JUNE 4, 2025

#EU GREEN WEEK

EU Green Week Partner Event

Systemic Approaches to Low Carbon Food Production: A Symbiosis-Based Assessment

Emel Yontar[1]*

[1] Tarsus University – Faculty of Engineering, Industrial Engineering Department Tarsus, Mersin, Türkiye

* e-mail: eyontar@tarsus.edu.tr

THE WATER-ENERGY-FOOD NEXUS: BUILDING RESILIENCE TO GLOBAL CHALLENGES

NexusNet

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

CONTENTS

MAIN AIM

This study explores the potential of industrial symbiosis (IS) as a transformative framework to redesign food production and distribution processes through cross-sectoral collaboration, waste valorization, and circular resource flows. This determines which industrial symbiosis scenarios should be prioritized when targeting low carbon.

FOOD SYSTEMS

The Impact of Food Systems on Climate Change

21-37% of global greenhouse gas emissions come from food systems

Non-production stages of food (processing, transportation, packaging, retail and consumption) can account for 30-40% of total system emissions.

1/3 food loss in supply chain-3.3 billion tons of carbon dioxide

11% of global greenhouse gas emissions come from land use changes

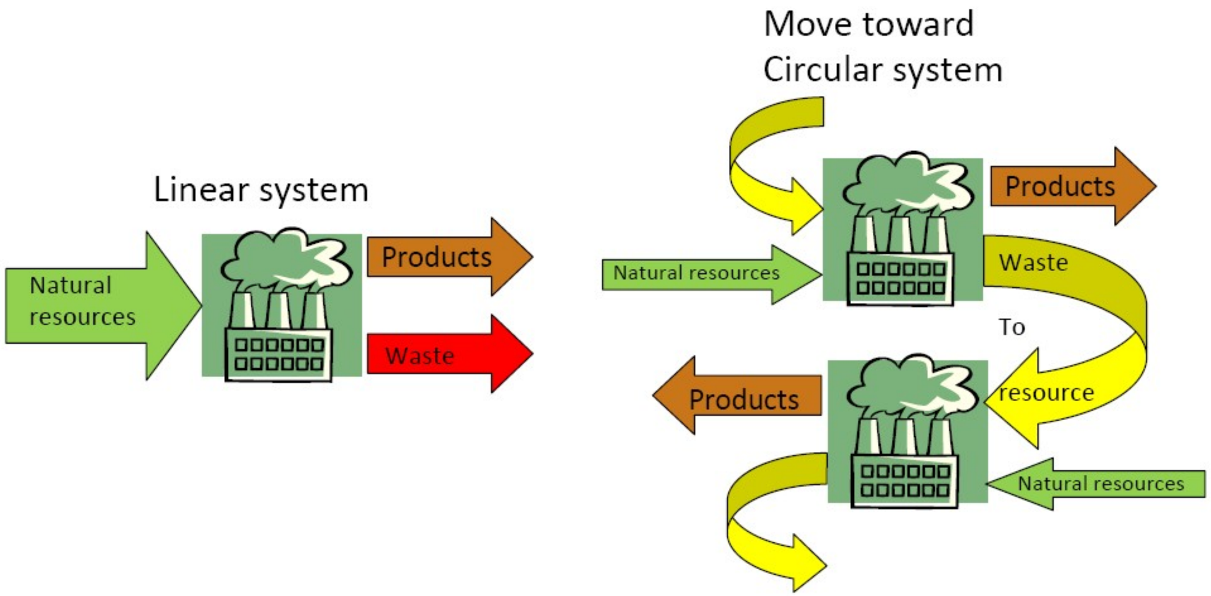
INTRODUCTION

In line with these explanations, it is urgent to find solutions that can provide ways to reduce carbon dioxide emissions, which are largely responsible for greenhouse gases, and to use resources more efficiently.

The study aims to uncover innovative pathways towards carbon reduction and long-term resilience through symbiotic configurations that link sustainability principles across agriculture, food processing, waste management and renewable energy systems.

A multi-criteria decision-making approach which is Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) is adopted to evaluate alternative strategies that align with environmental, economic, social, and regulatory goals.

INDUSTRIAL SYMBIOSIS



Industrial symbiosis is the use of the output of one industry/business as the input of another business/industry.

#EUGREENWEEK

RESEARCH QUESTIONS

RQ1: How can sustainable industrial symbiosis scenarios that can be implemented in the food sector be structured and evaluated in terms of low carbon emissions?

RQ2: Which of the industrial symbiosis scenarios for food should be addressed first in the low-carbon target?

Application of Industrial Symbiosis in Food Systems

Food Waste to Biogas in Denmark
Food manufacturers send organic waste to anaerobic digestion plants, which produce biogas used by local industries and district heating systems (Chertow, 2007).

Brewery Waste for Mushroom Cultivation – UK
Spent grains from breweries (a by-product) are used as a growth substrate for mushroom farming (Papargyropoulou, et al. 2014).

Aquaponics: Integrating Fish Farming and Hydroponics
Nutrient-rich wastewater from fish tanks is used to fertilize vegetables in hydroponic systems (Goddek, et al. 2015)

Dairy Industry Wastewater for Algae Cultivation – Italy
Dairy wastewater is used as a growth medium for microalgae, which are later processed into animal feed or biofertilizer (Uggetti, et al. 2014).

