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Assessing Circular Economy Opportunities at the Food Supply Chain Level: The Case of Five Piedmont Product Chains

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Abstract: The impact of linear agri-food supply chains is progressively leading to ever wider socio-environmental and cultural repercussions, undermining the balance of territories and communities to the point of disrupting the entire planet's health. Therefore, there is an urgent need for a paradigm change involving the agri-food sector, the economic sector, and local public policies, in the direction of a diffused ecological transition. In this scenario, the Circular Economy, supported by the adoption of a Systemic Approach, represents a useful operational tool to respond to complex transversal challenges, to reduce and enhance waste, minimize the use of new raw materials, and strengthen the territorial identity and relations among local stakeholders. This article describes a research project conducted for the Piedmont Region (Italy), through which it was possible to apply these innovative tools and approaches to five typical local agri-food chains (wine, dairy and cheese, rice, water, and bovine beef). Currently, at the Piedmontese level, concrete proposals for public policies capable of supporting the ecological transition of the local agri-food chains have not yet been developed, especially in terms of cyclicality of outputs and territorial co-evolution. For this reason, through the use of a multi-stakeholder approach, participatory mechanisms of local actors, and the analysis of several national and international case studies, the purpose of this research was to evaluate the possible enhancement of food waste and by-products, finally developing specific proposals for good practices and public policies capable of contributing to the achievement of the Piedmontese Regional Strategy for Sustainable Development.

Keywords: circular economy for food; sustainable food supply chains; systemic approach; multi-stakeholder approach; public food policy; local agri-food system; food waste management

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1. Introduction

The management and promotion of sustainability is an issue that is currently increasingly addressed within the various human productive activities. Among these, the agri-food system stands out, which plays a central role both in the generation of well-being and social development, and in the environmental balance. Today, such systems are extremely connected to the prevailing economic model, based mainly on the typical approach of a linear economy, "*take-make-dispose*" [1]. The large number of stakeholders involved, the complex network of material and information flows, and the socio-political importance of these systems make the more complex issues connected to them real *wicked problems* [2,3], for which the proposal of any alternatives leads to visible consequences only in the long term, without immediate evidence of the effectiveness of the actions taken [4]. In particular, the management of agri-food supply chains can be unsustainable and not entirely efficient for different reasons, specifically in terms of waste production in the

various stages of harvesting, storage, transportation, and distribution of agri-food products, which are subject to rapid spoilage due to their natural characteristic [5].

To address this type of problem, it is essential to adopt a systemic vision and perspective, which bring to the fore the notions of complexity and network [6], in which a system is understood as a complex of parties that establish relationships with each other, and the behavior of each is characterized by the connection in which it is involved. These components, taken together, do not represent the mere sum of the separate parts, but a single holistic system with a wider value [7]. From this point of view, the application of a systemic approach to the agri-food scenario is a valid design method, to trigger a paradigm shift that involves the transition from linear to circular structures, supported by a collaborative approach [8–10]. However, the concept of circularity is not new: it can be understood as a reinterpretation of rural economies, in which previous generations were accustomed to more sustainable uses of natural resources, based on the reuse and reduction of waste [11]. The novelty is represented by the constitutive elements of the circular economy, which have more articulated roots and derive from a fairly recent evolution of the concept of sustainable development and the economy–environment relationship. In recent years, scientific research and the political landscape are moving toward this new economic paradigm [12]. This is demonstrated by the progressive increase in the quantity of research projects relating to the circular economy in the scientific literature, in conjunction with the publication of the United Nations Sustainable Development Strategy in 2015 [13] and the growing sensitivity toward environmental, social, and economic potentialities of this disciplinary sector.

The energy crisis of the 1970s led to the search for new solutions to address the evident scarcity of resources due to the linear growth model [14], proposing a new regenerative paradigm in which production is based on the precept "*From Cradle to Cradle*", going beyond the simplistic vision of the mere recycling of materials [15] and looking to nature for the formulation of new circular business models [16]. Thus, human production processes can employ regenerative practices and guarantee the cyclical nature of materials, emulating the dynamics of natural systems, with a view to a *Circular Economy* [17].

The latter has been integrated into the environmental policies of the European Union, whose current priority is to promote the *European Green Deal* [18]. It proposes specific measures to make the production of energy and resources (including food) and, consequently, citizens' lifestyles more sustainable, to initiate an ecological transition that involves the protection of natural capital, the generation of employment, the development of sustainable technologies, and the extension of the life cycle of products, among others. In particular, the *Farm-to-Fork Strategy* [19], adopted by the European Commission in 2020, is considered the heart of the European Green Deal and aims to make food systems more equitable, healthier, and more sustainable from the economic, social, and environmental point of view. This strategy underlines the priority of acting on the food system to achieve a complete ecological transition, considering food as the basic unit that connects the *17 Sustainable Development Goals* (SDGs) [20]. The ultimate goal is to accelerate the transition to a more resilient food system that is able to cope with sudden contextual changes that would make life on the planet precarious.

Thus, the concept of the circular economy has begun to become part of the agenda of political institutions [21]. Finally, as part of a deep reflection on the dominant economic paradigm and on the need to bend the linear system to reduce its negative impact, in 2015, the European Commission promoted its first *Action Plan for the Circular Economy* [22], an important step financially supported by structural and investment funds such as, for example, the European Fund for Strategic Investments (EuSEF), Horizon 2020, and LIFE programs. In Italy, the Ministry of Ecological Transition followed the European line, introducing, in 2017, the *National Strategy for Sustainable Development* (SNSvS) [23]. It outlines a vision of a future centered on sustainability, as a shared and indispensable value for facing global challenges.

Specifically, in the context of Piedmont (Piedmont, Italy), the agri-food scenario does not only represent a strategic economic sector, but also a real key element in the pursuit of social and environmental objectives. Consequently, the need for an approach that ranges from practices to policies emerges, in which public institutions play a direct and concrete role, so that supply chain problems are not faced only by civil society or by individual virtuous producers [24]. Indeed, it is unthinkable to achieve the objectives of European policies without pursuing sustainable strategies on a local scale in the same way, adopting an approach that goes from *micro to macro* [25,26]. From here, the centrality of local authorities and the strategic role of regional policies as an engine of change becomes evident.

One of the most significant challenges for the development and implementation of integrated food policies is the definition of forms of governance that can support the active participation of stakeholders [27]. In fact, in the agri-food scenario, a multi-stakeholder approach based on a public–private–third sector partnership is fundamental, involving the various institutional levels in the same way [28]. The benefits of an ecological transition also implemented through the adoption of a circular economy go far beyond environmental protection and resource saving, leading to new opportunities and the design of new, systemic, highly innovative business models. This transition must be mainly driven by companies, through the support of regional authorities, stricter regulatory systems, and more demanding and aware consumers [29].

Going into detail, the objectives of European and international policies cannot be achieved if—*in cascade at each level*—a strategy that allows the achievement of global targets is not implemented territorially. For example, in the case of Italy, each region differs profoundly in terms of priority areas of action and internal organization. For this reason, it is necessary that public food policies take into account local specificities and be interpreted in different ways according to the context and the nature of the problems [30–32]. This shows the centrality of local authorities and the strategic role of regional policies as a driver of change, in contrast to the "*by nation*" approach that has characterized the past decades [33]. The development of effective public policies, therefore, requires in-depth research and analysis relating to the territory in which action is to be taken, to ensure objective action based on shared criticalities and priorities, not dictated by political preferences [34,35]. Scientific research is found to be fundamental for informing multi-sectoral policies that address trade-offs and synergies, also for enabling policy makers to orient themselves in complexity, through an objective knowledge support [36,37]. Along with this, as argued by den Boer et al. [38], it is fundamental to deepen R&I through the development of "transdisciplinary research approached by investing in the creation of meaningful interactions between researchers, societal actors, and policymakers."

Acting concretely from the local level is essential: half of the human population—3.5 billion people according to the United Nations—lives in urban areas and this number is destined to increase significantly by the end of the decade [39]. With population growth, resource demand in urban areas increases as well, and environmental criticalities and socio-economic differences among citizens emerge and deepen. A new food uncertainty enters cities all over the world, not only linked with the issue of lack of food and nutrients, but also with the issue of food excesses.

In 2030, the deadline for reaching the 17 Sustainable Development Goals is also sanctioned and, given the transversality of food with respect to each of them, this must be the strategy adopted to address the criticalities of our food systems. Food, a basic unit of connection among all SDGs, plays an essential role in the transition toward a sustainable development, as shown in the *Wedding Cake model* by Rockstrom and Sukhdev [20]; therefore, the role that the food system can and must play in the ecological transition toward a sustainable development paradigm is essential. In the food sector, the circular economy is presented as a sustainable practice to remedy some of today's greatest challenges, including population growth, inefficient use of resources, environmental impacts on climate, soil and oceans, and food waste [40].

