economic aspects of products and their positive and negative impacts along their life cycle. LCC: identifies economic hotspots to potentially reduce product life cycle costs.*	[14-15-16]

LEGENDA: MFA: Material Flow Analysis; IS: Industrial Symbiosis; GIS: Geographic Information System; SNA: Social Network Analysis; ABM: Agent-Based Modelling; SDM: System Dynamic Modelling; CF: Carbon Footprint; WF: Water Footprint; LCA: LIfe Cycle Assessment, LCC: Life Cycle Costing, SLCA: Social Life Cycle Assessment.

Some of these tools were developed with a unique functionality (e.g., GIS and Social Network Analysis), while others allow for the integration of different functions, although created for a specific purpose. Therefore, from a systemic analysis point of view, the flexibility of some of these tools makes it possible to use a single tool at the same stage, with economic (e.g., software with a licence fee) and time-related (e.g., use of a single database, duplication of calculations, etc.) advantages, as well as in the training of recipients and users. In addition, some tools allow for more than one function. Figure 1 shows how, for instance, some tools enable the development of Sankey Diagrams but also network analysis, or scenario simulation or impact assessment. Finally, the analysis shows how some tools are useful in three of the four application areas, while no tool is cross-cutting across all of them. The possibility of using only one tool/software could further simplify the development of the model.

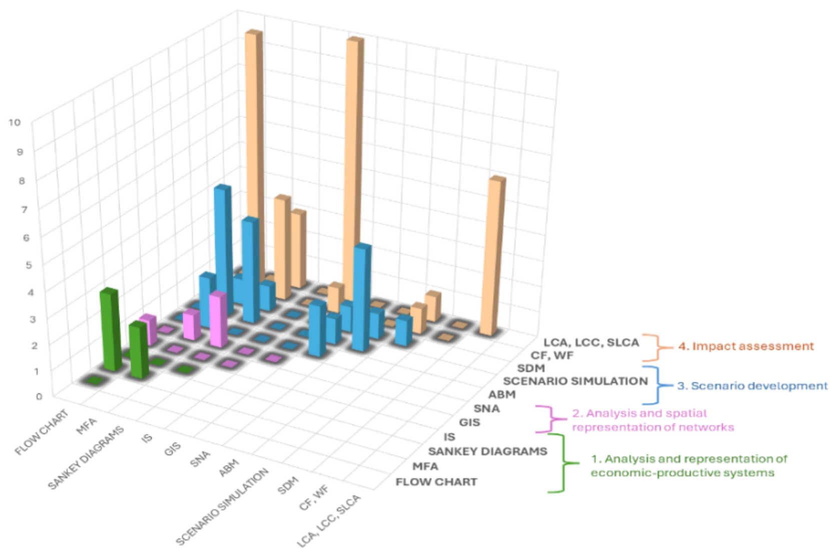

Figure 1. The multifunctionality of the tools for the integrated support in the four application areas.

LEGENDA: MFA: Material Flow Analysis; IS: Industrial Symbiosis; GIS: Geographic Information System; SNA: Social Network Analysis; ABM: Agent-Based Modelling; SDM: System Dynamic Modelling; CF: Carbon Footprint; WF: Water Footprint; LCA: LIfe Cycle Assessment, LCC: Life Cycle Costing, SLCA: Social Life Cycle Assessment.

Conclusions

At present, there are numerous tools from different disciplines, capable of analysing various aspects of a given system, which can be traced back to the field of study of CE and can highlight sustainability aspects related to products, processes and, more generally, to economic-productive systems. Several elements of interest emerge from the analysis conducted and open up for further investigation. For instance, some tools, created for different purposes, show areas of functional overlap with others. This highlights the potential with a view to the extension and integration of applications, even though these may, on the other hand, leave room for duplication of analyses. The need to use and implement dynamic tools that elaborate changing scenarios in time and space, such as circular ones, is another issue of great importance. Therefore, given the complexity of the contexts and the characteristics of the tools analysed, it is necessary that the models and tools also consider exogenous variables. These aspects, together with the potential for integrated use, represent one of the main areas for further investigation in the next phases of the project.

Acknowledgements

The present article is an outcome of the project “MAX-SHEEP: Modelling and assessment of circular scenarios in local contexts. Applications in the sheep supply chain” funded by the NextGenerationEU Plan, within the PRIN 2022 PNRR program promoted by the Italian Ministry of University and Research (Project code P202238JP9).

References

1. R. Taddeo (2021). Industrial Ecology and Innovation: At What Point Are We?. Editorial for the Special Issue “Industrial Ecology and Innovation”. Administrative Sciences, 11:93.
2. A. M. Walker, W. J. Vermeulen, A. Simboli, A. Raggi (2021). Sustainability assessment in circular inter-firm networks: An integrated framework of industrial ecology and circular supply chain management approaches. Journal of Cleaner Production, 286:125457.
3. S. Ritzéna, Ö. G. Sandströma (2017). Barriers to the Circular Economy - integration of perspectives and domains, Procedia CIRP, 64:7-12.
4. Ned Chapin. Flowchart. Encyclopedia of Computer Science. John Wiley and Sons Ltd., GBR. 2003, 714–716.
5. A. Marques, C. Jorge, D. M. Annelies, N. Kranti (2020). Contribution Towards a Comprehensive Methodology for Wood-Based Biomass Material Flow Analysis in a Circular Economy Setting. Forests, 11, 1:106.
6. T. E. Graedel (2019). Material flow analysis from origin to evolution. Environmental science & technology, 53(21), 12188-12196.
7. M.R Chertow (2000). Industrial symbiosis: literature and taxonomy. Annual Review of Energy and the Environment, 25, 313-337.
8. F. Escobar, G. Hunter, I. Bishop, A. Zerger (2008). Introduction to GIS. Department of Geomatics. The University of Melbourne. Available online at: https://geogra.uah.es/patxi/gisweb/GISModule/GISTheory.pdf (Accessed 30 August 2024).

9. R. Taddeo, A. Simboli, F. Di Vincenzo, G. Ioppolo (2019). A bibliometric and network analysis of Lean and Clean(er) production research (1990/2017). Science of the Total Environment, 653, 765-775.
10. A. Zehra, A. Urooj (2022). A Bibliometric Analysis of the Developments and Research Frontiers of Agent-Based Modelling in Economics. Economies, 10171.
11. J.W. Forrester (2016). Learning through system dynamics as preparation for the 21st century. System Dynamic Review, 32, 187–203.
12. R. Wang, Y. Murayama, T. Morimoto (2021). Scenario simulation studies of urban development using remote sensing and GIS. Remote Sensing Applications: Society and Environment, 22, 100474.
13. E. Ercin, A. Y. Hoekstra (2012). Carbon and water footprints: Concepts, methodologies and policy responses. United Nations Educational, Scientific and Cultural Organization (UNESCO).
14. ISO, 2006. Environmental Management - Life Cycle Assessment - Principles and Framework. EN ISO 14040:2006. International Organization for Standardization, Geneva, Switzerland.
15. L. Petti, M. Serreli, S. Di Cesare (2018). Systematic literature review in social life cycle assessment. International Journal of Life Cycle Assessment, 23, 422–431.
16. D. Hunkeler, K. Lichtenvort, G. Rebitzer (2008). Environmental life cycle costing, 2008, Crc press.

Use of biochar in metallurgical sector: potentials for industrial symbiosis and transition to circular eco-districts in Lombardy

Reza Vahidzadeh[1*], Marta Domini[1], Giorgio Bertanza[1]

[1]*Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM), Università degli Studi di Brescia, Italy.*
(E-mail: reza.vahidzadeh1@unibs.it)
*Corresponding author

Abstract

Biochar, derived from biomass pyrolysis, offers promising solutions to environmental challenges in the metallurgical sector, particularly as a substitute for fossil coal in iron and steel making. This study investigates the role of biochar within an industrial symbiosis network in Lombardy Region (Italy), connecting partners including iron and steelmakers, non-ferrous metallurgy, agriculture and energy sectors. It evaluates the production potential of biochar from regional biomass residues and its technical and economic viability compared to metallurgical coke. Current biochar production in northern Italy could replace one third of coke demand in metallurgical operations, underlining the potential for biomass availability to meet full demand through expanded pyrolysis and gasification processes. The findings emphasize the need for additional facilities and highlight how fostering industrial symbiosis in metallurgical sector can drive the transition to circular eco-districts in Lombardy.

Keywords: *Industrial symbiosis; Biomass; Pyrolisis; Circular Economy; Biochar.*

Introduction

The metallurgical sector is one of the most significant contributors to global greenhouse gas (GHG) emissions, primarily due to its reliance on fossil-based carbon materials [1]. Steel production, for instance, is responsible for approximately 7-9% of global anthropogenic CO_2 emissions [2]. The conventional Blast Furnace-Basic Oxygen Furnace (BF-BOF) steelmaking process generates approximately 1.8–1.9 tons of CO_2 per ton of steel, primarily due to the consumption of 800 kg of coal coke per ton of steel [2, 3]. The recycling route, which involves melting metal scraps in an electric arc furnace (EAF), reduces coal coke consumption by about 95% compared to the BF-BOF route; however, the EAF route is not entirely fossil-free, as it still depends on electricity and other carbon-intensive inputs [3]. Similarly, iron foundries, which process raw materials into cast iron products, emit significant amounts of CO_2 [4]. Though per-ton emissions can be even higher than in steelmaking due to specific energy and material requirements, their overall contribution is smaller due to lower production volumes. Beyond steel and iron, other metallurgical activities, such as the production of non-ferrous metals, face similar challenges in reducing their carbon footprint. This study aims to address these challenges by exploring the substitution of fossil-based coke with biochar, a renewable alternative derived from biomass pyrolysis [5]. Focusing on the Lombardy region, the study investigates how biochar integration could foster industrial symbiosis, reduce emissions, and enhance circularity within industrial symbiosis networks (ISNs).

Methods

The study followed a combined methodology including 5 steps for evaluating the feasibility of substituting fossil coke with biochar in various metallurgical processes in the industrial context of Lombardy. Firstly, the various possible synergies for the substitution of the inputs of the metallurgical activities in the business as usual (BAU) condition by biochar were identified using literature data [6]. Secondly, biomass suppliers and existing pyrolysis and gasification plants in the region were identified, and the biomass quantities were estimated [7]. The coke demand for 17 steel mills and 32 foundries in Lombardy was also analysed to determine how much could be replaced by biochar. In the third step, the technical feasibility of integrating biochar into existing furnaces was assessed, considering necessary adjustments to be made. In the next step, the benefits of the IS scenario was examined in terms of reduced emissions and increased circularity (UNI 11820:2022). Finally, non-technical aspects, such as the economic and logistical challenges, of the identified synergies were also considered, alongside regulatory issues regarding biochar classification. In Figure 1, a detailed schematic diagram is presented, illustrating the assessment procedure and its key components, including: biomass flow mapping, technical feasibility analysis, non-technical considerations, and the expected environmental benefits.

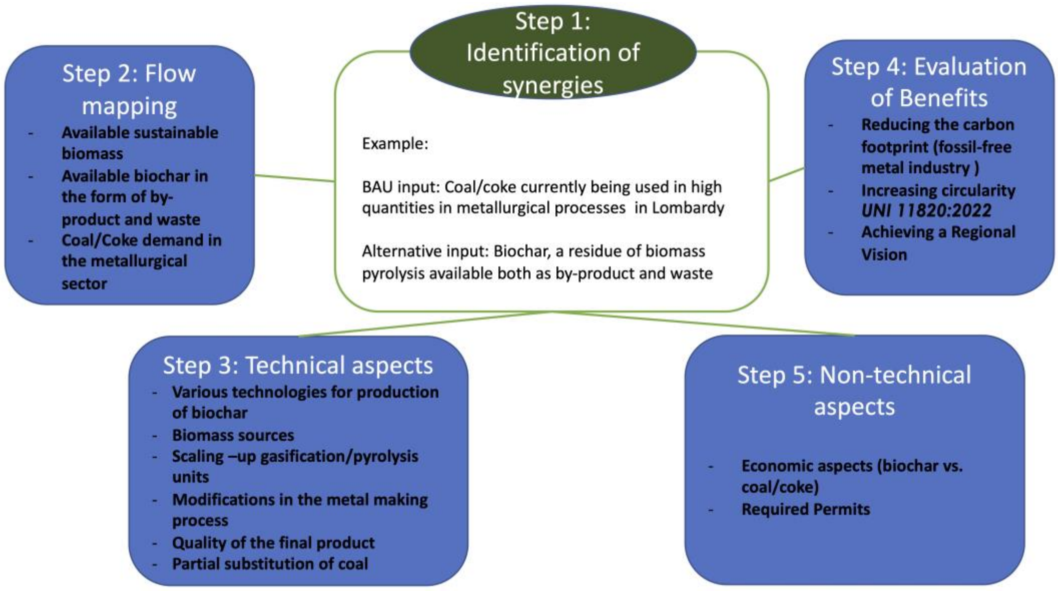

Figure 1. Assessment procedure and its key components for evaluation of the IS potentials of using biochar as an alternative resource in the metallurgical sector

Findings

The available biomass resources under optimal conditions can replace up to one-third of the in Lombardy Region's demand for metallurgical coke for iron and steel production. The production of biochar from agricultural and forestry residues is viable and can be integrated into current biomass supply chains. However, additional investments in pyrolysis and gasification infrastructure are needed. Technical assessments show that biochar can be used in metallurgical processes, but modifications to furnace systems are necessary. Environmentally, the available biochar can reduce fossil-CO_2 emissions by 33 % compared to BAU and enhances resource circularity, as it repurposes biomass residues into a valuable industrial input. For non-ferrous metal production, further study is required to tailor biochar use to each specific metal type. Additionally, economic feasibility remains a key factor, as biochar production costs need to be competitive with traditional coke.

