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Circular Economy for Food: A Systemic Interpretation of 40 Case Histories in the Food System in Their Relationships with SDGs †

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Abstract: While the Circular Economy is widely championed by academics, companies, and politicians, its implementation is still an open issue. Its applications reveal a split between theory and practice. This break makes it difficult to pinpoint how coherent practices are with the original concept and how to understand the purpose of the actions and assess the results' effectiveness. This is immediate when we consider the complexity of food. This paper aims to provide further insight on the applications and spill over of the circular economy into the food system. Through the systemic analysis of case histories, the research evaluates the effects of 40 circular economy actions in their relationship with Sustainable Development Goals, by assessing how they have been able to integrate and balance the economic, social, and environmentally sustainable development's dimensions into the food system. What emerges is that food can be a fertile ground for the implementation of a circular economy's principle and could also provide support in understanding its evolution and adjusting its objectives accordingly. Food is strategic and could be a perfect field for testing a new approach to raw material and waste and for the development of a new context of inquiry, defined as "Circular Economy for Food".

Keywords: circular economy; food system; sustainability; SDGs; system thinking; Agenda 2030

1. Introduction: Food in the Circular Economy

1.1. The Roots of the Circular Economy in the Dynamics of the Food System

The circular economy is a new production and consumption model based on interconnection. This paradigm has evolved and has been affected by different lines of inquiry, systematizing them, and partially readapting them to current challenges, developing a new perspective of circularity applied to the economy [1,2]. At the same time, it is a political–cultural proposal that can be seen as circular in that it is the antithesis of the linear model of "produce, consume, dispose". It requires a different design, new technologies, and production processes, as well as much more radical changes in culture and social relationships [3–6]. However, its origins go back even further, and for some time now, they have been expressed and can be retraced in the dynamics of the food system. They can be found, for example, in "farming bricolage" [7] in peasant societies, where every part of an edible product

is given value by creatively reinventing it in the following day's meal [8]. This is an expression of a domestic economy marked by circularity. It is knowledge that was initially considered part of domestic resource management and then transferred "as part of the knowledge that concerns the economy of nature" [9], in order to emphasize the need to respect natural cycles and timing [10]. Circularity returns in the subsequent flourishing of research into ecological community analysis, which resulted in the recognition of the food chain [11], material and energy flows between the components (nodes) of an ecosystem, where through the logic of "who eats who" has been possible to synthesize the complex interactions between communities of animals and plants effectively [12].

Furthermore, we can understand how these metabolic connections are the basis of a circular process of autopoiesis, that is, the redefinition and constant self-production of the system and of its actors, from a naturally evolutionary point of view [13]. The management of food as such, in our homes and in ecosystems, has been crucial for a growing awareness of the interdependencies between connected ecological webs [14], also through the evolution of "systemic thought" and the "open system" concept from the work of the biologist Von Bertalanffy [15].

Taking inspiration from the dynamics of natural ecosystems, the concept of "industrial metabolism" was born, in which waste, through closed circular processes, becomes a resource for new production cycles [16]. Hence the foundation of "industrial ecology" [17] that, by analogy with natural systems, also adopts a vision of "industrial symbiosis", which in this case extends beyond the limits of industrial systems to include ecological systems [18] and social welfare.

These beginnings demonstrate how the circular economy is the result of the development of scientific and cultural content that revolves around a constructive dialogue between humans and nature, where food, by representing a fundamental point of interconnection, incorporates and interprets circular economy principles well. For all these reasons, circular thought, and the economy derived from it, finds its origins and conceptual development in the complexity of food system dynamics, using food as a vehicle of meaning. It is no coincidence that the slogan "Waste is food" is used constantly, which immediately brings us back to the principles of natural cycles and the food web, as well as farming knowledge.

1.2. Circular Economy to Face the Actual Food System Challenges

While circularity has always been a conceptual category appropriated for the description and analysis of the food system, now more than ever, it seems necessary to reflect and propose this pair again. From being a category belonging to many schools of thought, circularity is now gradually passing from the theoretical/positive level to a normative/regulatory level. The theoretical framework summarized above has now gained the strength to be proposed globally as a new political perspective. Today, the circular economy can take shape and settle into a new model of production and consumption based on relationship between parts that can be applied into the food system (starting from the agriculture and agro-industrial production to the post-consumption) close to the other key area of implementation such as plastic, mining, construction, and public procurement, identified transversally from an analysis of European and international experience.