Therefore, there is a growing consensus on the need for public institutions to adopt a systemic approach to food policies to successfully address and solve complex, persistent, and interrelated problems such as food insecurity, climate change, use of resources, poverty, and public health [27]. A systemic approach to food systems allows us to broaden the view, promoting integrated and coherent policies to align different political agendas and transversal issues (e.g., agriculture, environment, trade, health, food safety) to better meet the needs of the actors involved and support multiple objectives (environmental, socio-economic, and healthcare) [41,42]. Therefore, improving the quality and sustainability of the food system means increasing the sustainability of all areas of the territory as a whole. A higher level of design for sustainability is reached through innovation at a systems level, a more radical and strategic approach that involves many stakeholders, such as communities, governments, companies, and customers [43,44]. Within this context, the circular economy applied to the agri-food sector, or Circular Economy for Food, is of considerable importance because it recognizes the mutually influential relationship between food and the circular economic model, the principles of which are taking the first but decisive steps towards a route change [45]. Thus, the need to achieve food systems that are sustainable is seen, recognizing the importance of the indivisible links that exist between healthy people, healthy societies, and a healthy planet (*One Health approach*). One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent [46].

Within this framework, the 3 Cs of the circular economy for Food [47]—Capital, Cyclicality, and Co-evolution—were taken as a theoretical-practical reference to systematically analyze the supply chains being researched and to arrive at the proposal of public policies that could be transversal as relational bridges between several MAS of the SRSvS of the Piedmont Region and the SDGs. Furthermore, the coexistence of the three criteria of interpretation of the system applied to food allows the transition to a paradigm—*Circular Economy for Food*—that is impactful and meaningful for a development that is sustainable. In particular, by designing the flows of matter, energy, and information that cyclically condition the food system, it is possible to have a positive impact on the 17 SDGs and contribute to regenerating the natural, cultural, and economic capital that supports coevolution between species [48].

This article aims to investigate some aspects of the Piedmontese Regional Strategy for Sustainable Development (in Italian, abbreviated as SRSvS) [49], paying particular attention to the issues of the circular economy applied to the food system. This action focuses on involving the agri-food system in an operational way, creating cross-cutting worktables, to share and initiate integrated policies on circular economy issues that are directly attributable to the objectives of SRSvS. With the aim of making the research as representative and relevant as possible for the regional food system, five different typical food supply chains were selected as a priority object of study. The attempt was to incorporate and restore the diversity and variety of the Piedmontese food production landscape in the best possible way, seeking the involvement of companies with different sizes and positions at the level of the supply chain. Addressing "real-life case studies" makes our research an important contribution to the existing academic literature, as a result of the strong interaction between researchers and key stakeholders aiming to highlight concrete evidence-based solutions to local existing criticalities [5].

In conclusion, to better contextualize the path of the research conducted and the narrative vein used, the contents of the following sections are reported below:

1. Section 2 shows the objectives and the design methodology that characterized the research, as well as the instrument and tools that have made it possible to carry out the investigation;
2. Section 3, in accordance with the stages of the methodological structure presented in Section 2, reports a particular emphasis on the outcome of *Desk-based Research*,

in particular describing the *Academic and Sectoral Document Discovery* (within which the scientific literature was analyzed), the *Quantitative and Qualitative Data Analysis* and the *Supply Chain Mapping* developed; furthermore, the results of the *Stakeholder Engagement* are summarized inside this section;
3. Section 4 shows the meaningful challenges for the development and the expansion of integrated food policies through the definition of a series of cross-cutting solutions;
4. Section 5 describes implications, limits, hypotheses, and future research directions about the *Research Proposal* developed.

2. Materials and Methods

2.1. Objectives of the Project

The process that led to the development of the "*Circular Economy in the Agri-food piedmontese sector*" project is based particularly on two of the seven strategic macro-areas (MAS) defined by the Piedmontese regional government (*MAS 1, accompanying the transition of the Piedmont production system toward a model capable of combining competitiveness and sustainability* and *MAS 3: taking care of cultural heritage and environmental heritage and the resilience of territories*) [49]. These deal with the promotion of an ecological transition of the regional productive system, and are aimed at understanding how the dynamics of the circular economy can be applied in practice to five supply chains of the Piedmontese food system, which coincide with those considered priorities by both the Piedmont Region and the University of Gastronomic Sciences of Pollenzo. This research focused on the agri-food supply chains that play an important and decisive role for the Piedmontese economy in terms of production and turnover, chosen in such a way as to include the agri-food production diversity of the region: wine, dairy and cheese, rice, bottled water, and beef supply chains (Figure 1).

Figure 1. The five local food supply chains were taken into consideration for the project.

The Piedmont region has promoted this research in order to focus on the regional agri-food system, with the aim of supporting the development of actions in line with the objectives of the SRSvS [49]. It stems from the need to realize the SNSvS on the circular economy front in the agri-food sector and, therefore, the regional government collaborated with UNISG to ensure that it would work to bring the sustainability targets set at national and then regional level to the ground.

Through the operational involvement of the actors of the agri-food system, it promoted the sharing of issues concerning the circular economy, identified as the key to the SRSvS. There are essentially two main objectives on which the *Research Proposal* is based:

1. to identify priority issues for the agri-food system regarding the possibility of transition toward a model based on a better use of renewable resources, reuse of raw materials, and waste valorization;
2. to identify and suggest regional system policies according to sustainability objectives in relation to the priority areas.

More specifically, the project objectives required the identification, through the involvement of stakeholders, of the main challenges and potentialities concerning the Piedmontese agri-food system in relation to the transition toward a circular economic model that focuses on the use, recycling, and recovery of waste or by-products from the processing phases of each supply chain. After that, the identification of those best practices, technologies, and services that could help in the development of alternative and innovative paths involv-

ing the reduction, but above all the valorization, of waste present in the agri-food chains was requested.

2.2. Instruments and Tools

As already mentioned in the Introduction, the majority of current scientific research about the opportunities for circular economy applications in the agri-food sector seeks to widen the focus of their control volume to include an entire food product's supply chain. In this way, it is possible to better address the complexity and wide-ranging impact of agricultural supply chains, whose analysis benefits from a systemic perspective, within which most of the inputs and outputs can be accounted for as an interconnected set of flows of matter, energy, and information, rather than as separate units.

In order to provide sufficient and accurate information for the development of public policy proposals in the context of the promotion of circular economy practices and the ecological transition of the chosen supply chains, the expansion of this focus has been translated into the research project described inside of this article. Such an approach, has further allowed for an in-depth understanding of the current circularity and baseline of ecological transition in regional food supply chains, as well as the possible obstacles and potentialities for further adoption. Specifically, a total of 72 people were involved in the development of the research project, nine of whom are members of the University's research team, while the remaining number can be traced back to 21 companies in the agri-food sector, three innovation poles in Piedmont, and 39 students following the course in *Systemic Design for Circular Economy* of the master's degree in *Food Innovation & Management* at UNISG, who contributed to the project by offering innovative solutions to what they perceived as the main challenges being faced by the supply chains.

Although there is a wide field of application for the research conducted within the discipline of Circular Economy in the agri-food sector, in terms of supply chain stages, from the scientific literature it has emerged that a singularly predominant tool (e.g., LCA, SLCA, WFA, LCIA) or variable chosen to measure impact is not generally used (e.g., carbon and water footprints, energy consumption, etc.), leading to a lack of comparability and reproducibility among studies [13]. Therefore, it seems preferable to employ an approach which gathers the results of more specific previous scientific research and applies it to the food supply chain system as a whole, generating a holistic understanding of the priorities to be defined and the challenges to be faced.

For this reason, on the basis of the methodology of the systemic approach adopted in the research path discusses in this paper, specific phases were followed (Figure 2): firstly, desk research allowed the discovery of academic and sectoral documents for the review of a scientific literature consistent with the research topic, after which it was necessary to carry out a qualitative and quantitative analysis of the five selected Piedmontese agri-food chains and map the main process steps and the actors involved in them, supported by an investigation of several innovative case studies, which made it possible to identify the best practices to be exploited. Finally, the organization and implementation of participatory mechanisms made it possible to finalize a shared research proposal regarding possible public policies applicable to the regional context, responding to the feasibility criteria and territorial requirements.