Conclusion

This study demonstrates that biochar can be a sustainable alternative to coke in the metallurgical sector, particularly in Lombardy. Substituting fossil coke with biochar offers significant environmental benefits, including a reduction in CO_2 emissions, though the exact extent of this reduction will depend on further detailed assessments of biochar production and usage. The available biomass in Lombardy could replace one-third of the region’s coke demand, with the potential for full substitution under optimal conditions. However, the transition to biochar faces challenges such as the need for large-scale pyrolysis and gasification facilities, as well as regulatory barriers regarding the classification of residual chars produced in energy production plants as a waste. Future research should focus on optimizing biochar use across different metallurgical processes, scaling up production, and creating supportive policies. The development of an industrial symbiosis network could facilitate widespread adoption of biochar, making it a viable alternative to fossil coke.

Acknowledgement

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from Next-GenerationEU (Italian PNRR – M4 C2, Invest 1.3 – D.D. 1551.11-10-2022, PE00000004 CUP D73C22001250001).

References

1. E. Mousa, C. Wang, J. Riesbeck, M. Larsson (2016). Biomass applications in iron and steel industry: An overview of challenges and opportunities. Renewable and Sustainable Energy Reviews, 65, 1247–1266.
2. S. Lu, Z. Liu, Y. Wang, J. Zhang (2024). Towards green steel-energy and CO2 assessment of low carbon steelmaking via hydrogen based shaft furnace direct reduction process. Energy, 309, 133080.
3. S. Safarian (2023). To what extent could biochar replace coal and coke in steel industries? Fuel, 339, 127401.
4. A. Abdelshafy, D. Franzen, A. Mohaupt, J. Schüssler, A. Bührig-Polaczek, G. Walther (2023). A Feasibility Study to Minimize the Carbon Footprint of Cast Iron Production While Maintaining the Technical Requirements. Journal of Sustainable Metallurgy, 9 (1), 249 - 265.
5. E. Mousa, C. Wang, J. Riesbeck, M. Larsson (2016). Biomass applications in iron and steel industry: An overview of challenges and opportunities. Renewable and Sustainable Energy Reviews, 65, 1247–1266.
6. S. Al Hosni, M. Domini, R. Vahidzadeh, G. Bertanza (2024). Potential and Environmental Benefits of Biochar Utilization for Coal/Coke Substitution in the Steel Industry. Energies, 17(11), 2759.
7. N. Greggio, E. Balugani, C. Carlini, A. Contin, N. Labartino, R. Porcelli, M. Quaranta, S. Righi, L. Vogli, D. Marazza (2019). Theoretical and unused potential for residual biomasses in the Emilia Romagna Region (Italy) through a revised and portable framework for their categorization. Renewable and Sustainable Energy Reviews, 112, 590 – 606.

Application of Multi-Criteria decision analysis approach for evaluating the sustainability of landfills waste

Massimo Riccardo Costanzo[1*], Agata Matarazzo[1], Salvatore Ingenito[1], Carla Serrano[1], Antonio Zerbo [1]

[1] Department Economics and Business University of Catania, *ITALY*
(E-mail: massimo.costanzo@unict.it)
**Corresponding author*

Abstract

In this study, an MCDA method, TOPSIS, is presented for managing complex environmental-economic-social decisions. The analysis, through a critical multidimensional approach based on a vector of weights, shows that the sustainability performance of different landfill sites varies largely due to differences in implemented best management practices. In a whole life cycle management approach, environmental dimensions are the most relevant in the remediation strategy and implementation processes, while social dimensions are relatively little considered. A sensitivity analysis of the TOPSIS method showed that random variations in the vector of weights did not produce significant changes in the modelled sustainability performance of the assessed sites, and thus the method represents a fairly robust approach. The MCDA approach developed will enable stakeholders to adopt best management practices to control risks and improve sustainability performance in landfill management, covering the entire life cycle of site remediation.

Keywords: *TOPIS method; landfills; waste emergency; sustainability performance; best management practices.*

Introduction

The waste crisis represents one of the most critical challenges of our time, with serious repercussions on the environment, public health and the quality of life of communities. In Sicily, despite existing regulations, the emergency persists due to saturated landfills, ineffective waste management, and the widespread proliferation of illegal dumps. Recent studies show that insufficient infrastructure and inadequacies in leachate and gas management at controlled landfills significantly exacerbate negative impacts on soil, water and air inside [1,2,3]. Assessing the sustainability of Sicilian landfills requires the use of indicators for specific evaluation. Among these, the recycling rate is fundamental to monitor waste management policies, highlighting inefficiencies and stimulating corrective actions [1,2,3]. Composting capacity, on the other hand, contributes to reducing the volume of waste going to landfills, improving environmental quality and supporting the circular economy [4]. Waste-derived fuel recovery (RDF) offers an opportunity to energetically valorise waste, reducing the reliance on landfill and promoting technological innovation [5]. Methane emissions from the anaerobic decomposition of organic waste represent a crucial challenge. Their reduction, thanks to the use of enhanced capture and treatment systems for biogas, will mitigate environmental impacts and ensure some economic benefits. Lastly, cost analysis of operating landfills and valuation of land values provide reasons for enhancing planning and management efficiency [6,7]. The study focuses on two Sicilian landfills, 'Motta Sant'Anastasia' and 'Lentini', analysing their sustainability performance through a multidimensional approach and the TOPSIS method. The results show significant variations due to differences in the management practices adopted [8].

Materials and methods

The Motta Sant'Anastasia and Lentini landfills are two strategic facilities for municipal waste management in Sicily, but they present critical issues that need advanced solutions to increase their sustainability. The Motta Sant'Anastasia landfill is located about 25 km from Catania, with an area of 35 hectares, serving approximately 1,100,000 inhabitants. Activities include the collection of biogas and leachate, with leachate disposed of at an authorised centre. The site, however, planned for a capacity of 3.2 million m^3, is now saturated and develops deposits in height [9]. The Lentini landfill is one of the largest in Sicily and covers an area of 40 hectares with an authorised capacity of 4.5 million m^3. It receives special and non-hazardous municipal solid waste subjected to mechanical and biological treatments that reduce its volume and biogas production. The infrastructure includes geotextile barriers and leachate and biogas collection and treatment facilities, with potential for energy generation through gasifiers. Biological stabilisation of organic waste, authorised by the regional D.R.S., improves the sustainability of the site. Both sites are currently under judicial administration due to irregularities, but represent given their longstanding existence good examples for the application of the TOPSIS method.

This approach evaluates alternatives based on criteria such as recycling rate, composting capacity, RDF recovery, methane emission reduction, operational costs and economic benefits [10]. The objective is to select the management practices that are closest to the ideal solution, minimising environmental impact and maximising efficiency [11]. This technique is based on the concept that selected alternative should have the least distance from the ideal solution (the best possible state) and the most distance from a negative idea solution (worst possible state) [12]. The TOPSIS method involves essential steps such as the creation of the decision matrix in which the alternatives and criteria are listed with their corresponding values; normalisation in which the values are made comparable by eliminating units of measurement; weighing in which the normalised values are multiplied by the weights of the criteria; the definition of the ideal solutions in which the ideal (best) and anti-ideal (worst) solutions are identified; the calculation of distances: which measures the distance of each alternative from the ideal and anti-ideal solutions; the determination of the closeness coefficient which calculates how close each alternative is to the ideal solution; and finally the final ranking in which the alternatives are ordered according to the closeness coefficient, choosing the one with the highest value. The optimal alternative can be decided according to the preference rank order of higher closeness value [13].

Results

TOPSIS application

The main purpose of this study is to verify that the sustainability performance of different sites varies considerably due to differences in the best management practices (BMP) implemented using the TOPSIS (Technique of Order Preference Similarity to the Ideal Solution) method. The method provides a relatively robust approach, although it assumes that preferences are monotone for each evaluation criterion and that qualitative scales are converted into quantitative scales before applying the method. However, both assumptions have been widely criticised in the literature [14]. The various phases of the method are described below. Step 1: We want to rank the alternatives using the criteria evaluated in Table 1. Step 2: Data: Table 1 presents the data for the various criteria.

Table 1. Data (our elaboration) * https://siculatrasporti.com/ ** http://www.oikosspa.com/

Criteria	Lentini *	Motta S.A. **	Weight
Percentage of Waste Recycled (%)	25	20	0.15
Composting capacity (tonnes/year)	40000	50000	0.20
RDF Recovery (tonnes/year)	10.000	15.000	0.20
Methane Emissions Reduction (tonnes CO_2 eq/year)	16.000	15.000	0.25
Operating Costs (million euro/year)	3	4	0.10
Economic Benefits (million euro/year)	1,2	1,5	0.10

Step 3: normalization of the Decision Matrix. Table 2 presents the normalisation of the data matrix.

Table 2: Normal Matrix (our elaboration)

Criteria	Lentini	Motta S.A.
Percentage of Waste Recycled (%)	0,78086881	0,62469505
Composting capacity (tonnes/year)	0,62469505	0,78086881
RDF Recovery (tonnes/year)	1	1
Methane Emissions Reduction (tonnes CO_2 eq/year)	1	1
Operating Costs (million euro/year)	0,6	0,8
Economic Benefits (million euro/year)	0,62469505	0,78086881

Step 4: Weighted Normalized Matrix. Table 3 presents the normalised matrix multiplied by the weights.

Table 3: Weighted Normalized Matrix (our elaboration)

Criteria	Weight	Lentini	Motta S.A.
Percentage of Waste Recycled (%)	0,15	0,11713032	0,0937043
Composting capacity (tonnes/year)	0,2	0,12493901	0,1561738
RDF Recovery (tonnes/year)	0,2	0,11094004	0,1664101
Methane Emissions Reduction (tonnes CO_2 eq/year)	0,25	0,1823843	0,1709853
Operating Costs (million euro/year)	0,1	0,06	0,08
Economic Benefits (million euro/year)	0,1	0,0624695	0,0780869

Step 5: Computation of the ideal solution and the ideal negative solution
Ideal solution A+=[0.1171,0.1562,0.1664,0.1823,0.06,0.0781]
Ideal negative solution A−=[0.0937,0.1249,0.1109,0.1709,0.08,0.0625]

Step 6: Determine the **distance between each alternative from the positive and negative ideals**.
d+(Lentini)= 0.0635 d+(Motta S.A.)= 0.0282 d−(Lentini)= 0.0282 d−(Motta S.A.)= 0.0635
Step 7: Determine **the relative proximity of each alternative to the ideal solution** and ranking the alternatives Cl+(Lentini)= 0.307 Cl+(Motta S.A.)= 0.693
Step 8: Ranking alternatives by Table 4.

Table 4. Ranking of alternatives (our elaboration)

	sustainability performance
Motta S.A.	0,693
Lentini	0,307

Table 4 presents the sustainability level of the two analysed landfills. Taking into account the OMI values [15] of the Agenzia delle Entrate's real estate market observatory, we compared the above result with the soil value in the two territories.

Table 5. OMI soil value (our elaboration)

OMI soil value	min mq	max mq	min mq	max mq
	MOTTA S.A.		**LENTINI**	
Affordable housing	450,00 €	630,00 €	385,00 €	570,00 €
Boxes	550,00 €	780,00 €	355,00 €	510,00 €
Villas and cottages	800,00 €	1.150,00 €	660,00 €	970,00 €
Warehouses	320,00 €	520,00 €	240,00 €	355,00 €
Typical sheds, workshops	350,00 €	550,00 €	345,00 €	495,00 €
MOTTA S.A. TIRITI'	LENTINI Grotte San Giorgio			

The analysis of Table 5 shows that the land value in the municipality of Motta Sant'Anastasia is always higher than the value in the municipality of Lentini. These values can also be considered as indicators of the perception of environmental sustainability performance. The sensitivity analysis, conducted using causal numbers, simulating variations in the criteria weights showed that they have minimal impact on the overall sustainability performance results. The application of the TOPSIS method provides a comprehensive and flexible approach to assessing the sustainability of landfill management practices. The results indicate that environmental factors play a crucial role in sustainability performance; The MCDA approach developed in this study helps stakeholders to make informed decisions and adopt BMPs that improve sustainability throughout the life cycle of landfills.

In summary, the Motta S.A. landfill has a better performance in terms of sustainability and reuse than Lentini, according to the criteria and data used for the analysis. This could indicate that Motta S. A. has implemented more effective management practices or has performed better with respect to the indicators considered.