Industrial Symbiosis in Sugarcane Industry – Brazil
Residues from sugarcane processing (bagasse and vinasse) are used: For bioenergy generation and as fertilizer on sugarcane fields (Souza, et al. 2016).

Bakery Waste into Animal Feed – Turkey
Unsold bread and baked goods are collected and processed into animal feed for livestock producers (Kurtulmuş, and Atalık, 2020).

The processing and reuse of meat waste was ensured among 13 companies and 36 production/service facilities within the Polish agri-food consortium (Kowalski, et al. 2023).

Waste from Italian olive oil production (e.g. olive pulp) has been used in other industries for energy production or animal feed (Stempfle et al. 2024).

METHODOLOGY

MARCOS (Measurement of Alternatives and Ranking According to Compromise Solution) is a Multi-Criteria Decision Making (MCDM) method developed by Stević and colleagues in 2020. The method allows alternatives to be ranked according to their relative attractiveness by comparing them with ideal (best) and anti-ideal (worst) solutions.

Step	Description
1. Construct the initial decision matrix	List the performance values of each alternative (Ai) against each criterion (Cj).
2. Add ideal and anti-ideal solutions	Include an ideal (best) and anti-ideal (worst) solution as reference alternatives.
3. Normalize the decision matrix	Normalize values depending on benefit or cost criteria.
4. Calculate the weighted normalized matrix	Multiply each normalized value by its corresponding criterion weight.
5. Calculate utility degree (S) of each alternative	Sum the weighted normalized values for each alternative (including ideal and anti-ideal).
6. Determine the utility function	Compare each alternative with the ideal solution.
7. Calculate the relative utility	Determine the usefulness compared to both ideal and anti-ideal.
8. Rank the alternatives	Rank all alternatives based on f values. Higher value = better rank.

SCENERIOS FOR FOOD SYSTEMS

- **S1: Use of waste heat from food processing plants in greenhouse farming**
- **S2: Use of organic food waste in biogas plants**
- **S3: Use of food production by-products (pulp, bran, etc.) as animal feed**
- **S4: Sharing packaging waste with local recycling cooperatives**
- **S5: Food companies' wastewater utilization in agricultural irrigation (pre-treated)**
- **S6: Donating excess produce in the food supply chain to food banks**
- **S7: Shared use of agricultural machinery by time-sharing among farmers**
- **S8: Use of solar-powered micro-cooling centers in the cold chain**

#EUGREENWEEK

CRITERIA AS LOW-CARBON FOCUS

C1: Carbon Reduction Potential
C2: Economic Viability
C3: Technical Viability
C4: Social Acceptance and Impact
C5: Level of Circularity
C6: Resource and Energy Efficiency
C7: Employment and Contribution to Local Economy
C8: Legislative Compliance and Legal Convenience
C9: Implementation Time and Ease
C10: Multi-Stakeholder Collaboration Potential

RESULTS AND FINDINGS

	Closeness to ideal	Distance to anti-ideal
S1	1.447	2.847
S2	1.669	3.285
S3	1.770	3.484
S4	1.727	3.398
S5	1.348	2.653
S6	1.776	3.494
S7	1.448	2.849
S8	1.588	3.124

RESULTS AND FINDINGS

FINAL SCENERIOS

1. Donating excess produce in the food supply chain to food banks
2. Use of food production by-products (pulp, bran, etc.) as animal feed
3. Sharing packaging waste with local recycling cooperatives
4. Use of organic food waste in biogas plants
5. Use of solar-powered micro-cooling centers in the cold chain
6. Shared use of agricultural machinery by time-sharing among farmers
7. Use of waste heat from food processing plants in greenhouse farming
8. Food companies' wastewater utilization in agricultural irrigation

IMPLICATIONS

S6: Donating excess produce in the food supply chain to food banks: Reduces food waste and supports food security for vulnerable populations

S3: Use of food production by-products (pulp, bran, etc.) as animal feed: Promotes circular economy by valorizing by-products and minimizing waste

S4: Sharing packaging waste with local recycling cooperatives: Encourages community engagement and awareness on sustainable waste management

S2: Use of organic food waste in biogas plants: Generates renewable energy and reduces reliance on fossil fuels

IMPLICATIONS

S8: Use of solar-powered micro-cooling centers in the cold chain: Decreases energy consumption and carbon emissions in food storage and transport

S7: Shared use of agricultural machinery by time-sharing among farmers: Reduces capital costs and increases machinery utilization efficiency

S1: Use of waste heat from food processing plants in greenhouse farming: Enhances energy efficiency by recovering and reusing waste heat

S5: Food companies' wastewater utilization in agricultural irrigation: Promotes water reuse and reduces freshwater consumption in agriculture

CONCLUSIONS

- Different practices, from donating surplus products to using organic waste for biogas production, contribute to both reducing environmental impacts and increasing social benefits.
- In addition, innovative approaches such as renewable energy use and resource sharing increase the efficiency and resilience of the supply chain, while also providing economic savings.
- In this context, the implementation of the proposed scenarios is critical for both environmental sustainability and social benefits.

THANK YOU FOR YOUR TIME

e-mail: eyontar@tarsus.edu.tr