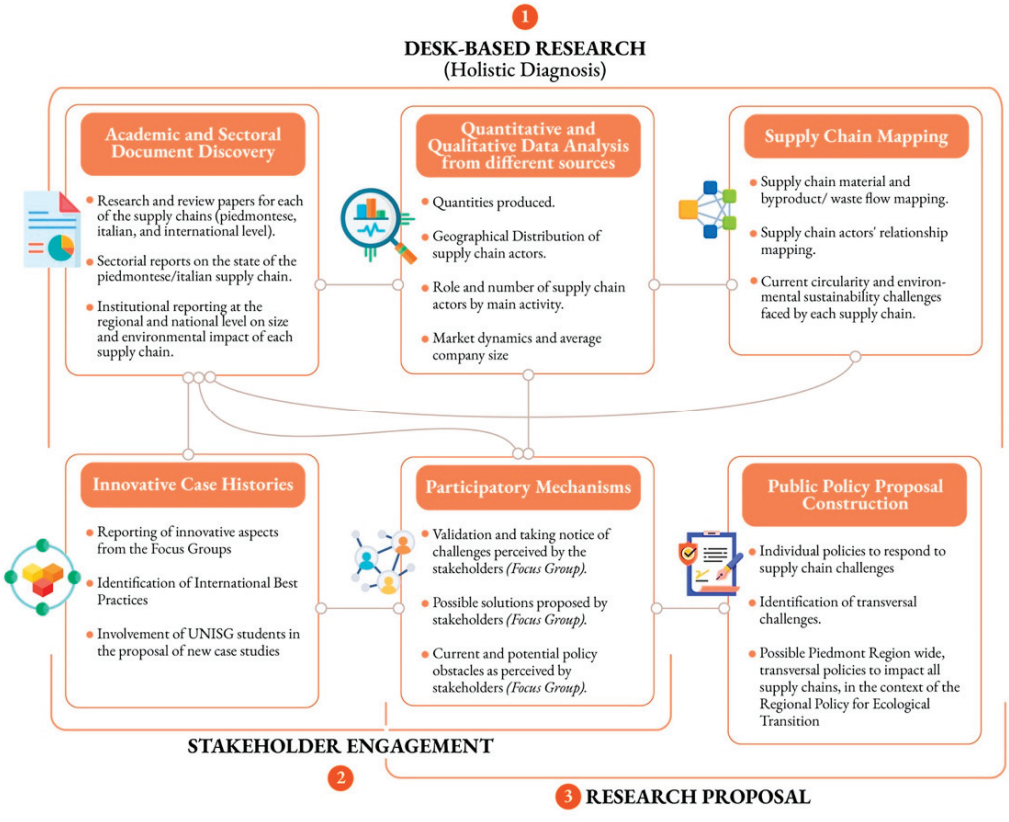


Figure 2. Design methodology: the representation of the single steps addressed and the links among them.

As follows, a description of each of the steps of the project are included, along with their relevance to the objectives stated by its definition:

- *Academic and sectoral document discovery*: as a primary step, and to better define the extent of each supply chain, relevant research papers and sectoral documents were researched. Using the keywords "*waste*", "*byproduct*", "*waste management*" and "*circular economy*", followed by each of the individual supply chain names, in an academic search engine (Google Scholar) and in a scientific article database (Scopus), with a total number of 75 selected articles, ranging from scientific articles reporting on similar initiatives on a smaller or similar scale, to sectoral documents, used to better delineate the size and boundaries of each supply chain. In addition to supply chain structure and boundaries, the documents were also analyzed for information regarding the current practices of waste or by-product disposal, valorization and/or and treatment, as well as for the private and public sectors' interests and understanding of the challenges currently present in the Piedmontese regional context. This step, using other terms, could also be called a *literature review* because it was performed to understand the scenario of the research proposal better and to analyze—*at a micro level*—the research gap identified. In fact, it consists of a thorough study review process of papers about the *circular economy, food waste management, sustainable food supply chains, and local agri-food system*. All the considerations developed during this phase have been inserted in the aforementioned text, in particular, in Sections 1, 3 and 4.

- *Quantitative and Qualitative Data Analysis*: once the current state and main challenges for each supply chain were taken into account, information regarding the distribution of actors in each step of the chain was procured by employing two datasets: one, provided by the Piedmont Region joint Chambers of Commerce (*Unioncamere Piemonte*) [50], containing statistical and location data for all the companies registered within the region, and the other by the University of Gastronomic Sciences' Food Industry Monitor, a performance observatory containing historical financial data for the most relevant companies in the Italian food sector. Both datasets were filtered by only including the companies whose economic activity code (*Codice ATECO*) was within those belonging to the mapped supply chain, with a resulting total of 3261 records analyzed. In addition to individual company data, other statistical databases for each of the supply chains analyzed were taken into consideration, in order to better understand the complexity and scale of each one. Namely, the regional and national agricultural registries were consulted for a region-wide perspective on the data that is reported by each supply chain's multiplicity of actors to the regional and national governments.
- *Supply chain stage mapping*: based on the information gathered in the document discovery stage, as well as the quantitative data gathered and analyzed, a simplified "map" of each supply chain was constructed; said map would feature the main actors in the supply chain as system nodes, as well as the financial, material, and information flows among them. The mapping covered the flow from direct material suppliers all the way to retail channels, including, in some cases, the actors involved in the treatment and valorization of waste and by-products, based on the level of connection to the main supply chain, and to the available information gathered. Following the development of each supply chain map, the research team validated their contents with actors present at different stages of each supply chain, who either attested to the accuracy of the mapping, as well as pointing out blind spots or missing nodes/connections. Having received this feedback, a definitive map for each supply chain, including the actors' feedback, was constructed.
- *Innovative case histories research*: in parallel, in keeping with the practical, implementation-centered intention and goals of the project, a set of 28 innovative case studies, relevant to each of the five supply chains were studied and summarized, intended to be used as input for both the proposed solutions to challenges, and to foster conversation in the participatory mechanism sessions further ahead.
- *Participatory mechanisms:* while a better understanding of each supply chain was established by mapping and quantifying their dimension, complexity, and economic relevance at a regional level, the next step of the project was designed to include the personal experience of several actors from each supply chain, as well as their interaction with institutional representatives. This phase was conducted, in line with the scientific literature analyzed, on the topic of the circular economy, which revealed the need to involve stakeholders at the level of the supply chain in the development and evaluation of possible directions for the transition from a linear to a circular and more sustainable system, in order to understand potential, dormant assets and possible barriers [13]. The process followed therefore placed emphasis on the engagement of relevant stakeholders for contemporary agri-food circular economy research. Taking the project's final objective of public policy development into account, it was decided that it was best to employ a participatory, deliberative approach to the validation of the quantitative analysis, as well as to the understanding of challenges faced by each of the supply chains. Therefore, a series of supply chain circularity and ecological transition-focused focus groups were designed and implemented.
- *Data analysis and drafting of public policy proposals*: as all necessary inputs were gathered, the following and final step was to synthesize and process the data gathered along every step of the research process and translate them into actionable recommendations for the Piedmontese regional government.

In total, five focus groups were performed, in which a total of 35 people participated actively and collaboratively. Of that number, 26 represented the rich diversity of the agribusiness sector: 21 companies, including agricultural producers, processors, and distributors, with participation from both family-owned businesses and some of the largest food and agriculture companies in the region.

In order to best represent the multiplicity of actors of each supply chain, at least five companies were selected per supply chain, considering the different production phases, the size of the company, the innovations implemented within some companies, and their size in terms of turnover and production. The need to involve the private sector is often cited in the scientific literature regarding the implementation and improvement of circular economy practices, given the key role that private companies play, as they possess greater capabilities and resources than other stakeholders [12]. Nevertheless, in addition to the private sector, all the regional innovation poles, regional government representatives, and the main regional research institutions (*Ires Piemonte* and *Environment Park Torino*) were invited to participate in these transversal worktables.

The focus groups were developed with the following structure:

- Introduction to the University's project and its objectives;
- Explanation of the context of the project at the European (*Green Deal*), national (*SNSvS*), and regional (*SRSvS*) levels;
- Presentation of the UNISG vision of the Circular Economy for Food (3C);
- Validation of the quantitative, qualitative, and financial representation of the specific supply chain;
- Illustration of the main waste products and by-products of the supply chain under analysis;
- Emerging issues related to the application of circular activities or the implementation of circular practices that also address the management and valorization of the supply chain's outputs;
- Presentation and identification of relevant case studies and virtuous business models of the circular economy applied to the agri-food sector, leaving a space for discussion among participants for their assessment of the feasibility of applying such examples in the Piedmont context;
- Further insight and discussion on the scenario of the circular economy in Piedmont.