The methods of linear management that have characterized the food system for the last 50 years have been the cause of environmental deterioration, have contributed to the impoverishment of natural capital and produced pollution from the field to the stomach.

Negative externalities can be found both upstream of the food system, a situation where humanity is turning out to be, year after year, a voracious being, taking resources from ecosystems and inserting factors into natural cycles that destabilize its balances [19]. Food production is one of the main causes of biodiversity loss worldwide, because of its impact on natural habitats and the overexploitation of certain species [20–22]. Food and Agriculture Organisation estimates that 75% of agricultural crop varieties have been lost and that three-quarters of the world's food depends on just 12 plant species and five animal species [23]. Industrial agriculture, based on intensive production, monocultures, a limited number of plant and animal species and external synthetic inputs (such as fertilizers and pesticides),

takes up roughly 34% of the total surface of the planet and about half its inhabitable surface [24]. It is estimated that agricultural production is the cause of 69% of water usage and because of this, by 2030, roughly 3 million people will not have easy access to drinkable water [25]. Alongside the other actors in the food system, agricultural production is responsible for about 30% of greenhouse gas emissions [26,27]. Of the 1.5 billion hectares of cultivated land worldwide, one-third is used to produce animal feed while another 3.4 billion hectares are used for grazing. However, animal products represent just 17% of the calories and 33% of the protein consumed by human beings worldwide [24,27].

This is also true downstream, where Food Losses and Waste are one-third of what we produce—four times the quantity necessary to feed the 795 million people that suffer from hunger today [28].

As part of this productive framework, every year, 1 billion and 300 million tones of food meant for human consumption are wasted [29]. That is enough to fill about 8600 cruise ships [30]. This food loss and waste occurs throughout the production chain: 32% during agricultural production, 22% in the stages immediately following harvest, 11% during industrial transformation, 13% during distribution and finally, and 22% at home or in places of food service [31].

In terms of environmental impact, this means wasting about 250,000 billion liters of water each year (enough to satisfy the domestic consumption of a city like New York for 120 years), wasting 1.4 billion hectares of farmland (roughly 30% of agricultural land worldwide) and at the same time causing, without any benefit, the release into the atmosphere of about 3.3 billion tons of CO_2 equivalent [31].

The economic value of wasted food worldwide, together with the estimation of costs to the environment and society, is 2600 billion dollars a year [32]. It is clear that we are experiencing a real "crisis of reason" [33] when we note that we would need about 267 billion dollars a year to eliminate hunger in the world by 2030: More or less 0.3% of the global GDP [34]. Along with issues of economics and environment, we must consider the wellbeing of the community and our health, jeopardized by a logic of quantity that reduces the quality of what we eat. The risk of death by diseases linked to poor nutrition has surpassed the risk of death by diseases caused by an insufficient calorie intake. While 795 million people suffer from hunger, about 1.5 billion people are obese or overweight. Around the world, roughly 36 million people die every year from lack of food, while 29 million die from diseases linked to overeating [35].

All these reasons underline the urgency for action in the food system. It is clear that food must become one of the main sectors to apply a new economic model. Nevertheless, the current level of implementation of circular economy into the food system (such as into the other different application fields) makes it difficult to combine practice with theory. This break makes it difficult to pinpoint how coherent practices are with the original concept, as well as to understand the purpose of the actions and assess the effectiveness of results. In particular, in this initial phase the relationship between circular economy and sustainability is still uncertain. In the specific case of food, it is necessary to deepen and verify that the application of the principles of the circular economy to food, contribute to the achievement of integrated sustainability objectives and food is used in its full potential to represent a transversal vector of sustainability for the achievement of the SDGs (Sustainable Development Goals 2030).

With the collection of 40 empirical case studies, the paper aims to have insights to these open issues by evaluating how circular economy is taking form and function in the food system and by assessing their effects on SDGs.

2. Methodological Steps

As a theoretical reference for connecting the circular economy and sustainability in the domain of the food system, we adopted the "the wedding cake" model theorized by Rockström and Sukhdev in 2016 [36], a conceptualization that shows the wide spectrum of possible goals that can be achieved regarding the biosphere, society, and economy, through actions connected to food (Figure 1).