Discussion and conclusion

The case study has shown that increased intensity of the diffusion of advanced EMPs results in an overall increase in sustainability. There is, however, a need to include social aspects for a more balanced evaluation. MCDA can provide periodic evaluations and adjustments of BMPs under changing conditions but requires sensitivity analysis due to parameter uncertainty [16]. This study can be integrated with the Monte Carlo method to perform sensitivity analysis on the TOPSIS model, using several iterations to randomly generate the initial weights of the indices, based on the assumption that the total sum of all weights must be equal to 1. In the last phase, the results were analysed and compared in terms of environmental impact categories and dimensions, and the results were analysed with conclusions drawn and recommendations made for policy and decision makers in the sector [17].

In future studies, we will apply the analysis using further multi-criteria methods that develop results using also qualitative data without converting them to quantitative data. We would also like to have the possibility of greater collaboration and interaction with stakeholders to ensure that different perspectives are taken into consideration in the decision-making process, improving therefore the effectiveness of landfill management practices.

References

1. European Commission (2020). 2030 Climate & Energy Framework*. European Commission.

2. European Environment Agency (2020), Air Quality in Europe — 2020 Report. European Environment Agency.
3. ISPRA (2020), Rapporto Rifiuti Urbani 2019, Istituto Superiore per la Protezione e la Ricerca Ambientale.
4. La Mantia, T., & Pasta, S. (2015), Compost Use in Mediterranean Agriculture: Benefits and Challenges, Italian Journal of Agronomy, 10(3), 189-195
5. Pires, A., Martinho, G., & Rodrigues, S. (2011), Waste to energy in EU: state of the art, Renewable and Sustainable Energy Reviews, 15(9), 3677-3684.
6. Mazzanti, M., & Zoboli, R., Pressure on natural resources in Sicily: "Municipal waste management, environmental policy and economic efficiency," Journal of Environmental Planning and Management, 2009.
7. Mazzanti, M., & Zoboli, R., Specificities of waste management in Sicily: "Waste generation, waste disposal and policy effectiveness: evidence on decoupling from the European Union," Resources, Conservation and Recycling, 2008.
8. Arfò S. & Matarazzo A., (2022), Environmental and Economic Performance Indicators in Composting Pilot Plant in Sicily, The industrial symbiosis for the national circular economy strategic plan Symbiosis Users Network – SUN Proceedings of the sixth SUN Conference
9. ARPA Sicilia, Report 1997
10. Hwang, C. L., Yoon, K., Hwang, C. L., & Yoon, K. (1981). Methods for multiple attribute decision making. Multiple attribute decision making: methods and applications a state-of-the-art survey, 58-191.
11. Azar, A., & Rajabzade, A. (2014). Applied Decision Making MADM Approach, Tehran
12. Yoon, K. and C.L. Hwang, (1995), Multiple Attribute Decision Making: An Introduction. Quantitative Applications in the Social Sciences, ed. U.o.I. Michael S. Lewis-Beck. Sage Publications, Inc. 83 to Field-Effect Transistors. Advance Materials, 27, 2656-2662.
13. Dodangeh, J., Modeling of Fuzzy Balanced Scorecard: Master Thesis, in Department of Industrial Management. 2006, Islamic Azad University, Science & Research Branch: Tehran. p. 130.
14. Hwang, C.L.; Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag.
15. OMI values of the Agenzia delle Entrate's real estate market observatory
16. Simanaviciene, R., Ustinovichius, L., (2010). Sensitivity analysis for multiple criteria decision making methods: TOPSIS and SAW. Procedia Soc. Behav. Sci. 2 (6), 7743–7744.
17. Oliveri L.M., Arfò S., Matarazzo A., D'Urso D., Chıacchıo F., (2023), Improving the composting process of a treatment facility via an Industry 4.0 monitoring and control solution: Performance and economic feasibility assessment, Journal of Environmental Management, 345, 1-13.

Mapping the Horizon projects concerning the development of incentives for industrial Symbiosis

Mariarita Paciolla[1]*, Marco La Monica[2], Annarita Ceddia[2]

[1]*Centro di Documentazione sui Conflitti Ambientali, ITALY.*
[2] *ENEA, Department for Sustainability (SSPT), Casaccia Research Centre, ITALY.*
(*E-mail: marpaciol@gmail.com*)
*Corresponding author

ABSTRACT
Industrial symbiosis is essential for the circular economy, as it aims to maximize resource efficiency through inter industrial cooperation. By analysing the Eurio database and using the cluster analysis, this research has explored post-2013 Horizon projects that have made a significant contribution to the development of incentives for Industrial Symbiosis (IS). The analysis investigates the possible correlation between Funding Scheme Topic, Country of the coordinator of the project and duration and highlights an interest from Small and Medium Enterprises (SMEs) in developing solutions that implement IS.

Keywords: *Industrial Symbiosis; Incentives; Circular Economy.*

Introduction
Coping with resource scarcity and import dependence represents a challenge for various countries, including Italy. The scientific literature and empirical evidence from projects and practices show that alternative models are available not just as theoretic term of reference but also implemented in concrete experiences to foster efficiency in resources management. Emerging as a stream of industrial ecology [1], industrial symbiosis (IS) [2] may represent a significant strategy to cope with the sharp rise in raw material prices and supply uncertainty [3]. In particular, it has been noticed how symbiotic relations between industrial actors are concrete expression of the adoption of circular economy principles, since in industrial symbiosis "waste from each production and consumption process circulates as a new resource in the same or another production cycle" [4]. IS practices may arise in different ways, both from private-driven initiatives or as a result of public interventions [5]. However, the way in which symbiotic relations could be supported to overcome short-term experiences deserves to be studied in both cases to widespread the benefits deriving from the adoption of symbiotic approach from their niche dimension [6]. Consequently, a key question to be addressed concerns the study of mechanisms and typology of incentives [7] to support IS. Provide an answer to this broad and ambitious question requires a preliminarily investigation on what type of incentives have been displayed so far. Nowadays, various contents are collected and

available on online portals and archives, in particular related to public investments, where actors interested to IS can acquire materials on practices and opportunities. Following the mandate of transparency, public databases set up at national and European level share information, which are increasing in volume and variety. Nevertheless, further elaboration may be required to highlights specific elements of interests, which may be not directly available as ready-to-use contents. The aim of this paper is to contribute to the study of symbiotic phenomena in industrial relations by presenting the results deriving from the exploration of dataset including variables and observations on projects registered in the EU Cordis portal [8]. The paper is structured as follows. Section 2 provides information on materials and method for the cluster analysis. Section 3 presents the main findings derived from the application of the selected method. Section 4 includes the discussion on the results obtained and provide the conclusive remarks on the work.

Methods

The methods used for the research work are predominantly quantitative. For what concerns access to data and extraction of dataset, the standardized query language SPARQL requirements were followed according to the instruction available is SPARQL endpoint section, linked to EURIO Knowledge Graph which encodes the original CORDIS data [9].

The obtained dataset in csv format included observations on projects tagged with the following labels: “title”, “abstract”, “startDate”, “endDate”, “fundingSchemeTopic”, and “results”. In particular, projects of interest were identified by applying the filters “industrial symbiosis” and “by-product” to the “title”, “abstract”, and “fundingSchemeTopic” fields. Consequently, all projects containing either “industrial symbiosis” or “by-product” in the title, abstract, or funding scheme topic were filtered. To focus on projects closely aligned with the current industrial system, an additional filter based on start dates was applied, selecting only projects that began after 2013.

In order to analyse the dataset, cluster analysis was selected due to the advantages deriving from this multivariate data analysis technique [10]. Among the numerous alternatives available to perform cluster analysis, partitioning based k-means algorithm was chosen considering that this type of algorithm partitions the data into k clusters by minimizing intra-cluster variance.

The variables selected for clustering include Duration (project length), Location (geographical area), and Funding Scheme Topic (thematic focus of funding). Further information on the focus of Funding scheme is available in Table 1, which is needed for the interpretation of the finding displayed in Figure 1, 2 and 3. Since Location and

Funding Scheme Topic are categorical variables, they were converted to numerical values using Label Encoding, which assigns unique integer labels to each category.
Before clustering, the data were normalized, hence all features contribute equally to the clustering process by scaling them to a standard range (mean = 0, standard deviation = 1). Initially, centroids (cluster centers) were randomly selected. For each data point, the algorithm has calculated the distance to all centroids, assigning the point to the cluster with the nearest centroid. The distance used in this study is the Euclidean distance. Once all points were assigned, the centroids were updated as the mean of the points in each cluster. This process iterates until convergence. To determine the optimal number of clusters, the Elbow Method was used. In the next Section results from this analysis are shown and discussed.

Results

This search filter out 2500 projects, in part financed through grants for research and training, while specific topics regard large scale demonstration, innovation actions and instruments for SMEs as shown in Table 1. By filtering out the projects focusing on the coordinator Country, final database includes 191 records. Having obtained this latter version of the dataset, the cluster analysis has been performed.
Figure 1 shows the result from the clustering process, consisting in three clusters. Duration, Location and Funding Scheme Topics are the parameters selected for individuating the cluster distribution of the projects. In the plot reported in Figure 1, the y-axis and x-axis represent, respectively, the coordinating Country of the project and the funding scheme, where is possible to observe ‘Cluster 0’, which is composed of 69 projects, while ‘Cluster 1’ and ‘Cluster 2’ include 61 projects each. The following figures show histograms referred to the distribution of projects according to countries and cluster (Figure 2), and the number of projects for Funding Scheme and cluster (Figure 3).

Table 1. Funding Scheme Number (N.) and Name description

N.	Name	N.	Name
0	*Boosting the potential of small businesses for eco-innovation and a sustainable supply of raw materials*	21	*Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE)*
1	*Boosting the potential of small businesses in the areas of climate action, environment, resource efficiency and raw materials*	22	*Marie-Curie Action: "Intra-European fellowships for career development"*
2	*Building a water-smart economy and society*	23	*Materials for new energy efficient building components with reduced embodied energy*
3	*Demonstration/pilot activities*	24	*Moving towards a circular economy through industrial symbiosis*
4	*ERC Advanced Grant*	25	*New solutions for sustainable production of raw materials*

5	*ERC Advanced Grant - Molecular and Structural Biology and Biochemistry*	26	*New technologies for the enhanced recovery of by-products*
6	*ERC Consolidator Grant*	27	*New uses for glycerine in biorefineries*
7	*ERC STARTING GRANTS*	28	*Peer learning of innovation agencies*
8	*ERC Starting Grant*	29	*Produce bio-based functional ingredients and additives for high-end markets*
9	*Eco-innovative demonstration projects*	30	*Raw materials Innovation actions*
10	*Energy and resource management systems for improved efficiency in the process industries*	31	*Raw materials innovation for the circular economy: sustainable processing, reuse, recycling and recovery schemes*
11	*Fast Track to Innovation (FTI)*	32	*Research for SME associations*
12	*H2020-EIC Accelerator pilot –SME Instrument- Green Deal*	33	*Research for SMEs*
13	*Individual Fellowships*	34	*Resource-efficient eco-innovative food production and processing*
14	*Innovative Training Networks*	35	*SME instrument*
15	*Marie Curie Action: "Industry-Academia Partnerships and Pathways"*	36	*Stimulating the innovation potential of SMEs for a low carbon and efficient energy system*
16	*Marie Curie Action: "International Incoming Fellowships"*	37	*Stimulating the innovation potential of SMEs for sustainable and competitive agriculture, forestry, agri-food and bio-based sectors*
17	*Marie Curie Action: "International Outgoing Fellowships for Career Development"*	38	*Supporting SMEs efforts for the development - deployment and market replication of innovative solutions for blue growth*
18	*Marie Curie Action: "Intra-European Fellowships for Career Development"*	39	*Sustainable European aquaculture 4.0: nutrition and breeding*
19	*Marie Curie Action: "Reintegration Grants"*	40	*Systemic, eco-innovative approaches for the circular economy: large-scale demonstration projects*
20	*Marie Skłodowska-Curie Individual Fellowships (IF-EF)*	41	*Tapping into the potential of Industrial Symbiosis*

Source: Authors' elaboration based on CORDIS data

Looking at Figure 1, it is possible to note how the diameter of the coloured bubbles varies proportionally to the duration-. The color intensity indicates the presence of multiple projects at that point in the Cartesian space, and -simultaneously- the involvement of the Coordinator in multiple projects. This condition is observed in each of the three clusters. Duration may coincide in some cases while in others, may vary. An example of this latter case is visible looking at the values of the pair (UK, 21), identifying projects coordinated by centers in the UK and funded under the Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) funding scheme. Projects belonging to Cluster 0 mostly have a duration between two years and six months, and the funding types used are those with codes ranging from 31 to 41 (Figure 3), primarily related to raw materials, circular economy, and the development of small and medium-sized enterprises with a wide geographical implementation (Figure 2).

Cluster 1 groups projects mostly located in United Kingdom, Netherland and Italy (see Figure 1) with a duration greater than 2 years and Funding Scheme more general such ERC, Marie-Curie Action or individual Fellowship (see Figure 3).