In order to engage people and encourage dialogue among different actors (business representatives, innovation poles and invited researchers, and regional government representatives), a number of questions were posed to each of the focus group participants whose subject was the critical issues in the circular economy. Through answering these questions, as well as helped by the context given by the previous interventions with regard to the current situation and the opportunities that a circular economy and policy change brings about, all participants of the focus groups gave interventions on the circular economy potentialities and proposals that individual businesses, the supply chain, and the regional context as a whole held, and the steps and concerns about the implementation of an ecological transition agenda.

These interventions were recorded and furthermore analyzed for commonalities and differences, as well as to their relevance to the SRSvS and SNSvS. After recording and summarizing all interventions, a brief report for each supply chain's focus group was constructed and shared with the participants, in order to validate that their positions and opinions were accurately represented and that no further inputs were missing from the research.

2.3. Construction of Public Policy Proposals from the Information Gathered and Processed

In order to help achieve the objectives of the SRSvS, a set of Public Policy and Best Practices proposals was given to the Piedmontese regional government. These proposals, outlined with the purpose of being put into practice by the institutional body, were the result of a careful analysis, based on the understanding of all those problems and opportunities in a circular and systemic key that characterize the agri-food sector of the Piedmontese

territory. In this way, with the participation of Slow Food, a non-profit international association committed to restoring value to food, sectoral and transversal recommendations were identified among the five supply chains that are consistent with the SRSvS in order to boost Piedmont's ecological transition, by the combination of desk-based research, the intervention of citizens represented by the Slow Food Piedmont and Aosta Valley Association [51], the focus groups and the proposals for innovative solutions suggested by the innovation poles, as well as by the students of the master's degree in Food Innovation and Management at UNISG.

In fact, a full understanding of the opportunities and problems that characterize a certain territory allows the political decision maker in possession of these elements to prepare adequate responses, giving impetus to innovation and social experimentation, in line with the objectives of the SRSvS and aligned with the Ecological Transition guidelines [52].

As a result of the gathered information, a total of 45 proposals for actions impacting the SRSvS divided by supply chain and nine transversal recommendations addressed to regional policy makers were listed. In the following Figure 3, it is possible to read a graphic synthesis of the process that led to the generation of the specific public policy proposals.

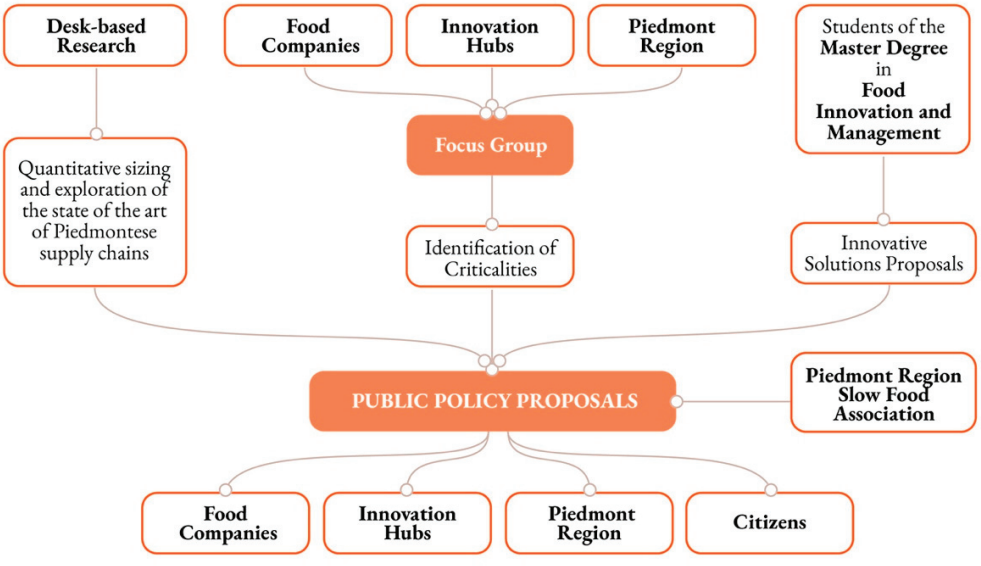


Figure 3. Process followed for public policy proposal generation.

3. Results

The entirety of the results and proposals produced by the *Circular Economy for the Piedmontese Food System Project* were delivered in a detailed report to the regional government of the Piedmont region, in order to support the regional government's ecological transition goals and implementation. However, in the following section, some illustrative examples, with the kind of results reported, their mode of presentation, and their relevance to the overarching project objective, are shown, in accordance with the stages of the methodological structure presented in the previous section, with a particular emphasis on the results of the stages of *Academic and Sectoral Document Discovery*, *Quantitative and Qualitative Data Analysis* from different sources, and *Supply Chain Mapping*.

Furthermore, the results from the *Participatory Mechanisms* stage are summarized in the following sections, as the transversal challenges found to be common to all of the five supply chains under consideration are included in the results.

3.1. Examples of Project Outputs

3.1.1. Academic and Sectoral Document Discovery

As the first product of the research, and in order to better understand the complexities of each supply chain at a glance, what were considered relevant production and actor numbers were reported for the latest recorded number, which, in most cases, was 2019 (Figure 4). These aggregate numbers, along with any relevant information were also shown during the focus group sessions, allowing for their validation and for a contextualization of the entire supply chain's scale available to all participants.

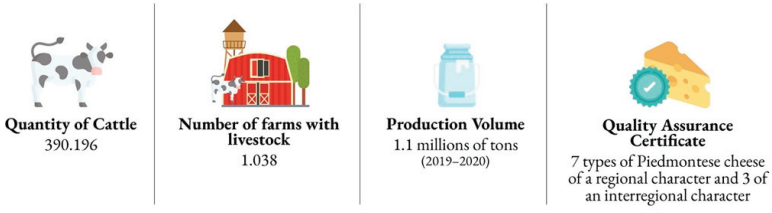


Figure 4. The production and actor quantitative, aggregate summary for the dairy supply chain in the Piedmont region.

3.1.2. Quantitative and Qualitative Data Analysis

Furthermore, employing the data from UNISG's Food Industry Monitor, it was possible to create a generalized representation for the aggregate economic performance for the main players in each supply chain, further contextualizing the reality of the supply chain in terms of its economic potential, as well as any possible investment or income challenges that might hinder a smoother ecological transition within the leading companies of the supply chain, and, by extension, smaller actors without the same access to financial or investment opportunities. These results are summarized in quick overview images (Figure 5).

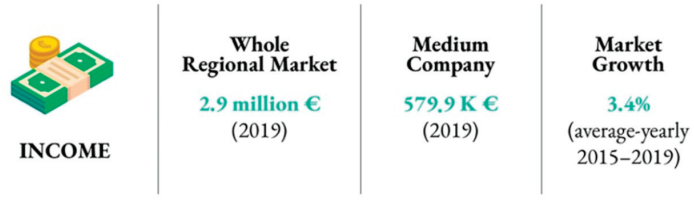


Figure 5. Cumulative supply chain income summary, as presented in the final project report.

In order to better place each supply chain's actors in the Piedmont region's territory, their distribution and possible sub-regional areas to be considered for grouping in future interventions, geographical heat maps were constructed (Figure 6), employing the information from the regional company registry. Furthermore, the geographical representation of the presence of the supply chain's actors in the regional territory helped view areas of overlap among supply chains, where possible transversal interventions could benefit two or more of them at the same time, further guiding policy suggestions by placing the supply chains in a geographical and territorial context.

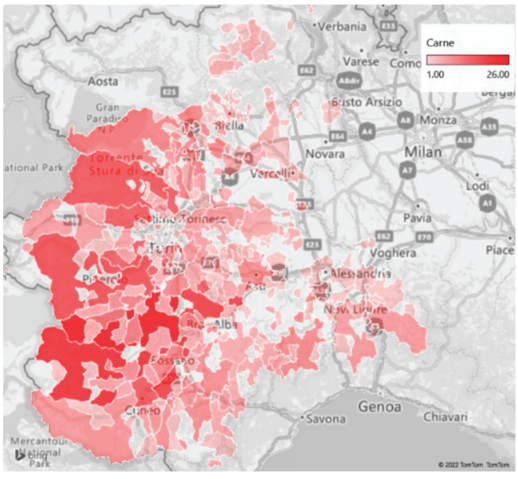


Figure 6. Heatmap of the concentration of businesses classified as participating in the Bovine Beef supply chain according to Unioncamere Piemonte's 2020 database [50]; as presented in the final project report.

3.1.3. Supply Chain Stage Mapping

For each of the supply chains, its corresponding supply chain steps, the number of actors counted as registered in the regional Chambers of Commerce database in each the steps, and the flows of information and material among them, were summarized in simplified supply chain diagrams (Figure 7), intended for a top-level view of supply chain dynamics. These diagrams served for both validation and understanding by each supply chain's selection of stakeholders participating in the focus groups, such that the level of understanding of these sessions, as well as the following steps of the research, were agreed among those involved.