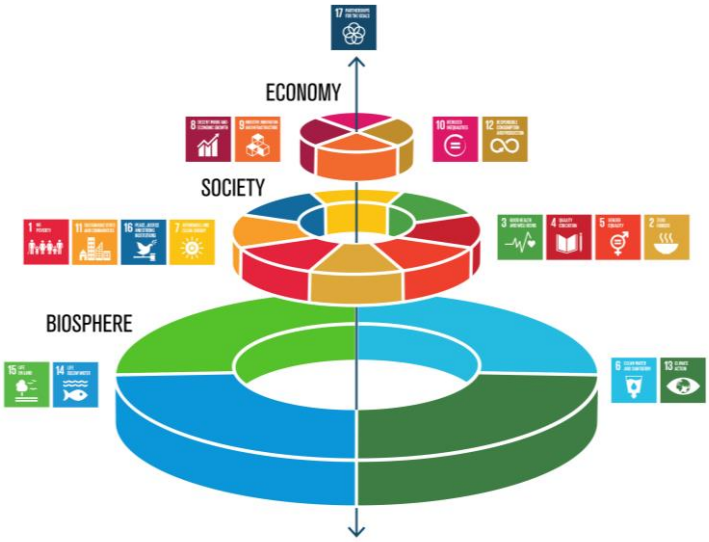

Figure 1. Sustainable Development Goals 2030 (SDGs) wedding cake [36] from Azote Images for Stockholm Resilience Centre, 2016.

The image of the "wedding cake" offered by Rockström and Sukhdev [36] shows how food can contribute directly and indirectly to the achievement of all 17 Goals established by the 2030 Agenda, consistently with the evolution of a sustainability model that goes from being anthropocentric to being eco-centric. It recognizes, at the base of the cake, that the biosphere dimension is what contains and supports any social and economic plan.

Therefore, a series of relationships connect the different SDGs through food. Some are more evident: The aim of Goal 12, for example, is sustainable production and consumption and is directly linked to the creation of a new relationship between producer and consumer (SDG 17), to the reduction of world hunger (SDG 2), to health and welfare (SDG 3), which are in turn influenced by the achievement of goals related to natural capital (SDGs 15, 14, 6, and 13).

Moving from this conceptual frame, we wonder where it is possible to grab the first results from circular economy actions and projects and what are the SDGs directly involved by these processes of change. From an initial mapping of Circular Economy practices in the sector, we collected companies' experiences in the food system that were representative of the different phases of the supply chain or with a close connection to it. Circularity practices were selected by companies of various sizes that were working on different food waste, food by-products, or waste related to the food supply chain (id. packaging) (Figure 2 and Table 1). A case history to be selected has to be identified as a relevant circular economy practice by an experienced third party (academic journals, specialized sites, and green press specialized media) as inherent to the Circular Economy.

Starting from this initial micro-level inquiry and verification of the coherence of the initiatives with the fundamental constructs and constituent elements of the circular economy [37,38] and the availability and reliability of the information provided, 40 case histories were selected (Table 1).

The choice to concentrate on mostly Italian case histories at this stage was made in view of our intention to better understand the influence of a common political/regulatory and communication framework [39].

A more in-depth analysis followed, through the collection of primary (interviews of businesses) and secondary data (analysis of sustainability and social reports, communication about the initiative on real and virtual channels as part of Corporate Social Responsibility) to collect information related to the product, process, service related to the circular initiative, to trace the flows of matter, energy, and knowledge connected by the same case history. To have more insight about the circular business model types, each case history has been systematized according to the six business actions depicted by the ReSOLVE framework from the Ellen MacArthur Foundation [40] (Figure 3).

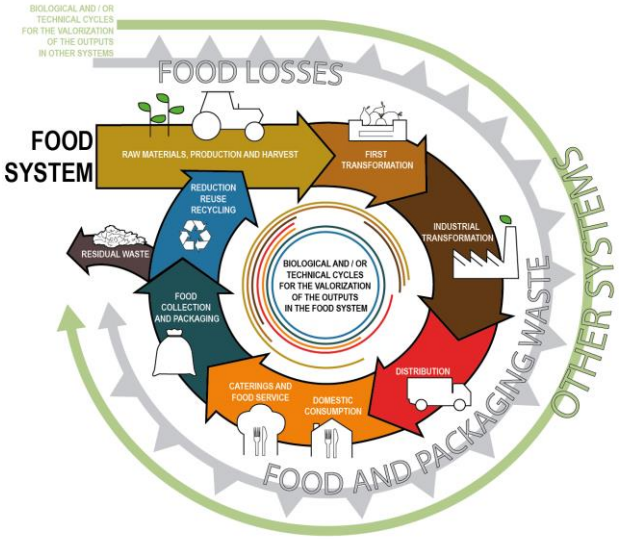

Figure 2. Food supply chain areas of implementation of the circularity actions selected as case histories (authors' elaboration).