The duration of Projects gathered in Cluster 2 is in a range between 2 and 4 years, with only a few projects lasting less than a year or more than 4 years. Coordination is held by centers in Spain, followed by Germany, Belgium, and the Czech Republic. The funding schemes supporting these projects include, in part, Marie-Curie or Individual Fellowships, as well as more specific funds for the circular economy, industrial symbiosis, and by-products (such as funding codes 24, 25, and 26).

Figure 1. Distribution of the Cluster considering the Countries eligible in Funding schemes *Source: Authors' elaboration based on CORDIS data*

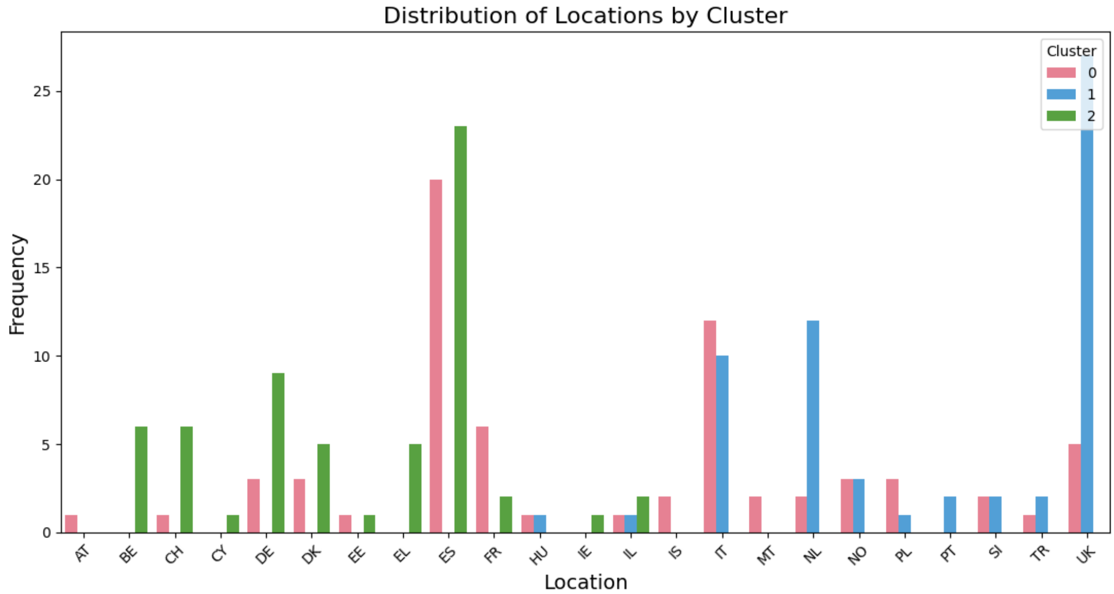

Figure 2. Focus on the more frequently Countries involved in the identified clusters
Source: Authors' elaboration based on CORDIS data

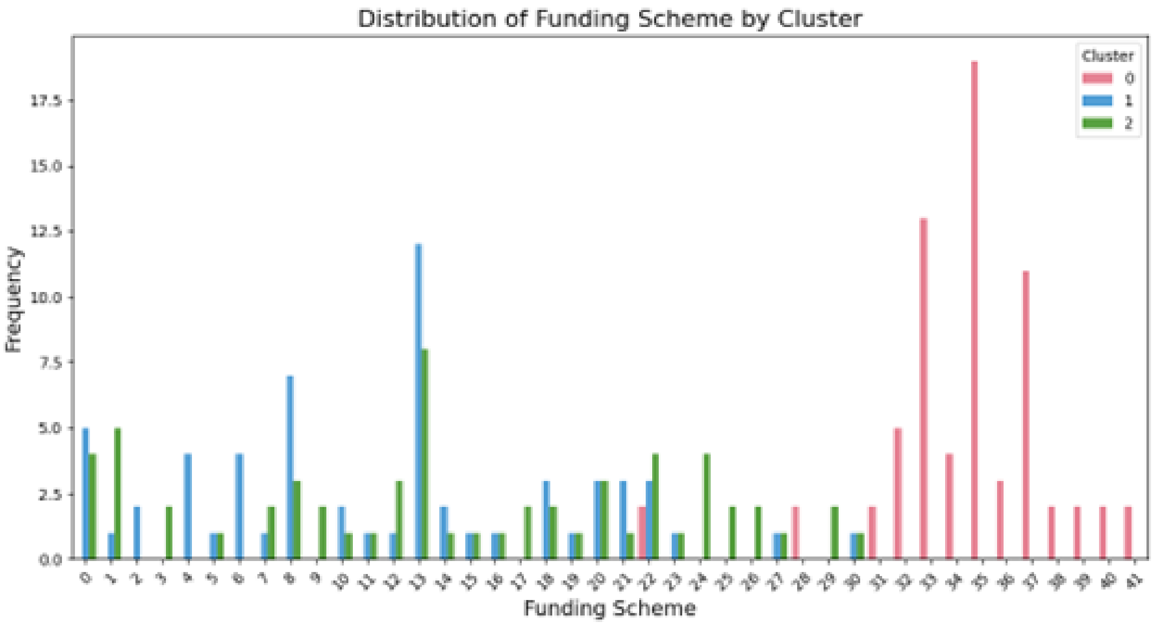

Figure 3. *Focus on the Funding Scheme in the identified clusters.*
Source: Authors' elaboration based on CORDIS data

Since the study aimed to identify incentive mechanisms to facilitate and promote industrial symbiosis, *a posteriori* filter on the selected projects whose "results" field (e.g., reports, papers, position papers, conferences, etc.) included "incentives", "by-product regulation", or related terms were selected. This process ultimately identified three projects financed under Horizon 2020, which are briefly described below to highlight the respective objectives and the identified incentive proposals.

The project DECISIVE [11] (A Decentralized management Scheme for Innovative Valorization of urban biowastE) focuses on local and decentralized management of organic waste, the project EPOS [12] (Enhanced energy and resource Efficiency and Performance in process industry Operations via onsite and cross-sectorial Symbiosis) explores cross-industry synergies, focusing on renewable energy integration and resource sharing, and the project SCALER [13] aims at a broad scalability of industrial symbiosis.

Regarding the evidence found on incentives, project deliverables concerning incentives both to improve services and equipment but also to support behavioral change were developed in the frame of first project, under the second were explored the incentives for agents operating in the wind energy markets while addressing the role of policy makers in defining the incentives needed. Within the third project, various incentives were identified to support policy integration and wide range synergies to be activated to support IS initiatives. However, by consulting and qualitatively analyzing the project documentation, it is possible to detect elements of interest and contextualize the lessons learnt from the applications detected.

Discussion and Conclusions

This study shows how the most present Funding Scheme Topic regarding Industrial Symbiosis involved interests towards SMEs. This could be interpreted as a sign of a will to develop an industrial system more resilient that maximizes resource management and resource efficiency. However, the results show that some topics could be furtherly integrated in the Funding Scheme. More space should be dedicated to those concerning Raw materials, due to their significant and crucial role for a Circular future. Wider considerations concern the role of quantitative methods in the study of complex phenomena. Cluster analysis has contributed to explore the numerous projects available and investigate specific features of the projects. However, qualitative methods and content analysis are still crucial to identify mechanisms or type of incentives to support IS. Further studies and research practice may benefit from the present study and extend the frame of research to other form of support for IS.

References

1. Chertow M.R. (2004), “Industrial symbiosis”, Encyclopedia of energy, vol. 3, pp. 407-415.
2. Chertow, M.R. (2007). “Uncovering” Industrial Symbiosis. Journal of Industrial Ecology, 11(1). https://doi.org/10.1162/jiec.2007.1110

3. Beltrani T. e La Monica M. (edito da). (2022). La simbiosi industriale per la strategia Nazionale di Economia Circolare - Atti SUN 2022, ISBN digitale: 978-88-8286-442-2.
4. Cutaia, L., Mancuso, E., e La Monica M. (2019). La simbiosi industriale e territoriale. Energia, ambiente e innovazione 3/2019, 112-114, DOI 10.12910/EAI2019-049
5. Adamides, E. D., & Mouzakitis, Y. (2009). Industrial ecosystems as technological niches. Journal of Cleaner Production, 17(2), 172-180.
6. Domenech, T., Doranova, A., Roman, L., Smith, M., & Artola, I. (2018). Cooperation fostering industrial symbiosis: market potential, good practice and policy actions. A Report for the European Commission, DG Internal Market, Industry, Entrepreneurship and SMEs.
7. Couder N., Katrakis E. e Nacci G. (2021), Incentives to Boost the Circular Economy – A guide for Public Authorities, European Commission Directorate-general for Research and Innovation, Indipendent Expert Report, https://op.europa.eu/it/publication-detail/-/publication/51378e0a-d303-11eb-ac72-01aa75ed71a1 .
8. European Commission – Cordis – Datalab web page. https://cordis.europa.eu/datalab/it .
9. European Commission – Cordis – Datalab web page "What is Linked Open Data?". https://cordis.europa.eu/about/sparql .
10. James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An Introduction to Statistical Learning. Springer Texts in Statistics, 112, 426.
11. European Commission – Cordis - A DECentralIzed management Scheme for Innovative Valorization of urban biowastE, available at: https://cordis.europa.eu/project/id/689229.
12. European Commission – Cordis - EPOS - Enhanced energy and resource Efficiency and Performance in process industry Operations via onsite and cross-sectorial Symbiosis, available at: https://cordis.europa.eu/project/id/679386.
13. European Commission – Cordis - Scaling European Resources with Industrial Symbiosis, available at: https://cordis.europa.eu/project/id/768748.

Literature review on nature based solutions for industrial landscape transformation in Europe and Italy

Maria Elena Bini[1], Alessandra Fiorucci[1], Sara Pennellini[1], Alessandra Bonoli[1]

[1] *Department of Civil, Chemical, Environmental and Material Engineering (DICAM), University of Bologna, ITALY.*
(E-mail: mariaelena.bini2@unibo.it)
*Corresponding author

Abstract

Nature-Based Solutions (NBS) are widely defined as interventions inspired and supported by natural processes that effectively address societal problems, providing environmental, social and economic benefits through the sustainable use of ecosystem services. This reflects the growing acknowledgement of the intrinsic value and practical benefits of exploiting natural systems even for industrial landscape transformation. This study aims to analyze the state of the art through a review of the literature on the implementation and impact of NBS for the regeneration of former industrial areas in Europe, with a specific focus on Italy. Numerous success stories of brownfields regenerated through the implementation of Nature-Based Solutions are reported in scientific literature. Such green interventions enabled the realization of recreational spaces, improving urban climate resilience and supporting local biodiversity.

Keywords: *NBS; Ex-industrial areas regeneration; sustainable-urban-planning; urban-resilience.*

Introduction

Supporting sustainable urban planning is a prerogative of the transition to more resilient cities to ensure human, animal, and environmental health and well-being [1]. Integrating Nature-Based Solutions (NBS) into this transformative path to urban sustainability provides ecological, economic, and social benefits in response to the needs of populations [2]. Specifically, some studies conducted in European cities state that in suburban industrial areas it is more likely to implement NBS because of the type of built structures and the availability of large spaces [3-5]. The industrial sector accounts for more than 20% of the European Union's economy [6]. In Italy, according to Istat data, industrial districts account for about a quarter of the country's production system [7], recording an increase in terms of units from 2011 to 2024 [8]. Lost their original function, dismissed industrial buildings and areas represent a strategic factor in territorial urban planning processes, answering to increasing demand for new spaces [9]. The regeneration of such areas using NBS would relieve the pressure of urban sprawl on natural territories by fostering the preservation of local biodiversity and providing citizens with new spaces for collective and recreational use [10]. This article reports a state of the art analysis through a literature review on the implementation and impact of NBS for the regeneration of former industrial areas in Europe, with a specific focus on the Italian territory.

Methods

The literature review was conducted using the Scopus database (www.scopus.com). No restrictions were placed on publication date, while an "All Open Access" search filter was used to ensure the accessibility of selected papers. Different combinations of the following keywords were used to identify publications relevant to the study: "Industrial areas", "Regeneration", "Italy", "Europe", "Nature-Based Solutions", "Brownfield". The search results grouped a total of 465 scientific productions. In the first stage, the selection process included screening of the title and abstract, then, before fully studying the texts of interest, any duplicates were removed, and the actual accessibility of the identified material was verified. The final skimming phase resulted in the selection of 36 papers, which were considered suitable based on the acceptance of at least one of the following criteria: (i) Reference to former industrial areas, (ii) Placement of such areas in Italy or Europe, (iii) Presentation of spatial planning projects, and (iv) Scientifically representative modeling of Nature-Based Solutions. Scopus search activity was further supported by gray literature through consultation of non-scientific publications accessible online such as official communications from government, institutions and professional bodies.