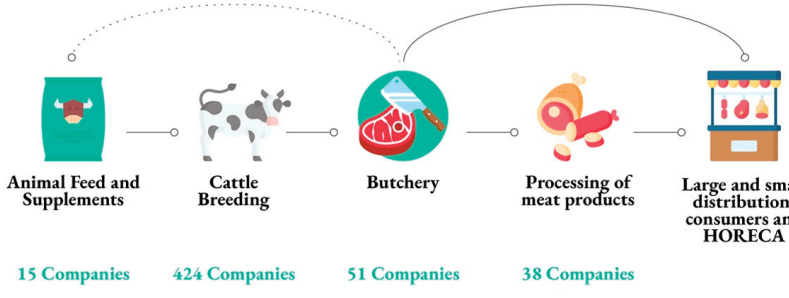


Figure 7. Simplified supply chain map diagram, as validated in the focus group session for the Bovine Beef supply chain.

Additionally, the information from previous diagrams was expanded, based on the information gained during the document and discovery steps of research. This is a more detailed flow diagram, in Figure 8, illustrating the standard steps of the production and supply chain for each product, as well as listing the main inputs, waste, by-products, and outputs for each.

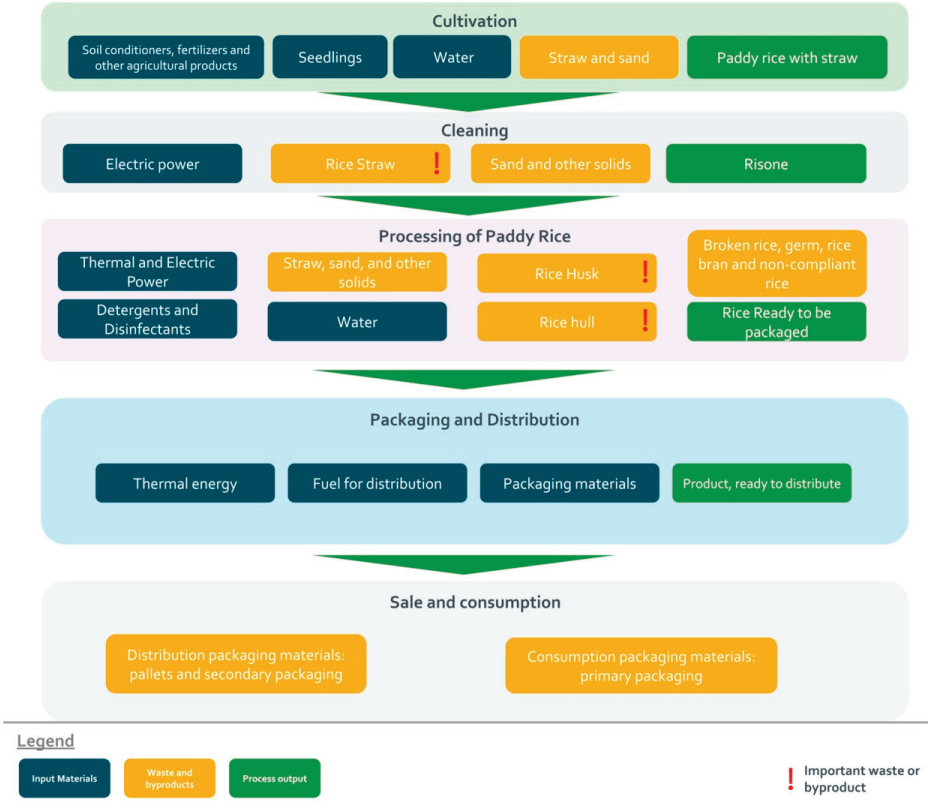


Figure 8. Flow diagram of the main supply chain steps with the main inputs (in blue), waste and by-products (in yellow), and products (in green), as reported both in the focus group sessions, as well as the project report for the Rice supply chain [53].

In addition to this information, an emphasis (marked as a red exclamation point) could be placed on any of the waste/by-products, denoting their importance and/or challenge for the supply chain as a whole, be it in terms of environmental impact on disposal, or volume produced per unit of finished product.

The final diagram produced to illustrate each supply chain's structure and dynamics was an actor categories map (Figure 9), in which all possible independent actor categories were identified and placed within a grouping according to their position within the supply chain. In this case, connections were also drawn according to the information gathered during the steps of document discovery and supply chain mapping, using both sectorial and academic sources in order to list the main actors of each supply chain, as well as their relationships. In it, categories of actors, grouped by their most relevant activity or input to the supply chain were presented, and then ordered into greater categories, representing their role in the supply chain overall. Finally, the direction (uni or bidirectional), intensity (direct/indirect or constant/sporadic) of their relationship were shown using arrows. The criteria employed for defining a relationship were the existence of either financial (e.g., payments for inputs or services), information (e.g., sales numbers, production practices, or marketing information) and material (inputs, semi-finished and finished products) flows.

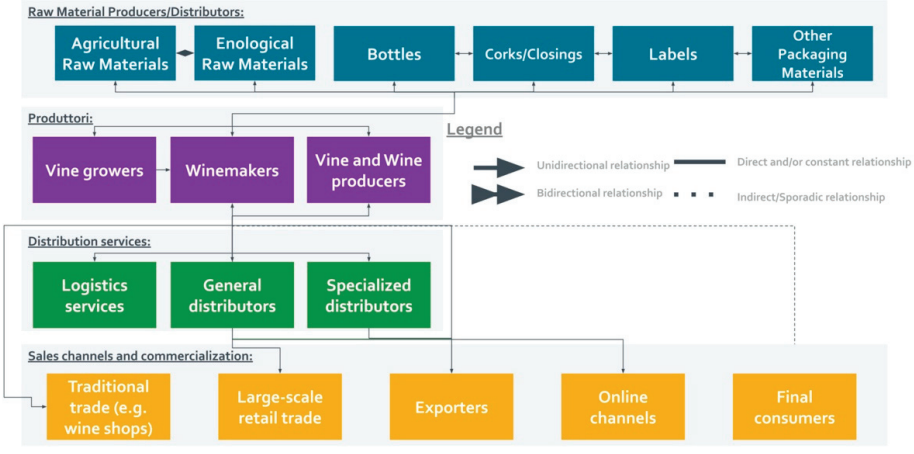


Figure 9. Mapping of the main supply chain actor categories and their groupings for the Wine supply chain, along with their commercial connections.

3.2. Main Waste Products and By-Products Found by the Project

After having carried out a thorough analysis of the material flows for each supply chain under consideration (Figure 8), a significant part of the investigation was dedicated to the current disposal methods for waste and by-products of the production chain and to the main problems related to their management. Thanks to the discussion fostered within the focus groups with the various stakeholders, both critical issues in the standard disposal method and possible solutions for their valorization in a circular way emerged, so that a solution could be found to maintain the value in a production chain of what would otherwise be thrown away.

Different types of packaging waste were indicated in the five supply chains and, through focus group comparisons, some sectors were found to be problematic (as in the case of meat, wine, and water, see Appendix A). However, they are to be considered as part of municipal solid waste management.

It is important to emphasize that those analyzed are five agri-food chains that are intrinsically different from each other and, for this reason, the disposal method for by-products and waste is different in each chain. This is evident in the case of the beef supply chain, where the circular economy is more mature, with a purpose being applied for almost all the outputs from the production process [54] and, therefore, few difficulties are found in the disposal of these, as their value is maintained by using them as inputs in a new production process. In the beef sector, in fact, many animal by-products are commonly used in important production sectors, such as the pharmaceutical, feed, and leather industries, where the by-products are employed to extract bioactive compounds, nutrients, or raw materials for the production of leather, respectively

Innovative Case Study Research

In conclusion, in order to better support the participative stages of the project, a series of 28 relevant case studies for each supply chain were gathered, specifically looking for already implemented, regional-to-multinational-scale initiatives that included circular economy practices or business models as their main feature. These were employed to foster discussion among focus groups participants, as well as included as examples for ideas or practices that could be applied to each of the regional supply chains.

Each case study was summarized on a quick-reference card (Figure 10), in which the main points of interest for their use as a basis for regional proposals (i.e., supply chain stages, principal resources, and reported benefits) were included.