Table 1. 40 case histories of circular economy into the food system.

Case Histories	By-Product or Typology of Food/Flow Involved in the Action of Circularity	Position of the Company into the Supply Chain	Sector for the Application of the Results
Agrindustria	Secondary materials from the food production industry (corncob, hazelnut and almond shells)	Food processing	Cosmetics, pharmaceutics, food industry, automotive industry
Amethyst	Oenological waste	Wine processing	Biotechnological phytodepuration
Autogrill	Geothermic and photovoltaic energy, water collection	Commercial catering	Construction
Bacardi	Citrus fruits, olives' stones	Industry and Food consumption	Cosmetics
Baladin	Brewery waste	Beer processing	Food industry, Energy production
Barilla	Bran	Bakery and pasta sector	Paper industry
Bio-On	Beet pulp and molasses	Beet processing	Bio-plastic, pharmaceutical and cosmetic sector
Carlsberg Italia	Disposable drums	Brewery	Beer distribution
Cir Food	Food surplus	Collective catering	Domestic food consumption
Comieco	Cellulosic packaging	Paper and cardboard recycling and collection	Wine packaging, territorial promotion
The food and Renewable Energy Community	Geothermal Energy	Agricultural production	Agricultural production and food processing
Coop Italia	Food surplus	Retail	Food charity
Costa Crociere	Aluminium packaging	Cruise industry	Street furniture
Costa Group	Wasted objects	Furnishing industry	Commercial catering

Table 1. *Cont.*

Case Histories	By-Product or Typology of Food/Flow Involved in the Action of Circularity	Position of the Company into the Supply Chain	Sector for the Application of the Results
Cuki Cofresco	Food surplus	Packaging industry	Commercial and collective catering
Duedilatte	Milk surplus	Milk fiber processing	Textile industry
Ecoplan	Olive pomace	Panels production	Furniture and objects construction
Edizero	Sheep wool surplus	Insulators production	Construction industry
Fortum Recycling and waste solutions	Food waste	Recycling and disposal	Energy industry
Elior Group	Energy and water	Collective catering	Collective catering
Fattoria della piana società cooperativa	Agri-food and livestock waste	Agriculture and food processing	Energy production
Ferrero	Hazelnut shells	Confectionary processing	Packaging industry, Pharmaceutic industry
Frumat	Apple waste	Paper factory	Paper industry
Future Power	Rice husk	Vases production	Horticultural industry
Growing Underground	Water and energy	Hydroponic production	Urban agriculture
Ikea	PET bottles	Home furniture	Furniture production
Keo Project	Wine barriques	Home and commercial furniture	Furniture production
Lavazza	Compostable coffee pod	Coffee processing	Coffee home consumption
Lavazza	Coffee ground	Coffee processing	Food production
Lucart	Tetra Pak	Tetra Pak recycling	Drink packaging
Lurisia Acque Minerali	Agricultural losses	Mineral water and beverages processing	Mineral water and beverages processing, Agricultural production
Novamont	Dismissed industrial areas	Biorefinery	Cosmetics, lubricants, bioherbicides and bioplastics industry
Novamont	Plant based components	Bioplastic	Retail
Orange Fiber	Citrus fruit pulp	Citrus fruit fiber processing	Textile industry
Palm	Wood pallet	Pallet production	Food logistics
Ricrea	Steel packaging	Steel recycling and collection	Food packaging
Ricrea	Cutin from tomato peel	Steel recycling and collection	Food packaging
Rilegno	Cork cap	Collection, restoration and recycling of wooden packaging	Construction industry
Sabox	Cardboard collection and recyng	Paper and cardboard recycling and collection	Canning and pasta sectors
Verallia Italia	Glass collection	Glass packaging	Food processing