Results

Among the consulted documents, 17 emphasize the importance of the spatial design phase when planning regeneration interventions in former industrial areas. In particular, they emphasize how architectural structures and hybrid landscapes based on new principles of sustainable urban planning can contribute to the renaturalization of the built environment [11]. To this end, several works propose action plans and business models for the implementation of rehabilitation projects of brownfields by implementing a holistic approach from the initial design phase [12-18]. In this context, NBS are essential for redevelopment works to generate a wide range of ecosystem services that can benefit both the environment and the population [19]. Although the potential of NBS as a cost-effective tool for urban sustainability has been recognized, their implementation faces numerous obstacles, including the effective assessment of the benefits brought [19]. To help fill this gap, several works among those analyzed have implemented, using modeling software, various NBS-based intervention scenarios for brownfield redevelopment in Italy and abroad [20-22]. In some cases, even going into detail about a specific Nature-Based Solution (e.g. green roofs), their benefits and potential applications are analyzed [23-25]. Finally, the role of citizens seemed to be crucial in developing long-term sustainable social-ecological plans and actions, thus favoring a bottom-up approach [26,27]. The 120 sites of interest identified were analyzed in detail to extract information useful in identifying Nature-Based Solutions implemented in industrial land regeneration. Results are summarized in Figure 2. The total is divided into 54 former industrial sites regenerated without the implementation of NBS or whose design does not include such solutions, hosting mainly museums, theaters and recreation centers. The remaining 66 areas considered, on the other hand, are the subject of spatial planning inclusive of NBS, simulations and 3D modeling integrated with scientific research projects or completed interventions characterized by the presence of one or more NBS (see Figure 1.a). Considering the large spaces available in industrial areas and the particular configuration of buildings, the most commonly implemented types are public parks and green roofs, followed by urban community gardens and tree planting, in less peripheral former industrial areas. (see Figure 1.b).

Discussion and Conclusions

This paper briefly reports the results of a literature review aimed at identifying virtuous examples of the implementation of Nature-Based Solutions in brownfield regeneration in Europe and Italy, and to provide insights for future decision-making and urban planning processes. Collected results have shown a higher concentration of regenerative interventions in more industrialized European countries and regions of Italy, preferring an approach geared toward optimizing the urban spatial pattern and capable of creating environmental, economic and social benefits through the use of different types of NBS [20]. Among the critical issues encountered, the gap between modeling or planning and actual implementation of regenerative interventions. In Italy, one cause is certainly the need to allocate large sums of money for this type of intervention, in addition to complicated bureaucratic procedures that lead to a lengthening of the implementation timeframe. Regarding implemented and completed projects, another critical issue encountered is the lack of detailed information on the interventions carried out, especially on the NBS installed. This aspect in some cases led to a partial assessment of the characteristics of the site of interest and consequently to the devaluation of the installation for the purposes of this study. Public and private organizations that choose to implement such solutions should extol and emphasize their commitment and contribution to the transition to resilient urban spaces. In Italy, for example, integrating the concept of NBS to the current constructions' regulation would facilitate the understanding and acceptance of such solutions in favor of greater transparency and clarity of data publicly available. Finally, traditional urban planning tools are challenged, criticizing the limitations of top-down processes and valuing active citizen participation

[16]. In support of future industrial symbiosis projects, in addition to the rehabilitation and restoration of existing brownfields, it is therefore necessary to use a holistic approach from the earliest stages of planning, and to strike the right balance between technocracy and social inclusiveness.

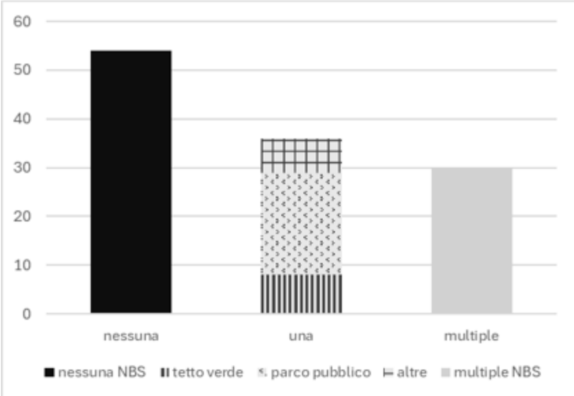

Figure 1a. *Number of NBS installations by site of interest*

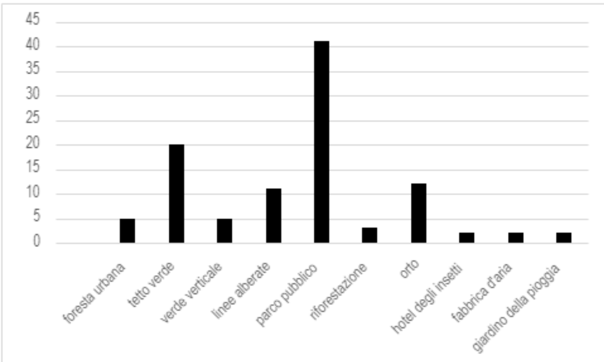

Figure 1b. *Types of NBS by site of interest.*

References

1. T. Yigitcanlar, S. Teriman, Rethinking sustainable urban development: towards an integrated planning and development process, International Journal of Environmental Science and Technology 12 (2015) 341–352. https://doi.org/10.1007/s13762-013-0491-x.
2. A. Alves, C. van Opstal, N. Keijzer, N. Sutton, W.S. Chen, Planning the multifunctionality of nature-based solutions in urban spaces, Cities 146 (2024). https://doi.org/10.1016/j.cities.2023.104751.

3. M. Žuvela-Aloise, K. Andre, H. Schwaiger, D.N. Bird, H. Gallaun, Modelling reduction of urban heat load in Vienna by modifying surface properties of roofs, Theor Appl Climatol 131 (2018) 1005–1018. https://doi.org/10.1007/s00704-016-2024-2.
4. C. Cortinovis, P. Olsson, N. Boke-Olén, K. Hedlund, Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities, Urban For Urban Green 67 (2022). https://doi.org/10.1016/j.ufug.2021.127450.
5. J. Langemeyer, D. Wedgwood, T. McPhearson, F. Baró, A.L. Madsen, D.N. Barton, Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona, Science of the Total Environment 707 (2020). https://doi.org/10.1016/j.scitotenv.2019.135487.
6. Consiglio dell'Unione Europea, "Politica Industriale dell'UE," (2024). https://www.consilium.europa.eu/it/policies/eu-industrial-policy/#:~:text=L'industria%20dell'UE%20%C3%A8,milioni%20di%20posti%20di%20lavoro
7. (accessed September 5, 2024).
8. Istat, "I distretti industriali," 2015.
9. Direzione Studi e Ricerche - Intesa Sanpaolo, "Economia e finanza dei distretti industriali" - Rapporto annuale n. 16, 2024.
10. Ispra, Patrimonio Industriale - Rivista AIPAI, 2017.
11. E. Dogan, F. Cuomo, L. Battisti, Reviving Urban Greening in Post-Industrial Landscapes: The Case of Turin, Sustainability (Switzerland) 15 (2023). https://doi.org/10.3390/su151712760.
12. E.Y. Zaykova, Zaryadye park as the new hybrid landscape and town-planning model in moscow's historic center, in: Proceedings of the Annual International Conference on Architecture and Civil Engineering, Global Science and Technology Forum, 2018. https://doi.org/10.5176/2301-394X_ACE18.459.
13. C. Vizzarri, V. Sangiorgio, F. Fatiguso, A. Calderazzi, A holistic approach for the adaptive reuse project selection: The case of the former Enel power station in Bari, Land Use Policy 111 (2021). https://doi.org/10.1016/j.landusepol.2021.105709.
14. R. Ingaramo, I.M. Lami, M. Robiglio, How to Activate the Value in Existing Stocks through Adaptive Reuse: An Incremental Architecture Strategy, Sustainability (Switzerland) 14 (2022). https://doi.org/10.3390/su14095514.
15. C. Becchio, D.G. Ferrando, E. Fregonara, N. Milani, C. Quercia, V. Serra, The cost-optimal methodology for the energy retrofit of an ex-industrial building located in Northern Italy, Energy Build 127 (2016) 590–602. https://doi.org/10.1016/j.enbuild.2016.05.093.
16. A. Villacampa, Y. Villacampa, Re-use of the industrial heritage of Bovisa: A model for urban and cultural regeneration, WIT Transactions on Ecology and the Environment 155 (2011) 869–880. https://doi.org/10.2495/SC120732.
17. O. Gervasi, B. Murgante, A.M.A.C. Rocha, C. Garau, F. Scorza, Y. Karaca, C.M. Torre, eds., Computational Science and Its Applications – ICCSA 2023 Workshops, Springer Nature Switzerland, Cham, 2023. https://doi.org/10.1007/978-3-031-37117-2.
18. L. Amenta, M. Russo, A. Van Timmeren Editors, Regenerative Territories, n.d. https://doi.org/10.1007/978-3-030-78536-9.
19. V. Battaglia, N. Massarotti, L. Vanoli, Urban regeneration plans: Bridging the gap between planning and design energy districts, Energy 254 (2022). https://doi.org/10.1016/j.energy.2022.124239.

20. M. Masiero, A. Biasin, G. Amato, F. Malaggi, D. Pettenella, P. Nastasio, S. Anelli, Urban Forests and Green Areas as Nature-Based Solutions for Brownfield Redevelopment: A Case Study from Brescia Municipal Area (Italy), Forests 13 (2022). https://doi.org/10.3390/f13030444.
21. K. Tu, Y. Niu, A. Reith, Regeneration design of mining brownfield based on nature-based solutions, Pollack Periodica (2024). https://doi.org/10.1556/606.2024.01089.
22. F.M. Alves, A. Gonçalves, M.R.D.C. Enjuto, The Use of Envi-Met for the Assessment of Nature-Based Solutions' Potential Benefits in Industrial Parks—A Case Study of Argales Industrial Park (Valladolid, Spain), Infrastructures (Basel) 7 (2022). https://doi.org/10.3390/infrastructures7060085.
23. B. Rugani, B. Pölling, M. Della Casa, G. Guidolotti, C. Baldacchini, A. Timpe, C. Calfapietra, Coupled life cycle assessment and business modelling to estimate the sustainability of using regenerated soils in urban forestry as nature-based solutions, Urban For Urban Green 95 (2024). https://doi.org/10.1016/j.ufug.2024.128327.
24. C. Ciacci, N. Banti, V. Di Naso, F. Bazzocchi, Green strategies for improving urban microclimate and air quality: A case study of an Italian industrial district and facility, Build Environ 244 (2023). https://doi.org/10.1016/j.buildenv.2023.110762.
25. F. Silva, C.S.C. Calheiros, A. Albuquerque, J.P. Lopes, A.M. Antão-Geraldes, Technical and Financial Feasibility Analysis of Rainwater Harvesting Using Conventional or Green Roofs in an Industrial Building, Sustainability (Switzerland) 15 (2023). https://doi.org/10.3390/su151612430.
26. M.C. Catalbas, B. Kocak, B. Yenipınar, Analysis of photovoltaic-green roofs in OSTIM industrial zone, Int J Hydrogen Energy 46 (2021) 14844–14856. https://doi.org/10.1016/j.ijhydene.2021.01.205.
27. M. Bottero, M. Bravi, C. Caprioli, F. Dell'Anna, Combining Revealed and Stated Preferences to design a new urban park in a metropolitan area of North-Western Italy, Ecol Modell 483 (2023). https://doi.org/10.1016/j.ecolmodel.2023.110436.
28. G. Trentanovi, T. Campagnaro, I. Kowarik, M. Munafò, P. Semenzato, T. Sitzia, Integrating spontaneous urban woodlands into the green infrastructure: Unexploited opportunities for urban regeneration, Land Use Policy 102 (2021). https://doi.org/10.1016/j.landusepol.2020.105221.

Assessing the advancement of Circular Economy practices in the Agri-food sector: applying the TRL framework in Italy

Agata Matarazzo[1], Massimo Riccardo Costanzo[1], Tiziana Beltrani[2], Salvatore Ingenito[1*], Carla Zarbà[3], Alessandro Scuderi[3]

[1] *Department of Economics and Business, University of Catania, Corso Italia, 55, Catania, 95129, Italy*
[2]*RISE (Valorization of Resources in production and Territorial Systems*) Laboratory, ENEA, Italy
[3]*Department of Agriculture, Food and Environment, University of Catania, Via S. Sofia, 100, 95123, Catania, Italy*
(E-mail: massimo.costanzo@unict.it)
*Corresponding author

Abstract

This study explores the adoption of sustainability and Circular Economy (CE) practices within the agri-food sector, focusing on their potential to mitigate crisis effects and enhance resource efficiency. The research leverages the Technology Readiness Levels (TRLs) framework, adapted to assess the advancement stages of CE good practices (GPs), particularly those registered in the Italian Circular Economy Stakeholder Platform (ICESP). Analyzing 44 agri-food GPs across various regions and sectors in Italy, the study identifies significant disparities in TRL stages, with regions like Emilia Romagna and Piemonte exhibiting a higher concentration of advanced practices. The results reveal that agricultural GPs generally exhibit a lower stage of advancement, while Food and Beverage (F&B) practices are more prevalent in later stages, particularly during market introduction and expansion. These findings underscore the need for tailored strategies to support CE adoption, address sector-specific barriers, and promote the scalability of innovative practices. The study concludes that a structured TRL framework is essential for advancing sustainability in the agri-food sector, offering insights that can guide future research and policy interventions aimed at fostering a more widespread and effective transition to a circular economy.

keywords: *Circular Economy; Agri-food Sector; Technology Readiness Levels; Good Practices; Sustainability.*

Introduction

Adopting sustainability and circular economy (CE) practices can help organizations mitigate crises by reducing risks, managing resources efficiently, and minimizing supply disruptions. CE may reduce dependence on physical resource exchange between economic systems and the environment, aiming for sustainable development through efficient resource utilization (Lopes J. & Farinha L., 2019). Despite 114 definitions of CE (Kirchherr et al., 2017), they share the goal of reducing natural resource strain by promoting cyclical, minimal-waste models. This approach could save €1.8 billion annually in Europe by 2030, boosting GDP and employment. However, global circularity fell from 9.1% to 8.6% recently due to limited material recycling capabilities worldwide. In the agri-food sector, organizations are piloting innovative CE good practices (GPs), but adoption remains limited due to sector-specific challenges like using another company's waste. The Italian Circular Economy Stakeholder Platform (ICESP) has documented 242 GPs across sectors, including 44 from agri-food, to quantify and promote their environmental, social, and economic impacts. To enhance adoption, a model to measure the advancement of these practices is needed. Technology Readiness Level (TRL), initially developed by NASA, provides a structured framework for evaluating technological maturity and readiness. This study proposes a methodology to link GPs to TRLs, supporting agri-food companies in adopting CE practices and evaluating their progression across Italy.