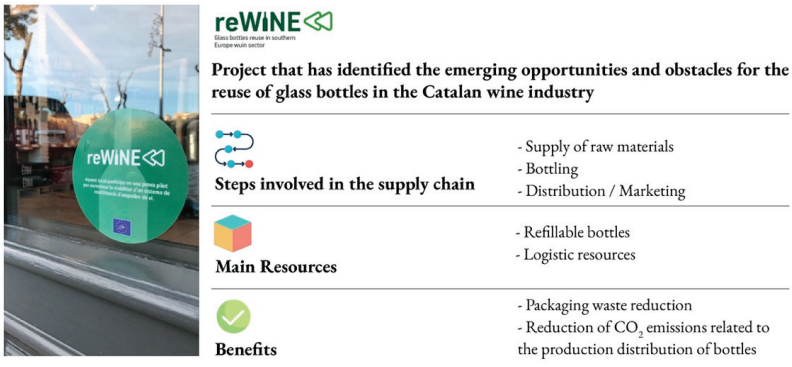


Figure 10. Example of one of the quick-reference cards for a case study regarding the Wine supply chain.

All of the 28 circular economy business model and practice case studies included in the detailed report are shown in Table 1. They represent a relevant overview of the possibilities for circular economy developments in each supply chain, serving as reference for the construction of the proposals tailored to the Piedmont region's reality and current issues in each supply chain.

Table 1. A summary of the case studies presented and validated in the focus group sessions, and included in the final project report.

Supply Chain	Name of the Case History	Circular Business Model/ Practice Shown
Wine	reWINE	System for the return and reuse of glass wine bottles at a local level
	VEGEA	Valorization of grape pomace for manufacturing of leather-like fabrics
	Caviro group	Production of bioenergy and compost from waste from pruning and destemming
	Poliphenolia	Extraction of grape pomace polyphenols for cosmetics production
	NOMACORC	Adoption of cork substitutes from recycled and bio-based alternatives to cork wood
Milk and Cheese	KRINGLOOP WIJZER	Monitoring soil nutrient cycle
	FrieslandCampina	Tool for assessment of biodiversity improvement in the dairy sector
	BIOCOSI'	Production of bioplastics from wastewater
	ORIGAMI Organics	Production of fabrics based on milk waste
	fluence	Biogas production from ricotta whey, buttermilk, and wastewater
	UNTER/EGGER	Production of cosmetics based on nutrients extracted from whey
	Milk Brick	Production of building materials based on milk waste
Rice	VIPOT	Production of biodegradable pots based on rice husk
	GENIA BIOENERGY	Biogas production from rice straw
	IKEA India	Production of furniture items from rice straw
	RICE HOUSE	Production of building materials based on rice waste (husk, chaff, straw)

Table 1. *Cont.*

Supply Chain	Name of the Case History	Circular Business Model/ Practice Shown
Water	PABOCO	Bottles made from sustainably sourced wood fibers
	Carlsberg	Reduction in plastic use in beverage multipacks
	E6PR	Biodegradable and compostable secondary packaging for beverages (multi-pack rings)
	Ferrarelle	Bottles composed of 100 percent R-PET
	VERITAS	Returnable glass bottle service in partnership with retailer
	Pfand System-Germany	Public bottle return system with incentives for adoption
Bovine Meat	BovINE	Reward systems to farmers who practice regenerative agriculture
	Water2Return/Bioazul	Extraction of nutrients in slaughterhouse wastewater
	Circ4Life/Alia	Co-creation of circular synergies among various actors in the supply chain
	La Granda	'Symbiotic farming' for animal husbandry
	BTS	Biogas production through wastewater
	Fileni	Biodegradable and recyclable packaging for meat products

In addition to the analysis of these real case studies, which made it possible to examine the existing circular realities in the panorama of the five selected agri-food chains, 39 students of the graduate degree in Food Innovation and Management at the University of Gastronomic Sciences of Pollenzo were encouraged to respond to the challenges that emerged in the food sectors involved and to draw up hopefully applicable circular project proposals. A total of 20 potentially innovative food projects have emerged, involving the point of view, sensibilities, and ideas of the future generation of professionals in the food sector in the design.

3.3. Challenges and Obstacles to a Regional, Supply Chain-Level Transition

To contextualize the challenges and issues raised during the desk-based research, as well as during the participatory mechanism stages of the project, a series of *transversal issues* (i.e., pertaining to two or more supply chains) (Appendix B) were identified, as well as their connection to the theoretical framework chosen for the research, and their potential impact on the goals set by the regional ecological transition plans.

In this scenario, it is preferable to make a brief focus on the 3 Cs of the Circular Economy for Food, presented in the Figure 11 [48], to better understand why it was decided to analyze the transversal problems also from that point of view.

In short, the new circular economic paradigm, when applied to food, takes as its starting point the preservation and regeneration at a local level of *Capital*, the first C, the natural Capital that contributes to providing goods and ecosystem services for humanity and which are necessary for the survival of the environment from which they are generated. In particular, natural, cultural, and economic Capital are therefore inseparable factors, supported and in dialogue thanks to relational Capital. The second C is *Cyclicality*, which invites us to think in regenerative terms, which comprises the three fundamental concepts of extension, metabolization, and renewability. Extension refers to an expansion of the responsibility of a business; metabolization means the final adding of value, or upcycling [55], with the goal of generating only resources for the same system or another system (biological and technical metabolization cycle) and not waste. In these terms, the emphasis is on renewability, because every action must be in harmony with the regenerative cycles found in nature.

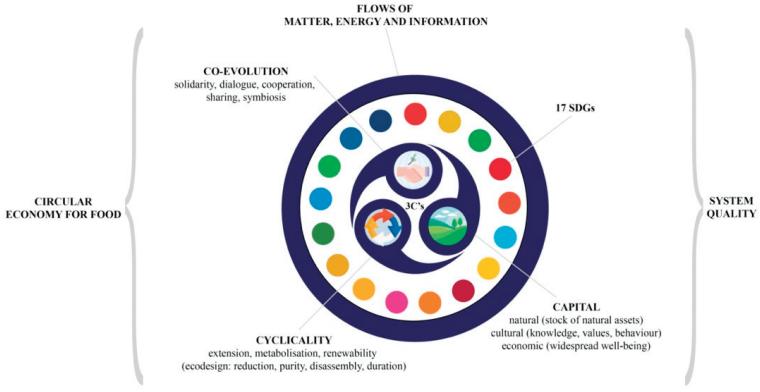


Figure 11. The 3 Cs of the Circular Economy for Food [48].

The last C is *Co-evolution*, inspired by mutualistic symbiosis in nature. It develops thanks to a collaborative paradigm, which through the application of a win–win logic generates a solution that is advantageous for all, among which the environment is included.

Solidarity (between individuals and peoples to reduce social inequality and increase access to quality food), dialogue (between natural and artificial ecosystems, to eliminate the asynchronicity of the human economic model with natural cycles), cooperation (between communities that share values and objectives), sharing (of materials, energy, and information to accelerate the transition and facilitate evolution) and symbiosis (between businesses and between businesses and the community, the local area and the five natural kingdoms) are the priorities on which we must work to give resilience to the circular economic paradigm.

4. Discussion

Once all individual and transversal issues about the five supply chains considered were analyzed and listed, a series of transversal solutions were identified (Table 2), to give their potential for inter-supply chain efficiencies and to generate a higher impact on the food supply chains analyzed, naturally considering the interconnectedness of issues and solutions in the scenario of *Ecological Transition* and *Circular Economy*. In fact, one of the most meaningful challenges for the development and the expansion of integrated food policies was the definition of a series of cross-cutting solutions.

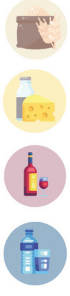
Table 2. The relevant transversal opportunities.