CASE HISTORIES	REGENERATE	SHARE	OPTIMIZE	LOOP	VIRTUALISE	EXCHANGE
AGRINDUSTRIA	X		X	X		
AMETHYST	X		X	X		X
AUTOGRILL	X		X	X		
BACARDI			X	X		
BALADIN	X		X	X		
BARILLA	X		X	X		
BIO-ON	X		X	X		X
CARLSBERG ITALIA	X					X
CIR FOOD		X	X			
COMIECO	X					
THE FOOD AND RENEWABLE ENERGY COMMUNITY		X	X	X		
COOP ITALIA	X		X			
COSTA CROCIERE	X		X	X		
COSTA GROUP		X				X
CUKI COFRESCO		X	X			
DUEDILATTE			X	X		
ECOPLAN	X		X	X		
EDIZERO	X		X	X		
FORTUM RECYCLING AND WASTE SOLUTIONS	X		X	X		
ELIOR GROUP	X		X			
FATTORIA DELLA PIANA SOCIETA' COOPERATIVA	X		X	X		
FERRERO	X		X	X		X
FRUMAT	X		X	X		
FUTURE POWER	X		X	X		
GROWING UNDERGROUND	X					
IKEA			X	X		
KEO PROJECT			X	X		
LAVAZZA COFFEE POD			X	X		
LAVAZZA CIRCULAR COFFEE	X		X	X		
LUCART			X	X		
LURISIA ACQUE MINERALI	X	X	X	X		
NOVAMONT BIOREFINERY	X					X
NOVAMONT MATER-BI BAGS			X	X		X
ORANGE FIBER			X	X		X
PALM	X		X	X		
RICREA STEEL CAN COFFEE		X	X	X		
RICREA FOR PACK TOMATOES			X	X		X
RILEGNO	X	X	X	X		
SABOX	X		X	X		
VERALLIA ITALIA	X	X	X	X		

Figure 3. Systematization of the case histories according to the 6 business actions of the ReSOLVE framework [40].

The results achieved for each case history was then mapped through a SDGs check list for circular economy for food associated to a spreadsheet, to evaluate the contribution of the action taken into analysis on the 17 SDGs and the relative 169 targets of the Agenda 2030 [41]. The check list has been elaborated according to the framework provided by the Guide for Applying the Sustainable Development Goals, Targets, and Indicators in Results Frameworks of the Organisation for Economic Co-operation and Development [42]. Due to the lack of comparable data, in the checklist, it has been evaluated the compliance of the results from each action with the SDGs target (Figure 4). The display

of the final results by aggregation of the 40 case histories results, was graphically processed on the model of the Wedding Cake [36] (Figure 5).

CASE HISTORIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
AGRINDUSTRIA							7.2 7.3					12.2 12.5			15.1 15.4 15.5		
AMETHYST		2.4				6.3 6.4	7.3		9.4 9.5								
AUTOGRILL						6.4	7.2 7.3				11.2 11.6						
BACARDI											11.6	12.4					17.14 17.16
BALADIN		2.3 2.4					7.2		9.2			12.2 12.5			15.1 15.4 15.5		
BARILLA									9.4 9.5			12.2 12.4			15.2		17.14 17.16
BIO-ON						6.3			9.1 9.4			12.4 12.5					
CARLSBERG ITALIA											11.2 11.6	12.4 12.5	13.3				17.14 17.16
CIR FOOD				4.7							11.6	12.3					
COMIECO											11.6	12.2 12.5			15.2		17.14 17.16 17.17
THE FOOD AND RENEWABLE ENERGY COMMUNITY		2.3 2.4					7.2	8.2 8.3 8.4			11.6				15.1 15.4 15.5		17.14 17.16
COOP ITALIA	1.3	2.1									11.6	12.3					17.14 17.16
COSTA CROCIERE											11.2 11.6	12.4 12.8					17.14 17.16
COSTA GROUP								8.4				12.2 12.5					17.14 17.16
CUKI COFRESCO		2.1									11.6	12.3					17.17
DUEDILATTE			3.9						9.4 9.5			12.2 12.5					
ECOPLAN								8.4				12.2 12.5					
EDIZERO									9.2 9.4 9.5		11.6	12.2 12.5					17.14 17.16
FORTUM RECYCLING AND WASTE SOLUTIONS							7.2		9.1 9.2 9.4 9.5		11.3 11.6	12.2 12.5					17.17
ELIOR GROUP		2.1 2.4		4.7			7.2 7.3					12.3					
FATTORIA DELLA PIANA SOCIETA' COOPERATIVA		2.3 2.4					7.2	8.2 8.4 8.3			11.6	12.2 12.4 12.5					17.14 17.16
FERRERO			3.4						9.2 9.4 9.5			12.2 12.4 12.5					
FRUMAT									9.4 9.5			12.2 12.5			15.2		17.14 17.16
FUTURE POWER							7.2		9.2 9.4 9.5			12.2 12.5					
GROWING UNDERGROUND		2.4				6.4	7.2 7.3				11.3						
IKEA									9.4			12.2 12.4					17.14 17.16
KEO PROJECT									9.4			12.2 12.5					17.14 17.16
LAVAZZA COFFEE POD									9.4 9.5		11.6	12.2 12.4	13.3				
LAVAZZA CIRCULAR COFFEE		2.1	3.4								11.6	12.2 12.5					17.14 17.16
LUCART						6.3			9.1 9.4 9.5			12.4 12.5					17.14 17.16
LURISIA ACQUE MINERALI						6.4 6.6	7.3		9.1 9.2 9.4			12.4 12.5			15.1 15.4		
NOVAMONT BIOREFINERY								8.4	9.1 9.2 9.4 9.5		11.3	12.2			15.4 15.8 15.9		17.14 17.16
NOVAMONT MATER-BI BAGS									9.4 9.5		11.6	12.2	13.3				17.14 17.16
ORANGE FIBER								8.2 8.4	9.2 9.4 9.5			12.2 12.5			15.1 15.4 15.5		17.14 17.16
PALM									9.1 9.2 9.4			12.4 12.5	13.3		15.2		17.14 17.16
RICREA STEEL CAN COFFEE									9.4			12.2 12.5					17.17
RICREA FOR PACK TOMATOES			3.9						9.1 9.2 9.4 9.5			12.2 12.5					17.14 17.16 17.17
RILEGNO											11.6	12.2			15.1 15.2		17.14 17.16 17.17
SABOX									9.2 9.4		11.6	12.2 12.4 12.5			15.1 15.2		17.14 17.16
VERALLIA ITALIA							7.3		9.4			12.2 12.4 12.5			15.2		17.14 17.16