Methods

This study proposes a TRL framework adapted to the nature of circular economy GPs, which encompasses non-technological aspects. Similarly to Buchner G. A., et al. (2019), to identify stages of advancement, the model distinguishes Working Flow (WF) and Tangible Result (TR) for each TRL (Table 1). TRLs corresponds to EARTO clusters including the following main stages: invention, concept validation, prototyping and incubation, pilot production and demonstration, initial market introduction, and market expansion (EARTO, 2014). The key variables taken into consideration are the following: GP description, qualitative and quantitative result from the GP implementation, sector (i.e., food and beverage or agriculture), geography, barrier encountered in the implementation, financing need, current investment. The agri-food GPs assessed are 44 out of a total set of GPs amounting to 242 (which includes different sectors) as of the first of May 2024 in the ICESP database. By evaluating the current WF from the description of GPs and assessing the current TR attained from the key variables provided by ICESP, the model allows to track the positioning of GPs with the appropriate advancement stage of a circular economy GP. (Sauser B., et al., 2006). This study, through such a descriptive model, assess all 44 agri-food practices registered in the ICESP database around Italy and not only, as of the first May 2024.

Table 1. Adapted TRL framework for circular economy GPs, outlining WF and TR across EARTO stages and key assessment variables.

EARTO maturity model	Invention		Concept validation		Prototyping and incubation	Pilot production and demonstration		Initial market introduction	Market expansion
TRL	TRL1	TRL2	TRL3	TRL4	TRL5	TRL6	TRL7	TRL8	TRL9
Definition	**Idea**	**Concept**	**Proof of Concept**	**Preliminary process development**	**Detailed process development**	**Pilot trials**	**Full-scale demonstration**	**Commissioning**	**Production**
Working flow (WF)	general research (literature, existing practices, survey)	Initial practice concept formulation	practice concept validation / economic and or legal assessment	practice development / validation / scale-up preparation	properties and functionality detailing / simulation of practice using bench scale information	practice properties and functionality finalization	testing in relevant working environmental (industrial or retail)	Final practice generation / testing the market acceptance	Full scale practice properly working / final integration of GP into the business culture
Tangible result (TR)	idea / rough concept / vision	effective concept / list of solutions / R&D plan	MVP / proof of concept in laboratory or office	MVP validated / experimental results	detailed practice model found / Beta practice ready	working pilot practice / practice model finalized	optimized pilot practice / sample production or process / finalized and qualified system	full scale practice constructed / initial market test	Practice ready to scale in the market / practice operated over the full expected condition

Results

The outcome of the adapted TRL model allows to assess the readiness level of circular economy GPs, emphasizing differences among practices of different geographies, sectors and areas of application. Figure 1 illustrates the number of GPs labeled in TRL per Italian region. It is evident that Emilia Romagna and Piemonte are the regions with the greatest number of GPs, while Campania and Friuli Venezia Giulia report only one GP per region. By contrast, several Italian regions do not register any GP. At the same time, GPs with the highest TRL (TRL8 and TRL9) are represented by Emilia Romagna, Basilicata and Calabria as well as two GPs at national level. Figure 2 shows a comparison on advancement levels of GPs distinguishing agriculture from Food and Beverage (F&B). In between concept validate and incubation stage, i.e., TRLs 3, 4 and 5, the presence of agriculture GPs is by far greater compared to F&B.

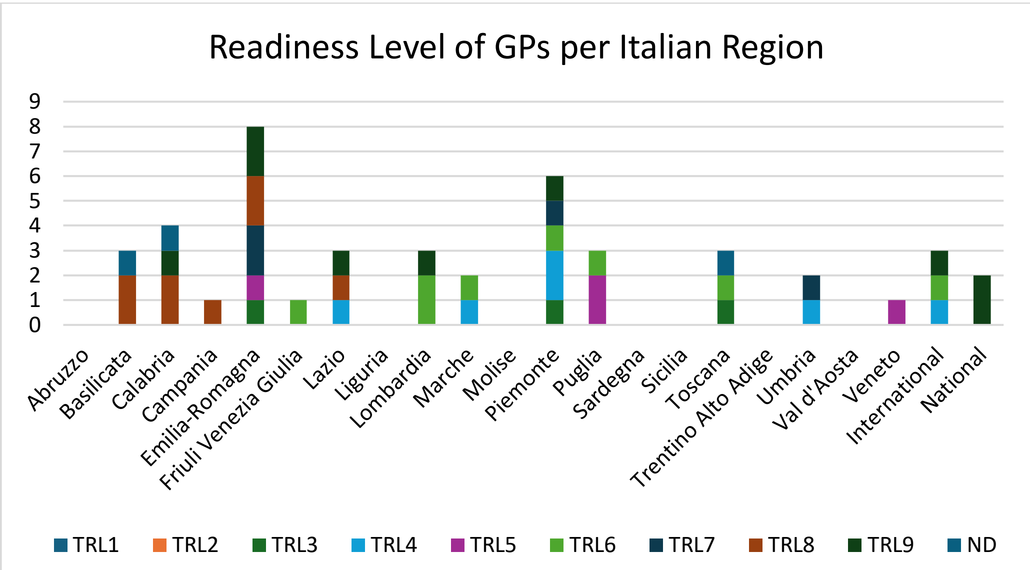

Figure 1. *Readiness Level of ICESP GPs per Italian Region (05/2024). Source: authors' elaboration.*

Within the middle TRL groups, circular economy GPs are equally distributed, i.e., four GPs in TRL6 and two GPs in TRL7. In the initial market introduction phase (i.e., TRL8) there are six F&B good practices against four in the agriculture sector. Finally, GPs in the market expansion phase (TRL9) amount totally to seven with agriculture having one GP more of F&B.

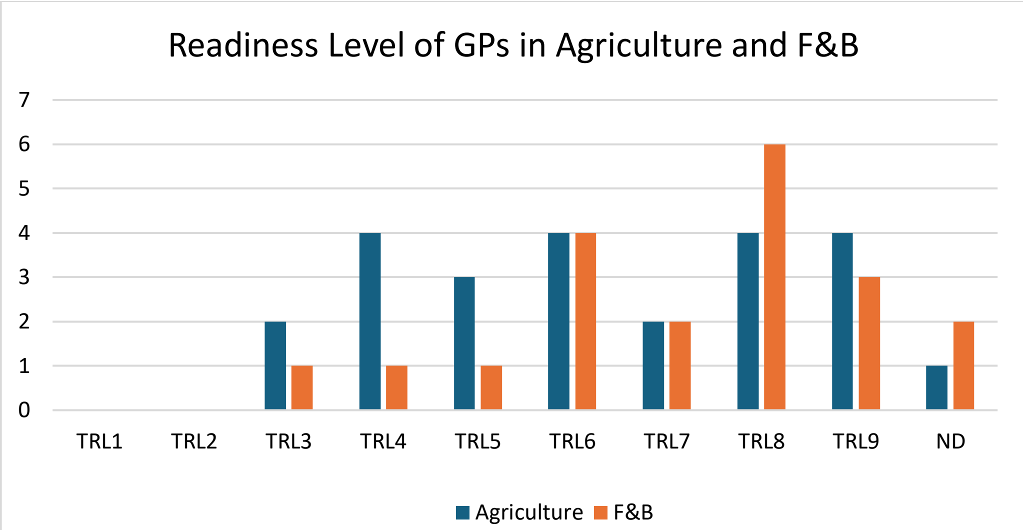

Figure 2. *Readiness Level of ICESP GPs in Agriculture and F&B (05/2024). Source: authors' elaboration.*

Conclusions

The findings of this study highlight the critical importance of adopting sustainability and circular economy (CE) practices within the agri-food sector, particularly in mitigating the effects of crises and contributing to broader environmental and economic goals. By reducing dependency on natural resources and minimizing waste, CE practices not only promote resource efficiency but also bolster organizational resilience against supply chain disruptions and economic fluctuations. This research emphasizes the necessity of developing a robust framework for assessing the readiness and maturity of CE practices (Carmack W. J., et al., 2017), particularly in the context of agri-food businesses, which face unique challenges due to the sector's inherent characteristics. The adaptation of the Technology Readiness Levels (TRLs) model to evaluate the advancement of CE good practices (GPs) presents a novel approach to understanding the progress and potential scalability of these practices. The results indicate significant variation in the TRL stages across different regions and sectors in Italy, with regions like Emilia Romagna and Piemonte leading in the number of advanced GPs. However, the uneven distribution of TRLs and the absence of GPs in certain regions underscore the need for targeted interventions and support to foster CE adoption across the country.

References

1. Carmack W. J., Braase L. A., Wigeland R. A., Todosow M., (2017), Technology readiness levels for advanced nuclear fuels and materials development, Nuclear Engineering and Design, 313, 177-184.
2. European Association of Research and Technology Organizations (EARTO), (2014), TRL Scale as a Research & Innovation Policy Tool, EARTO Recommendations; 2014.

3. Italian Circular Economy Stakeholder Platform, GdL 6, (2022), Analisi della replicabilità delle buone pratiche e quantificazione dell'impatto ambientale, economico e sociale a scala nazionale, 2, 2022.
4. Lopes J., Farinha L., (2019), Industial symbiosis in a circular economy: towards firms' sustainable competitive advantage, In International Journal of Mechatronics and Applied MechanIndustrial. 5. 206-220.
5. Mankins, J. C., Technology Readiness Levels, A White Paper (1995, Edt. 2004); Advanced Concepts Office, Office of Space Access and Technology, NASA: 2004.
6. Kirchherr, J., Reike, D., Hekkert, M., (2017), "Conceptualizing the circular economy: an analysis of 114 definitions". Resour. Conserv. Recycl., 127, 221–232.

In order to establish an ecosystem of preparation for reuse centres in Italy

Alessio Fabrizi[1]*, Luca Pompili[1]

[1]*Research & Development Office, Pomili Demolizioni Speciali Srl, ITALY.*
(E-mail: a.fabrizi@pomilids.it)
*Corresponding author

Abstract

In 2022, 90% of Italians contributed to the reuse of products, with 70% emphasizing the importance of Life Cycle Assessment (LCA) to extend product life and reduce waste ("Fragilitalia" Report, 2023). Directive 2008/98/EC prioritizes waste prevention and management to minimize production impacts and improve resource efficiency. Preparation for Reuse (PfR) is essential in the waste hierarchy, promoted through the establishment of Preparation for Reuse Centres (PfRCs) as per Directive 2018/851/EU. These centers focus on recovery operations and this document examines how to optimize their processes in compliance with regulations, while also facilitating the calculation of benefits. Through an analysis of Decree No. 119/2023 issued by the Italian Ministry of Environment and Energy Security, the authors aim to study the implementation of a digital tool suitable for optimizing processes for PfRC. Digitalizing these processes can improve regulatory compliance and ensure operational certainty, product and waste control, while promoting green jobs.

Keywords**:** *Waste; Reuse; Preparation for reuse (PfR); Preparation for reuse centre (PfRC)Food sensors; electrical impedance*

Introduction

In the current context of increasing awareness about the importance of material recovery and sustainable practices, product reuse and Life Cycle Assessment (LCA) have become critical to reducing waste and extending product lifespans [1, 2, 3]. European legislation, notably Directive 2008/98/EC, emphasizes these practices, aiming to minimize the negative impacts of production and waste management while improving resource efficiency. The "waste hierarchy" places a strong emphasis on preparation for reuse, which includes recovery operations allowing products to be reused without further treatment. In Italy, the establishment of Preparation for Reuse Centres (PfRCs) is a key step towards a circular economy. The Italian Ministry of Environment and Energy Security (MASE)'s Decree No. 119/2023, effective from September 16, 2023 [4], outlines simplified procedures for these centers, enhancing the interception of repairable waste.