N°	Relevant Transversal Opportunities	Affected Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
1	Biogas production through shared plants for the recovery of waste and by-products of organic nature				3—Air pollution 7—The volatility of energy prices 9—Management and treatment of wastewater from production processes 11—The low valorization of organic waste/subproducts 13—Individual and little collective effort in executing and promoting circular initiatives

Table 2. *Cont.*

N°	Relevant Transversal Opportunities	Affected Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
2	Use of regenerative cultural practices and symbiotic agriculture for biodiversity presentation and resilience				1—Climate Change 3—Air pollution 4—Biodiversity loss 8—The lack of attention to animal welfare 9—Management and treatment of wastewater from production processes 13—Individual and little collective effort in executing and promoting circular initiatives
3	Use of by-products for green building, to propose an alternative to traditional materials made from non-renewable resources				3—Air pollution 7—The volatility of energy prices 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
4	Cross-sectional research on the production of bioplastics from organic packaging waste				1—Climate Change 3—Air pollution 5—Exploitation of non-renewable resources for packaging production 6—The end of life of after-consumer packaging 9—Management and treatment of wastewater from production processes 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives 14—Difficulty of dialogue and confrontation of companies/innovation poles with regional institutions

Table 2. *Cont.*

N°	Relevant Transversal Opportunities	Affected Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
5	Creation of joint participatory tables for the common achievement of competitiveness and sustainability objectives				12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives 14—Difficulty of dialogue and confrontation of companies/innovation poles with regional institutions
6	Using R-PET for water bottles				1—Climate Change 3—Air pollution 5—Exploitation of non-renewable resources for packaging production 6—The end of life of after-consumer packaging 14—Difficulty of dialogue and confrontation of companies/innovation poles with regional institutions
7	Extraction of nutrients from processing and manufacturing waste and by-products for pharmaceutical and cosmetic production				9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
8	Realization of spaces that exploit the sharing economy for the creation of economies of scale				7—The volatility of energy prices 9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives 14—Difficulty of dialogue and confrontation of companies/innovation poles with regional institutions

The *Transversal Opportunities* were analyzed through various aspects, such as:

- *Affected supply chain*: in particular, describing which supply chain they refer to;
- *SDGs affected:* describing which of the SDGs are affected by the opportunity;
- *3 Cs of Circular Economy for Food:* indicating which 3 C they concern—Capital, Cyclicality, Coevolution;
- *Related issues:* describing which other transversal problems are referred to. In particular, reporting the content connection between the transversal opportunities and the individual issues. In particular, they refer to the contents present in the regional MAS.

As a final result of the research, a series of *Public Policy Proposals* were presented to the regional institutional bodies. In particular, they were based on the evidence gathered and analyzed along all stages of the project. The proposals were designed in such a way that they could be indirect to the Piedmontese territory and its supply chains, as well as being consistent with the goals for Ecological Transition and the CEFF framework [48].

Especially, the analysis of the five chains allowed the adoption of a systemic approach based on the needs of the territory, suggesting integrated and coherent recommendations with the SRSvS to align different political agendas and cross-cutting issues. From the synthesis of these, some *Transversal Public Policy Proposals* have been developed and collected in Table 3, which suggest interventions, tools, and strategies common to all research focuses, to be implemented according to different contexts.

Table 3. The Transversal Public Policy Proposals.

N°	Transversal Public Policy Proposals	Affected SDGs	3C of CEFF
1	Promote business participation in specific funding programs aimed at boosting agribusiness investments to improve the competitiveness of the agricultural sector, ensure sustainable management of natural resources, and promote climate actions, achieve balanced territorial development of rural economies and communities (supply chain and district contracts, RDP 2014–2022)		
2	Promote new forms of territorial aggregation between enterprises aimed at fostering innovation in agribusiness and the integration of activities characterized by territorial proximity (food district contracts)		
3	Involvement of stakeholders through the establishment of specific working tables to identify shared solutions with impacts on the community		

Table 3. *Cont.*

N°	Transversal Public Policy Proposals	Affected SDGs	3C of CEFF
4	Advisory activities and accompaniment of economic operators toward the development of a by-product and waste supply chain and to the development of new sustainable materials from them.		
5	Connecting the regional economic tissue with research and development facilities (Piedmont universities, research institutions, innovation hubs, etc.) by enhancing their expertise for positive spillover to their local area		
6	Promoting the digitization of bureaucracy and its simplification/streamlining		
7	Mapping the supply chain for by-products and waste in the Piedmont region		
8	Promote the provision of training courses aimed at practitioners focused on sustainable production systems, facilitating access to resources, best practices, and useful tools		
9	Involvement of stakeholders (municipalities, farmers, restaurateurs, teachers, consumers, recycling operators) by setting up roundtables to promote conscious and responsible consumption by the citizenry		

The Transversal Public Policy Proposals were proposed and analyzed through two of four aspects already mentioned for the Transversal Opportunities: SDGs affected and the 3 Cs of the Circular Economy for Food.

These proposals are not only transversal to all supply chains, but points of contact between them can also be highlighted. For example, the relaunch of investments in the

agri-food sector requires a combination of interventions that promote synergy between companies and, at the same time, support their financial commitments.

There is also a major issue of capacity development, namely, the need to create skills within companies and the public administration. In fact, during the analysis of many supply chains, training gaps were found in relation to the impact (especially in the long term) of good/bad agricultural practices, as well as technological and *information technology* gaps. Digitization is now a necessary step to remain competitive in the current context, allowing companies that decide to invest to work more productively, and plan and organize processes more efficiently [56].

In addition to this, the Piedmont area has a specific need, as emerged during the phases of the holistic diagnosis: to strengthen the network at several levels, promoting positive synergies both between operators in the same sector and between players in the same supply chain but who work in different areas.

From this point of view, even those network nodes not included in this research could be included in subsequent analyses (such as restaurateurs, teachers, but also consumers in general) whose awareness and personal decision-making capacity certainly plays a fundamental role in transition to a more sustainable and shared Piedmontese food system.

The information obtained through the research and design path addressed was useful in outlining which circular *Public Policy Proposals* should be indicated to the institutions in order to improve the performance of the circular economy in the region.

With a view to analyzing the potential, already existing circular aspects within the supply chains taken into consideration, during the research process, there was a need to further explore the presence or absence of a waste and by-product recovery chain of the five supply chains, as part of the mapping stage, as well as including any potential actors involved in these activities, in further stages.

This need represented a more solid information base for the phase of elaboration of local policy proposals, expanding the range of analysis of the individual supply chains and allowing us to consider also the phases subsequent to those of the sale of a food product, or those connected to the disposal and to the correct management of the outputs. Extending the analysis to this phase, not always considered in the evaluation processes of a supply chain, allows a more effective integration of further waste valorization chains in the regional economic landscape, triggering high-value systemic economic and production networks, in terms of sustainability. At this point, the phase of participatory processes could be extended to include these additional stakeholders, beginning the construction of a common perspective.

In fact, the participatory mechanisms put in place along this research path represented an opportunity for sharing knowledge, for networking among professionals and companies that, albeit in the same territory and in the same agri-food sector, use different production methods.

In brief, the strengths of the research developed were already highlighted and guaranteed by a broad, evidence-based, and constructed picture of the current state of art of the five Piedmontese agri-food supply chains—*wine, milk and cheese, rice, water, and bovine meat*—in which over 3200 companies were analyzed, and by their hypothetical future scenario, which emerged during the focus groups. In detail, as reported above, the scientific research enclosed the results of the five focus groups, in which a total of 35 people participated in an active and collaborative way, in particular, in a free and spontaneous discussion about the sustainability perspective of the food supply chain. Of this number, 26 represented the rich variety of the agri-food sector: 21 companies, including agricultural producers, processors, and distributors, with the participation of both family-run businesses and some of the largest agri-food companies in the Piedmont region. In this context, the information collected, the points of view, and the concerns expressed during the focus groups, the inspiring case studies and the priorities of the SRSvS, were summarized in:

- 45 recommendations/proposals for impacting actions on SRSvS divided among the five sectors most deeply involved in research innovation poles and research centers;

- 11 recommendations with a transversal approach (on the fivesupply chains);
- 20 indications on areas that should be explored through specific applied research (on the five supply chains).

5. Conclusions

Food has always been an element of connection between the environment, culture, society, and economy. For this reason, nowadays, it can be the key to addressing some of the many and complex contemporary challenges [9]. From this point of view, public policies, in conjunction with a socially and environmentally responsible design approach, become an indispensable tool and aid to act concretely, to respond to the needs of territories and communities, and to support their identity, acting on a local level, but leading to wider positive spillovers [26,57–59]. In more detail, the systemic approach adopted in this research path, located in the Piedmont area, plays a significant role in the design of adequate articulated solutions in response to complex and interconnected problems, such as those connected to a local linear agri-food system that requires a sustainable transition in harmony with the different peculiarities of the territory. To achieve this objective, which started from the analysis of the specific agri-food chains of the region to direct the development of targeted food policies, the active participation of the interested parties was fundamental, through the creation of real focus groups, whose objective knowledge supports policy makers in the formulation and implementation of more sustainable and identity-based decision-making and operational plans. Certainly, this research will be able to undertake further future developments, expanding the field of action not only to other Piedmontese companies belonging to the agri-food chains already mentioned, but also to entrepreneurial realities outside the identified territory. Furthermore, continuing to exploit a multi-stakeholder approach, it will be interesting to implement the network of territorial connections, among companies, research institutions, universities, and agri-food professionals, more generally, in order to find new and more interesting opportunities for the enhancement of agri-food sector waste, supporting the levels of territorial resilience. This potential direction necessarily implies the continuation of a transdisciplinary research, which aspires to innovative results through the strategic interaction among different disciplines and areas of study, involving not only agricultural and gastronomic sciences, but also the branches of chemistry–energy, systemic design, eco-design of processes, products, services, biological and environmental sciences, and much more. In this scenario, the role of an enlarged and permeable scientific community is essential to contribute to the evaluation of the opportunities of the circular economy at the level of the food supply chain, first of all to spread awareness of the existence of good practices and innovative processes capable of making organic and non-organic waste of the agri-food chain new and precious resources for other production possibilities; secondly, to decisively support political decision makers in undertaking sustainable long-term solutions. In fact, it is good to remember that without a collaborative and co-evolutionary effort, scientific research is not enough. At the same time, the political class cannot undertake sustainable pragmatic solutions without interaction with the scientific community, with the network of local businesses, citizens, and the multitude of local actors. The natural, social, and cultural capital of the planet requires urgent actions, in terms of protection and regeneration; for this reason, it is right to ask how to accelerate the ecological transition. Circular solutions close to those proposed in this contribution are progressively developing, in the current panorama; however, for a paradigm change to really take hold, it is necessary to guarantee an economic feasibility of the solutions found, which today represents perhaps one of the most complex limits to be overcome in research projects in the sector of the circular economy and environmental sustainability. For this reason, it is necessary to develop transparent support methods for companies and organizations that decide to undertake circular and sustainable solutions, through a system of benefits and concessions, which can reduce the economic challenges to be undertaken along this transition path. This would consequently make it possible to make more accessible products and services that derive from sustainable and circular