Figure 4. Systematization of the case histories according to their connection with SDGs.

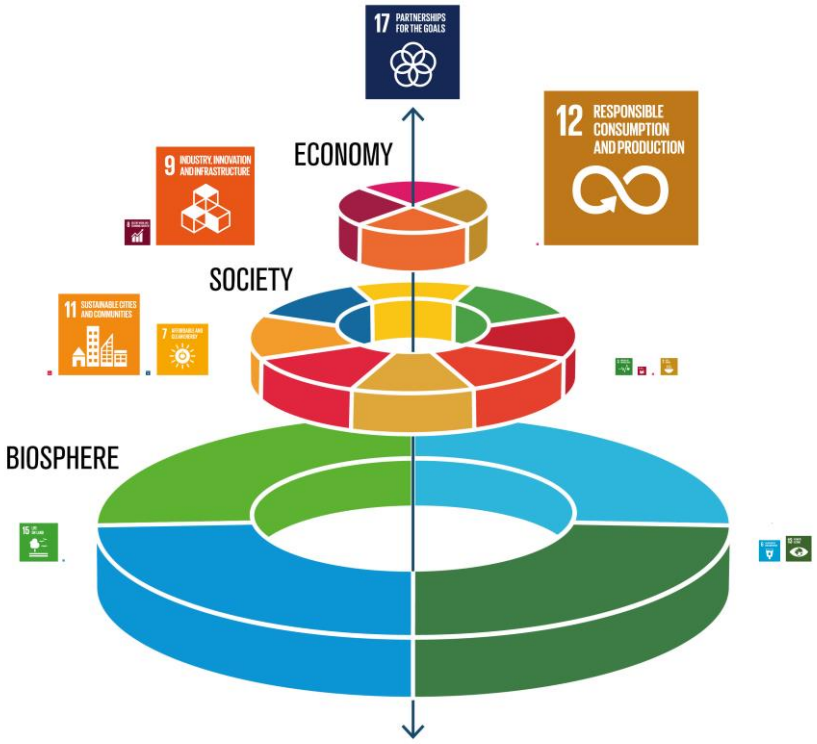

Figure 5. Contribution of the 40 case histories of circular economy into the food system on the SDGs by adopting the representation of the wedding cake [36].

3. Results

Forty "circular practice reports" from 37 companies were produced, a sort of initial "holistic relief" [39] describing the changes underway, the resources and energy put into circulation, the actors involved, the specific effects on company dynamics, the information conveyed to the community, and the creation of new relationships and connections.

In the experiences analyzed at different points in the food system, from production to post-consumption, we identified expedients for product, service and process, fostering efficiency, and effectiveness, as well as new connections. While dealing with experiences that have big variations among them due to the company sizes, positions within the food system, type of product, secondary material or services used for circular action (from corn cobs to beet molasses, and from olive pomace to nut shells, as well considering the specific characteristic of materials in the complex food system), the analyzed actions of circularity revolve mainly around three of the six classification criteria that characterize circular business model types according to the ReSOLVE framework [40]: Optimize, loop, and regenerate.