Methods

The method is based on the analysis of the text of MASE Decree No. 119/2023 [4], a regulatory innovation for PfR operations in Italy, to develop an optimized workflow through a digital management system and on the use of this software by staff in a warehouse over a two-month period. The underlying premise is that the use of ready-to-use software, with no production costs and lower testing and implementation costs, can enhance the performance of a Preparation for Reuse Center (PfRC), ensuring its economic sustainability and administrative compliance. This would make it a replicable best practice, serving as a foundation for creating a stable ecosystem for the national system.

European Regulatory Context Overview

The Waste Framework Directive 2008/98/EC establishes a legal framework for waste management in the EU, amended by Directive 2018/851/EU [5] to further promote the circular economy and this includes the "waste hierarchy": a principle that prioritizes prevention, preparation for reuse, recycling, energy recovery, and disposal (Figure 1).

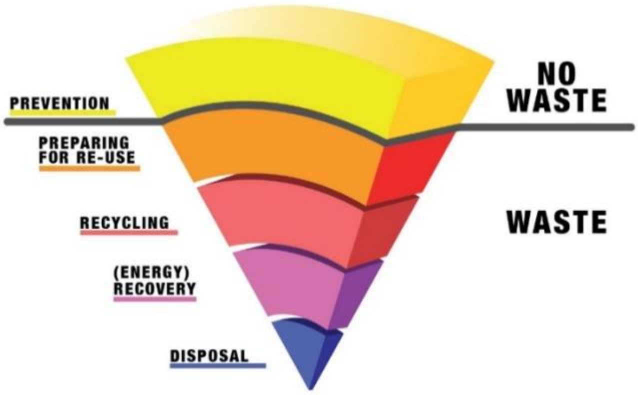

Figure 1. *"Waste hierarchy"*

PfRCs are dedicated to collecting, inspecting, cleaning, and repairing waste products, preparing them for reuse. They play a crucial role in the waste hierarchy, reducing waste, recovering value, promoting the circular economy, creating green jobs, and raising awareness about sustainability.

Go2Life: digital platform for PfRCs

The core idea is the adoption of management software, crafted in compliance with the MASE Decree of July 10, 2023, No. 119. This software, designed for both operational and administrative management, offers a significant opportunity to improve efficiency and ensure the traceability of operations at a PfRC. To achieve this, Pomili Demolizioni Speciali Srl's R&D Office, with Giunko Srl - Terranova Group, developed “Go2Life”: a management software for PfRCs.

Preparation for Reuse Centre Workflow

The authors conducted a thorough text and data analysis of the MASE Decree of July 10, 2023, No. 119. This analysis led to the creation of a workflow divided into three main sections in accordance with the requirements of the PfR Centre's "Schedario" (Record Book) [4]:

A. Delivery and Storage: this section includes protocols for the initial delivery and storage of products and waste.
B. Management: focuses on the ongoing management of products within the centre, excluding Waste Electrical and Electronic Equipment (WEEE) which must follow CENELEC EN 50614:2020 standards [6].
C. Storage and Product Transfer: covers the final storage and transfer of products post-preparation.

Results

The primary outcome of this study is the successful implementation and integration of the "Go2Life" software at the Capena Warehouse. This Pomili Demolizioni Speciali's depot, primarily handling furniture and small equipment, served as the real-world operational center for testing the software. Implemented in June 2024, “Go2Life” has ensured enhanced traceability and operational management. The software seamlessly integrates with other programs enabling efficient workflow management and advanced data analysis through devices like desktop computers, tablets, and smartphones (Figure 2).

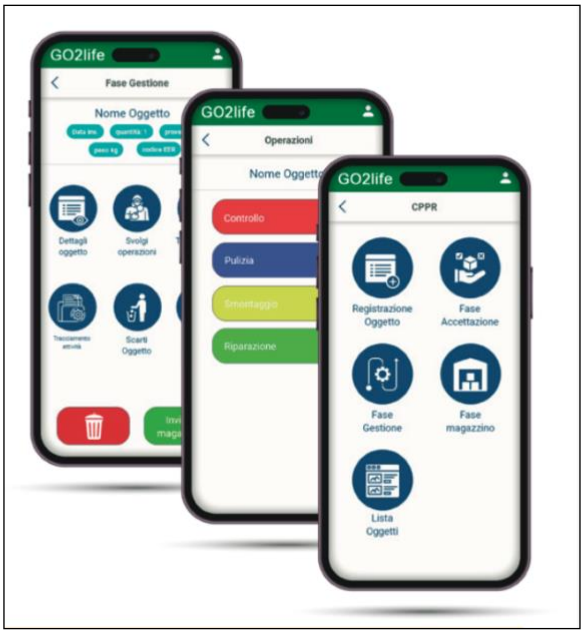

Figure 2. *Go2Life (APP)*

The Capena center facilitated several key operations: inspection, cleaning, possible dismantling, possible repair, and resale of used products. Key findings include process optimization, data analysis, sustainability (increasing the volume of reused products), operational efficiency, traceability, regulatory compliance with the MASE decree and GDPR. Several critical points were identified: the analysis was conducted at a used products warehouse with limited staff; significant time and resources were required for system integration and staff training, which initially reduced productivity; the software implementation incurred costs.

The environmental benefits of a PfRC include reduced emissions, conservation of resources, and decreased landfill pressure. Accurate calculation of these benefits requires interpreting data on CO_2 savings, related to the quantity of processed items and their weight, alongside repair and transportation activities. The initiative yields significant economic, social, and technological benefits. Economically, it facilitates the creation of a market for used and repaired products, reduces waste disposal costs, and generates new employment opportunities. Socially, it promotes a culture of reuse, enhances the quality of life, and fosters more resilient communities. Technologically, it stimulates the development of new repair technologies, driving innovation and competitiveness.

Conclusions

The principles and generalizations inferred from the results highlight the significant advantages of integrating management software like "Go2Life" for operational and administrative management at PfRCs. The study revealed some limitations and challenges. The theoretical implications suggest that the digitalization of PfRC processes can profoundly impact waste management, supporting sustainability goals and promoting circular economy practices. Practically, the software facilitates improved waste management, regulatory compliance, and efficient resource use. Conclusions drawn and recommendations include:

1. Principles and generalizations: PfRCs are essential for promoting reuse and sustainability, contributing to waste reduction and resource conservation.
2. Exceptions and problems: challenges include staff training, system integration, and initial costs.
3. Theoretical and practical implications: emphasize the importance of digital tools in enhancing waste management practices and regulatory compliance.
4. Conclusions and recommendations: advocate for the widespread adoption of management software at PfRCs to optimize processes, ensure compliance, and promote a circular economy. Collaboration among institutions, businesses, and communities is crucial for creating a sustainable PfRC ecosystem.

References

1. E. Risso, B. Toci (2023), Fragilitalia, Area Studi Legacoop, Game Changers Ipsos Inflazione e consumi, luglio 2023.
2. OECD (2024), Monitoring Progress towards a Resource-Efficient and Circular Economy, OECD Publishing, Paris.
3. 6° Rapporto sull'Economıa Cırcolare in Italıa (2024), Circular Economy Network e Fondazione Sviluppo Sostenibile, ENEA, Consorzio CETMA, CNA.
4. Italian Ministry of Environment and Energy Security - Mınıstero dell'Ambıente e della Sıcurezza Energetıca - MASE (2023), DECRETO 10 luglio 2023 n. 119, Regolamento recante determinazione delle condizioni per l'eserciziodelle preparazioni per il riutilizzo in forma semplificata, ai sensidell'articolo 214-ter del decreto legislativo 3 aprile 2006, n. 152.(23G00126) Vigente al: 16-9-2023, (Gazzetta Ufficiale n.204 del 1-9-2023).
5. Dırectıve (EU) 2018/851 of the European Parlıament and of the Councıl of 30 May 2018 amending Directive 2008/98/EC on waste.
6. Dırectıve (EU) 2012/19 of the European Parlıament and of the Councıl of 4 July 2012 on waste electrical and electronic equipment (WEEE), Annex I, Annex III.

Evaluating circularity and economic feasibility in organic waste management: a case study of a sicilian composting plant

Salvatore Ingenito[1]*, Massimo Riccardo Costanzo[1], Agata Matarazzo[1], Luisa Sturiale[2], Giuseppe Guagliardi[3], Angelo Lapiana[3]

[1] *Department of Economics and Business, University of Catania, Italy.*
[2]*Department of Civil Engineering and Architecture, University of Catania, Italy.*
[3]*Progitec Srl, Italy.*
(E-mail: salvatore.ingenito@unict.it)
*Corresponding author

Abstract

The surge in global population has heightened demand for food production and created complex waste management challenges. Composting offers a sustainable pathway to convert organic waste into agricultural fertilizers, supporting a circular economy. This study evaluates the performance of a Sicilian composting plant using the UNI/TS 11820:2022 framework to measure its Level of Circularity (LC), achieving 65.5% in 2023. Key strengths include waste and emissions management (96%) and resource efficiency (70.17%), but significant gaps remain in energy and water use (38.8%). Economic challenges stem from high disposal costs and limited revenue from compost sales. Recommendations include leveraging high circularity levels to access premium markets and integrating advanced composting technologies to boost financial performance. These findings underscore the role of circular economy strategies in transforming organic waste management into an economically viable, sustainable model.

Keywords: *Composting plant; Circular economy; Organic fertilizer; Sustainability; Economic feasibility.*

Introduction

The exponential growth of the global population has triggered an urgent need for sustainable solutions in agriculture and waste management. While chemical fertilizers have historically driven increased agricultural yields, their widespread use has raised concerns about soil health, environmental degradation, and resource sustainability. Concurrently, solid waste generation has surged, necessitating innovative approaches to resource recovery.

Composting has emerged as a pivotal strategy in addressing these dual challenges, converting organic waste into valuable fertilizers while reducing environmental impact. Circular economy principles underpin this approach, emphasizing resource optimization, waste reduction, and regenerative practices. This study investigates the operational and economic dimensions of a composting plant in Sicily, focusing on its Level of Circularity

(LC) as a metric for sustainability and exploring strategies to enhance its financial and environmental performance.

Methodology

Data Collection

A structured data acquisition process was implemented to assess the composting plant's circularity. Primary data were collected through direct interviews with management and workers, complemented by on-site inspections and sustainability reports. The interview design included detailed inquiries into material inputs, outputs, energy use, logistics, and waste management practices. Data validation involved cross-referencing responses with documented records and conducting follow-up interviews for clarity.

Circularity Assessment Framework

The UNI/TS 11820:2022 framework, a robust tool for measuring organizational circularity, was employed to analyze the plant's performance. This framework incorporates 71 Environmental, Social, and Governance (ESG) indicators across six categories: material resources, energy and water, waste and emissions, logistics, products and services, and human resources. Table 1 reports the 35 parameters out of the whole set of them computed to obtain the final level of circularity.

Table 1. Circularity indicators computed

Category	Type	Numerator definition	Denominator definition
Energy and water resources	Ps	Self produced electricity from ren. res. or recovery	Total electricity consumed
	Ps	Purchased electricity from ren. res.	Total electricity purchased
	Ps	Inbound water from reuse and recycling	Total water need
Material resources and components	Ps	Inbound raw materials and secondary res. from local suppliers	Total inboud raw material and secondary resources
	Ps	Inbound material res. equipped with tracking systems	Total inboud material res. equipped with tracking systems
	Pc	Inbound by products and(or) secondary res.	Total inbound material res.
	Pc	Renewable of recycled res, for packaging	Total packaging used
	Ps	Total restricted or authorised substances	Total inboud material res.
	Pc	(Inbound resources – Residues produced)	Total residues produces
Waste and emissions	Pc	Urban and(or)special waste sent to landfills	Total urban and(or)special waste generated
	Pc	Municipal and(or)special waste collected separately	Total urban and(or)special waste generated
	Ps	Has the organization carried out the assessment of its carbon footprint according to UNI EN ISO 14064 in year n and/or n-1 and/or n-2?	
Logistics	Ps	Waste treated at local valorisation plants	Total waste treated at valorisation plants (local or not)
	Ps	Actual load capacity used by vehicles (round trip)	Total capacity of the vehicles
	Ps	Number of employees adhering to sustainable mobility	Total employees
Products and/or services	Pr	Outbound resources with a tracking system	Total outbound resources
	Ps	Are there present systems of resource accounting/auditing?	
	Ps	Quantity of products generated	Quantity of resources employed

	Ps	Value of products and services from local suppliers	Total value of products and services
	Ps	Has the organization made investments in the circular design of its products and/or services in years n and/or n-1 and/or n-2?	
	Ps	Has the organization made investments in circular design of its processes in years n and/or n-1 and/or n-2?	
	Ps	Has the organization made investments in circular design of its assets in years n and/or n-1 and/or n-2?	
	Ps	Investment in R&D linkes to the circular economy	Total investment in R&D
	Ps	Inboud water resources from industrial symbiosis	Total inbound water resources
	Ps	Outbound water res. valorized with industrial symbiosis	Total outbound water resources
	Ps	Inboud energy resources from industrial symbiosis	Total energy water resources
	Ps	Outbound energy res. valorized with industrial symbiosis	Total outbound energy resources
Human resources, assets, policy and sustainability	Ps	Has the organization already carried out staff training on the circular economy in the current year and in the two years before?	
	Pc	Which is the average energy performance index of buildings for civil use of the organization? Class A = 100%; Class B-C = 50%; Class D-F = 25%; Class G = 0%.	
	Pc	Has the organization developed and implemented a circular economy strategy?	
	Ps	Does the organization carry out external communication of its sustainability and circularity performance (through sustainability reports, non-financial statements, etc.)?	
	Ps	Has the organization planned to carry out internal staff information and training activities on the circular economy?	
	Ps	Has the organization carried out external training and information plans on the circular economy aimed at stakeholders?	
	Pr	Does the organization have an energy efficiency plan?	
	Ps	Does the organization adopt an Environmental Management system?	