Optimize actions across the case histories are focused on increasing the performance/efficiency of a product and removing waste in the production process and in the supply chain by closing loops. It means that not necessarily changing the product but working to transform what is wrongly considered waste or little value in the production process and in the supply chain, into a new service for another productive or consumer cycle according to an upcycling perspective. Unlike what traditionally happens with recycling processes, where materials often experience a loss in value (downcycling), the material/immaterial and/or relational value is kept or even enhanced, while reducing disposal costs, where possible, especially with regards to special waste that is subject to specific legal regulations.

This is the case with Duedilatte and Orange Fiber that obtain textile fibers from milk and orange by-products, respectively. In the first case, the fiber is obtained from the processing of casein, separated from the whey through a biochemical process. In the second case, the textile fiber is made up of

cellulose extracted from the citrus pulp, which is the waste coming from the industrial processing of citrus fruits.

Upcycling is also the procedure carried out by Frumat company, where apple peel and cores become paper, or when hazelnut shells are transformed by Agrindustria into plant granules for vibratory, finishing, polishing, and sanding procedures or as they are used by Ferrero, in the production of packaging cardboard and to extract probiotic fiber.

The other key principle is regeneration by exploiting circular supplies. Here, we are dealing with a decision: To use "circular" resources because they are reusable, some of which in (almost) endless cycles, such as glass and steel for packaging; to prefer renewable material and energy resources; to keep purity of resources throughout the various stage of the value chain; to favor single-material use and stop material and stop material contamination or to adopt new technology that disassembly and recovery operations. Proximity in accordance to the regenerate criteria, takes on a new value, both in the rational use of locally available resources and in the search for creative solutions for their uses, as well as the value attached to the relations of local industrial and territorial symbiosis. In this respect, the non-alcoholic drink Unico is a good example. It is produced by Lurisia Acque Minerali with 70% of Barbera grapes and 30% apple juice, and mashed pears and peaches. This case history represents the potential of circularity in finding answer to local needs, such as the market crisis faced by Piedmont Barbera grapes, which might otherwise have been left unpicked, since the cost of picking them was too high compared to the revenue generated with their sale. The Unico drink production took place between 2013 and 2016, up until the Barbera grape market stabilized again, thus showing the value of circularity and its ability to adapt to temporary situations that would otherwise engender food loss and waste.

Looking at coverage of SDGs within the food system of the selected case histories, we believe that the positive externalities regarding some specific SDGs are evident, but the practical translation of the Circular Economy into the food system is still lagging behind the potential impact on a significant part of them.

An interpretation regarding the connection with the SDGs confirms the elevated degree of connectivity and power of "transmittance" of circular economy actions in the food system, especially in favoring business models that affects Goal 12, "Ensure sustainable consumption and production patterns", Goal 9 "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", and Goal 17, "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development"

The check list highlights how the adoption of the principles of circularity and technological innovations that are inspired, in the individual experiences, has resulted in a more sustainable management and efficient use of natural resources (12.2), in a reduction of waste generation through prevention, reduction, recycling (for the case histories especially upcycling) and reuse (12.5), and in a more environmentally sound management of chemicals and all wastes (food and packaging) throughout their life cycle (12.4). The contribution to the Goal 12 has been materialized through the reduction in the quantity of virgin raw material used in the production processes and the relative cost in terms of extraction, the possibility to find a new destination of use for downstream, by-products, and secondary raw materials, maintaining the identity of resources, acquiring in some cases a new economic value in and for more cycles, in an optimization of the efficiency of the production processes and in the reduction of their impact in terms of savings in energy consumption, in the quantities of polluting emissions produced, of which, however, a precise quantification for the environmental dimension is missing. Circular economic food actions are the result of innovation processes mainly triggered by the adoption of new clean and environmentally sound technologies and industrial processes, infrastructural and logistic adaptation (9.4), together with an enhancement of the investments made in research and development by companies, individually or in partnership (9.5). In several cases, innovation has been driven by the local availability of resources or by site market circumstances. In most of the case histories, new multi-stakeholder partnerships (17.6 and 17.7) were born. These

relations of industrial symbiosis share, according to the case histories, share knowledge, expertise, or technology.

We also observe an evolution of the product quality concept, which extends over time and extends to the entire production chain, contributing to the redefinition of the relationship between consumer and producer, thus returning to the SDG's field of action 12 and to the enhancement coherence for the institutional commitment toward sustainable development (17.14).

However, by the adoption of the wedding cake model [36] to display the aggregate results, it emerges that the actions undertaken so far have concentrated on the upper part of the cake and have made a little or even not existing contribution to the environmental (making references here in particular to SDGs 6, 13, and 14) and social dimension (making references here in particular to SDGs 1, 2, 3, 4, and 5). What emerges is a picture in which it is clear that companies who are currently working on Circular Economy for Food still pay little attention to safeguarding the basis of the "cake", the dimension of the biosphere, which contains and supports the social and economic plan. The new paradigm assumes a predominantly economic connotation, in which the environmental and social dimensions are currently poorly integrated.

The use and generation of renewable energy, the process and product innovation that comes from the introduction of biomaterials, social innovation in urban contexts, the fight against hunger and food waste, the diffusion of circular economy culture, and the promotion the role of women in circular business: These are all areas whose potential has been recognized, but that can still grow and find further room to engage the SDGs that are currently only marginally involved in circularity practices.

A new system can thus be created around the outputs, but cannot be limited to the creation of "a waste economy". The development of the circular economy from a predominantly economic perspective, where there is a new destination of use for a by-product or waste is likely to become a differently linear model. This would risk introducing in the circular economy transition, a kind of rebound effect: the development of a manipulative approach to waste [43] to offer a placebo effect that does not affect the current development model and that paradoxically, despite the premises, could trigger a mechanism that is seemingly regenerative and sustainable.

4. Conclusions

This paper aimed to move from the theoretical plane of the circular economy to the empirical one, analyzing how this model has taken form and function in the food system and how the selected case histories have been able to work on the pattern laid down by the SDGs. The food system, because of its specific features, was used as a "litmus test" to understand how the implementation and interpretation of principles has occurred in one sector.

It was at the same time that an initial attempt to collect case histories and complete an across-the-board analysis. It is meant to be instrumental in the sharing of experience that, if put into the system, can take on new significance, can participate in the characterization of the business model on the practical transition to circular economy, and can foster its transferability.

The steps toward the Circular Economy for Food, revealed by the 40 case histories, shows us how the food system could be fertile ground to test and implement regenerative, optimize and loop actions, by focusing in particular on the up-cycling principle and on new processes of eco-design, with relevant contribution on SDG 9, 12, and 17. The case histories reveal, however, an inadequate contribution for the conservation of natural capital and on life's essentials: Integrations necessary for a real transition toward sustainability. At the moment, results seem still only partial when compared to the actual possibilities and the full potential of the food system. Greater efficiency in production systems cannot be sufficient for the achievement of a production and consumption model that can be defined as sustainable, eco-effective, unless it is combined with socio-economic, and environmental consideration within the collective value proposition depicted by the SDGs

These finding contribute to the critical, but constructive approach to the circular economy and its relationship with sustainable development present in the scientific literature [44–46].

As we state in the introduction, food can embody the principles of the circular economy, but it can also provide support to identifying a track for its theoretical-practical evolution and in adjusting its goals accordingly. The cascade effect food practices could have, because of their cultural significance, connections and their pervasiveness in the system, could become a driving force that, applied to the circular economy, could lead to the awareness that everything is interconnected, that the circularity that is developed in systems thinking is not just another new constraint or requirement, but instead the natural outcome of an alliance between parties. We only need to think about the role that food waste already plays, within the whole of the circular economy. However, it is not just any field. Food involves not only our bodily nutrition, but also the nature of our relationship with the world and with others [47]. This connection between the environment and humanity was clearly expressed in Pope Francis' Laudato si', where the concept of "Integral Ecology" is defined [48]. The circular economy for food can be, therefore, a perfect field of experimentation for a new way of understanding the production and use of goods, a new approach to raw materials and waste, and a new paradigm for the construction of economic and social relationships that are integrated and positive for everyone, nature and humans. What seems clear is the need for greater integration, that is, coordination between actions and stakeholders within the cycles of production and consumption, as well as between short and long-term perspectives, that is, between goals for economic growth and environmental and social goals. Reaching effective results seems to require an expansion of single-term dialectics [49], so far focused on more efficient management of outputs. We need to shift from a circularity focused on the optimization of outgoing flows to a regenerative model in a holistic sense, in which the definition of a multi-dimensional [50] and system [51] quality characterizes a food system that is in balance with nature and in step with the times.

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