Source: authors' elaboration from UNI/TS 11820:2022.

Indicators are classified as core, specific, or rewarding, with scores aggregated using a weighted function (1) to calculate the LC.

$$LC = \frac{\sum I_c + \sum I_s + 50\% \sum I_r}{nI_c + nI_s} \qquad (1)$$

The final score provides a comprehensive measure of the plant's alignment with circular economy principles.

Results

The plant achieved an overall LC of 65.5%, a commendable result that reflects significant progress in integrating circular practices. Key strengths were observed in waste and emissions management (96%), driven by efficient waste separation and minimal landfill dependency. Material resources also performed well (70.17%), underscoring effective utilization of local inputs and resource recovery processes.

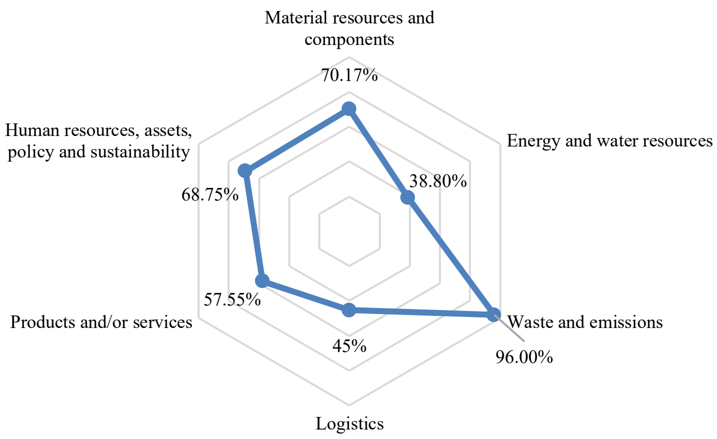

Figure 1. Radar chart on the level of circularity (authors' elaboration)

However, energy and water resource circularity lagged behind at 38.8%, highlighting inefficiencies in renewable energy sourcing and water recycling. The findings emphasize the need for targeted interventions to enhance energy sustainability, such as adopting renewable energy solutions and optimizing water reuse systems.

Economic analysis revealed a dual revenue model: fees from waste collection and sales of biological compost. Municipalities pay the plant €30-130 per ton for waste disposal, depending on the waste type, providing a steady income stream. However, compost sales, at just €0.10 per ton, contribute minimally to revenue due to market limitations and insufficient storage capacity.

High operational costs, particularly for residue disposal, further strain financial viability. Percolate disposal costs €70 per ton, while sovvallo incurs €160 per ton, significantly impacting profitability. Strategies to mitigate these challenges include exploring premium markets for compost and investing in advanced waste processing technologies to reduce disposal expenses.

Discussion and Conclusion

The plant's LC score of 65.5% is not only a regulatory achievement but also a strategic asset. High circularity levels can serve as a compelling value proposition, appealing to environmentally conscious consumers and enabling premium pricing for compost products. Marketing campaigns emphasizing the plant's waste and emissions management efficiency (96%) and material resource circularity (70.17%) can enhance its competitive positioning.

To fully capitalize on its circularity, the plant must address gaps in energy and water resource efficiency. Renewable energy adoption and advanced water management practices could elevate the LC, enhancing both environmental performance and market appeal.

The disparity between high residue disposal costs and low compost revenue underscores the need for strategic adjustments. Expanding market channels, introducing co-composting technologies, and leveraging circularity metrics as a marketing tool are critical to improving profitability. Furthermore, integrating cross-sector collaborations, such as partnerships with agricultural stakeholders, can foster innovation and reduce operational barriers.

This study highlights the potential of circular economy principles to transform organic waste management into a sustainable and profitable venture. The Sicilian composting plant's LC of 65.5% reflects a commendable alignment with sustainability goals, though challenges remain in energy efficiency and economic viability.

Addressing these gaps will require both technological advancements and strategic market positioning. Leveraging high circularity as a competitive advantage, the plant can attract premium markets and foster consumer trust. By continuously improving its metrics and communicating achievements transparently, the plant is well-positioned to lead in the transition toward a circular economy.

References

1. UNI/TS 11820:2022 (2022). Misurazione della circolarità, Metodi ed indicatori per la misurazione dei processi circolari nelle organizzazioni.
2. Ofei-Quartey M. H. L., Appiah-Efah E., Akodwaa-Boadi K., Ampaw B., Taylor T. S. and Millogo N. Z. E. (2023). Enhancing the economic potential of organic waste by co-composting using ratio modelling toward a circular economy Journal of Material Cycles and Waste Management, 25, 1560–1580.
3. Breitenmoser L., Gross T., Huesch R., Rau J., Dhar H., Kumar S., Hugi C., Wintgens T., (2019). Anaerobic digestion of biowastes in India: Opportunities, challenges and research needs, J. Environ. Manage, 236, 396–412.
4. Velenturf A.P., Purnell P. (2021). Principles for a sustainable circular economy, Sustain. Prod. Consum, 27, 1437–1457.
5. Ellen MacArthur Foundation (2022). What is circular economy? https://ellenmacarthurfoundation.org.

SE.LI.F. Second life furniture

Michela Reale[1*], Tamara Pellegrini[1], Moreno Rotondi[2], Nicola Bartucca[2]

[1]*Rinnovative Srl Women and Youth Startup, Ferentıno (FR) Italy*
[2]*CARTONECO RETE DI IMPRESE SOGGETTO, Ferentıno (FR) Italy*
(E-mail: micreale5@gmail.com)
*Corresponding author

Abstract

The objective of the SE.LI.F. project is to reuse industrial residues from cutting and milling MDF and chipboard panels, such as powders and shavings classified as "by-products", to make new items. The by-products are transformed with a method using direct molding technology, either alone or mixed with other polymers also sourced from industrial residues, without the use of adhesives but only through the action of pressure and heat. The expected result is, in addition to the creation of eco-products, the demonstration of a virtuous circular economy cycle that is scalable and replicable in all companies that use using MDF and chipboard, which can apply an alternative solution to the costly disposal of their industrial residues.

keywords: *Circular economy; Direct Molding; By-product; Recycling; Medium-Density Fiber board.*

Introduction

Chipboard and Medium-Density Fiberboard (MDF) panels are made from wood fibers that are pressed together with resin or glue at high temperatures and later ennobled with melamine paper covering to impart different colors and finishes. Chipboard and MDF production is steadily increasing today, fueled by the growing demand for furniture and wood products. MDF is a composite material widely used in the furniture and construction industries thanks to its versatility, dimensional stability and workability. However, the increasing production of MDF poses a significant waste management challenge, as it contains thermosetting resins that complicate its recycling. This project explores techniques and prospects for recycling MDF and chipboard powders (Fig. 1a), with a focus on thermosetting polymers as key components. MDF mainly consists of wood fibers (about 82-85%), derived from FSC® certified wood waste or plantations, mixed with thermosetting resins (8-10%), usually urea-formaldehyde (UF) or melamine-formaldehyde, used as binders. Chemical additives (2-3%) are additionally present to improve physical characteristics and strength. Thermosetting polymers give MDF mechanical strength and stability, but they are also responsible for making its recycling complex, as they cannot be easily remolded or remelted after hardening. Recent research into ınnovative recycling technologies has concentrated on techniques for recovering the wood fibers and, in some cases, the thermosetting polymers. Some of the current strategies include chemical decomposition, thermal hydrolysis, and the use of chemical agents, for example acid or alkaline solutions, to break the bonds between the wood fibers and thermosetting resins. This technique allows recovering high-quality wood fibers, but requires treating the resulting chemical waste. Furthermore, there is the possibility of using specific enzymes to degrade the thermosetting resins without damaging the wood fibers. The development of a new technology identified in the SE.LI.F. project involves a recycling process with powder molding through the sole use of pressure and heat. This innovative industrial process is called direct molding and can be separated into three stages: pulverization, molding, and secondary processing. The pre-prototypes made (e.g., Fig. 1b) have led to optimistic prospects and an expansion of possible combinations with other by-product polymers.

Methods

The equipment used for making pre-prototypes included a press with heated plates and a mold able to contain the MDF and chipboard powders, while the working method already broadly identified needs to be improved with the collection of data on the variables applied, followed by their connection with the results of the panel made.

Figure 1a. MDF and Chipboard Powder; **Figure 1b.** Pre-Prototype Panel

Figure 2. Recycling

Results

Direct molding can be separated into three stages: pulverization, molding, and secondary processing. In our case, the mechanical pulverization process has already been carried out, as the process begins with micronized MDF and chipboard powders. Broken bonds are formed with the pulverization on the outer surface of the individual produced particles: when the powder particles are brought to a high temperature, molecular mobility allows the various particles to form new bonds. The combined application of pressure increases the contact between the particles and makes the generation of new bonds more likely. Powder molding with high pressure acts on the thermoset material which, having passed into the rubbery state due to temperature, better adapts to the shape of the mold and can ensure moldability, benefiting possible applications. Many goals must be reached in order to effectively fine-tune this single molding stage. First, the process conditions depend on the individual material and each powder. The material must be heated to allow it to transition to the rubbery state and chemically activate it, and the two phenomena are closely linked. In practice, cross-linking kinetics intersect with typical molecular mobility mechanisms, and the result of this interaction is far from scientifically clear. The need for the combined application of pressure and heat in order to consolidate the materials easily allows creating massive shapes, sometimes even with complex geometric details. However, it is very difficult to make shapes with very large variations in cross section or with through cavities. The powder can move to a significant extent during molding and combined with the fact that the powder itself does not flow easily, it is very difficult for more winding areas of the mold to be filled effectively. Poor filling then also results in poor pressure transfer and, therefore, poor consolidation. An in-depth analysis of how to overcome the problem at hand allowed identifying splicing, or more precisely gluing, as a useful approach to a solution. Secondary processing is being studied, and in the case of cutting/sectioning, the experience gained leads us to believe that any problems which may arise can be overcome by identifying the best variables in terms of rotational speed, feed rate and tool type, while it seems varnishing and/or ennobling practices have yet to be explored.

Discussion/Conclusion

The identified technology is still in the experimental phase and must be optimized for industrial scalability. The initial results obtained with the pre-prototypes (Fig. 2) pave the way for further insights, which may find high value-added industrial applications. Challenges in recycling MDF powders include difficulty separating the thermosetting resins chemically bound to the wood fibers, making it difficult to recover them without degrading the fibers themselves. During disposal or recycling processes, harmful volatile organic compounds (VOCs) can also be released due to formaldehyde emissions. Recycling MDF and chipboard powders significantly reduces the volumes sent to landfills: this leads to less exploitation of resources, as the demand for wood dramatically decreases. The use of by-products to make new products reduces greenhouse gas emissions, as the pre-existing energy content is not destroyed.

Reference

1. Quadrini F, Bellisario D, Iorio L, Proietti A, Regi M, Santo L. Recycling of Powders from Cutting of Medium Density Fiberboard, Key Engineering Materials, 2022, Vol. 926, pp 1719-1724.

Agenzia per la Coesione Territoriale

Amici della Terra

ASM Rieti

Assocarta

ART-ER

Camera di Commercio del Molise

Catalyst

Centro Tessile Cotoniero-Centrocot

Confindustria

Consiglio Nazionale delle Ricerche

Consorzio CAPAS

Consorzio Dragona

Consorzio LEAP

DINTEC

Ecoinnovazione

ENEA

EnergoClub

Eurac Research

Fondazione Cluster Marche

Federacciai

Lazio Innova – Regione Lazio

Ministero dell'Ambiente e della Sicurezza Energetica

Ministero delle Imprese e del Made in Italy

Novamont

Politecnico Bari

Politecnico di Milano

Sistene Esco

Sviluppumbria

Università di Bari

Università di Bologna - DICAM

Università di Brescia

Università di Catania

Università di Messina

Università di Milano Bicocca

Università di Modena e Reggio Emilia - En&Tech

Università di Pescara “G. D’Annunzio”

Sapienza Università di Roma

Università di Roma Tre - DISA

Università della Tuscia - DEIM

CRF Organismo di Ricerca

RESILCO – Resilience Company for Climate change

Lorena Alessio Architetti

ENEA - Promotion and Communication Service

enea.it

Printed in June 2025 at the ENEA Technographic Laboratory – Frascati

Symbiosis Users Network – SUN

ISBN: 978-88-8286-525-2

www.enea.it