choices, which today, as in a paradox, remain the prerogative of a high-spending public, making sustainability an economic, as well as an environmental, challenge.

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Institutional Review Board Statement: Not applicable for studies not involving humans or animals.

Informed Consent Statement: Not applicable for studies not involving humans.

Data Availability Statement: A part of the data was obtained from Unioncamere Piemonte and is available with the permission of Unioncamere Piemonte.

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Conflicts of Interest: The funders took part in the organized focus groups and contributed to the data collection essential to the realization of the research project described in this paper, making their databases available.

Appendix A

This section contains details and supplementary data on the main issues identified within the individual supply chains.

Table A1. A Summary of the main issues with standard disposal, and circular opportunities for waste and by-product valorization by the supply chain.

Supply Chain	Waste or By-Product	Standard Disposal Methods	Disposal-Related Issues	Circular Opportunity of Valorization
Wine	Prunings and Stalks	• Livestock Feeding • Burning in the field • Soil Fertilizer	• Poorly digestible for animals • Creation of particulate matter in the atmosphere	• Biogas production • Recovery of antioxidant compounds (polyphenols) • Activated carbon or lignocellulosic fractionation from stalks • Bio-based packaging from prunings
	Grape Pomace	• Production of distillates (i.e., grappa) • Spread on the ground • Compost	• Release of carbon substances	• Biogas production • Extraction of polyphenols for cosmetics/pharmaceutical purposes • Leather-like fabric production • Natural textile dye
	Wine lees	• Used for wine aging • Distillery	• Can give an unpleasant taste	• Biogas production • Compost • Natural textile dye

Table A1. *Cont.*

Supply Chain	Waste or By-Product	Standard Disposal Methods	Disposal-Related Issues	Circular Opportunity of Valorization
	Waste water and filter cakes	Regular disposal	Difficult to manage	• Biogas production • Extraction of components
Dairy and Cheese	Whey	• Ricotta production • Additive • Livestock Feeding	• Large quantity produced	• Biogas production • Extraction of components for cosmetics/pharmaceutical purposes • Bioplastics production • Milk fiber production
	Packaged expired and non-compliant milk at the factory	• Thrown away according to the rules of recycling	• Food waste	• Livestock feeding • Materials for bio-building • Bioplastic production • Biogas production • Milk fiber production
Dairy and Cheese and Bovine Meat	Waste waters and Sludge	• Regular disposal	• Difficult to manage	• Bioplastic production from waste water • Filtered sludge for biogas production, using the digestate as litter for dairy cow breeding
	Manure	• Soil fertilizer	• If not properly handled, it can create pollutants	• Biogas production
Rice	Rice Straw	• Livestock Feeding • Soil fertilizer • Burning in the field	• Poorly digestible for animals • Deterioration of the growth of rice plants and increased methane emissions • Creation of particulate matter in the atmosphere	• Materials for bio-building • Biogas production • Furnishing objects
	Rice Husk (lolla)	• Disposed as special waste • Animal litter • Electricity production	• Difficult to dispose for high percentage of silica	• Materials for bio-building • Biodegradable pots for floriculture • Extraction of components for cosmetics/pharmaceutical purposes • Production of wood-like material
	Rice Hull (pula)	• Livestock breeding	• Large quantity produced	• Materials for bio-building • Extraction of components for cosmetics/pharmaceutical purposes
Bottled Water	Plastic water bottles	• Disposed of according to the regulations of recycling collection	• Large presence of plastic material • Often dispersed in the environment by consumers • Not designed for repeated use	• R-PET production • Bottles made from sustainable wood fiber • Returnable glass bottle to the shop • Deposit return model

Table A1. *Cont.*

Supply Chain	Waste or By-Product	Standard Disposal Methods	Disposal-Related Issues	Circular Opportunity of Valorization
Bovine Meat	Blood	• Soil fertilization	• If blood is mixed at the slaughterhouse, it is not legally possible to use it as fertilizer	• Creating a bovine-only slaughterhouse for soil fertilization • Biogas production
Bovine Meat Rice Dairy and Cheese	Final packaging	• Disposed of according to the regulations of recycling collection	• Large presence of plastic material • Often dispersed in the environment by consumers	• Use of biodegradable and recyclable packaging • Use of recycled PET trays

Appendix B

In this section, the *Transversal issues* were analyzed through various aspects, such as:

- *Supply chain:* in particular, describing which supply chain they relate to;
- *SDGs affected:* describing which SDGs they refer to;
- *3 Cs of the Circular Economy For Food:* describing which 3 C they pertain to—Capital, Cyclicality, Coevolution;
- *Related issues:* describing other transversal problems concerned. In particular, reporting the content connection between the individual problems.

Table A2. The Transversal issues.

N°	Transversal Issues	Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
1	Climate Change				2—Soil acidification 3—Air pollution 4—Biodiversity loss 5—Exploitation of non-renewable resources for packaging production 9—Management and treatment of wastewater from production processes 12—Lack of communication of information or best practices among the various players in the same supply chain

Table A2. *Cont.*

N°	Transversal Issues	Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
2	Soil acidification				1—Climate Change 3—Air pollution 4—Biodiversity loss 8—The lack of attention to animal welfare 9—Management and treatment of wastewater from production processes 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain
3	Air pollution				1—Climate Change 2—Soil acidification 4—Biodiversity loss 5—Exploitation of non-renewable resources for packaging production 6—The end of life of after-consumer packaging 9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
4	Biodiversity loss				1—Climate Change 2—Soil acidification 3—Air pollution 5—Exploitation of non-renewable resources for packaging production 8—The lack of attention to animal welfare 12—Lack of communication of information or best practices among the various players in the same supply chain

Table A2. *Cont.*

N°	Transversal Issues	Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
5	Exploitation of non-renewable resources for packaging production				1—Climate Change 3—Air pollution 4—Biodiversity loss 7—The volatility of energy prices 13—Individual and little collective effort in executing and promoting circular initiatives
6	The end of life of after-consumer packaging				1—Climate Change 3—Air pollution 5—Exploitation of non-renewable resources for packaging production
7	The volatility of energy prices			 Social and economic Capital	1—Climate Change 5—Exploitation of non-renewable resources for packaging production
8	The lack of attention to animal welfare				2—Soil acidification 3—Air pollution 4—Biodiversity loss

Table A2. *Cont.*

N°	Transversal Issues	Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
9	Management and treatment of wastewater from production processes				2—Soil acidification 3—Air pollution 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
10	Logistics for the management of waste/organic by-products				9—Management and treatment of wastewater from production processes 11—The low valorization of organic waste/subproducts 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
11	The low valorization of organic waste/subproducts				9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 12—Lack of communication of information or best practices among the various players in the same supply chain 13—Individual and little collective effort in executing and promoting circular initiatives
12	Lack of communication of information or best practices among the various players in the same supply chain				1—Climate Change 2—Soil acidification 3—Air pollution 4—Biodiversity loss 8—The lack of attention to animal welfare 9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 13—Individual and little collective effort in executing and promoting circular initiatives 14—Difficulty of dialogue and confrontation of companies/innovation poles with regional institutions

Table A2. *Cont.*

N°	Transversal Issues	Supply Chains	SDGs Affected	3 Cs of CEFF	Relationship to Issues
13	Individual and little collective effort in executing and promoting circular initiatives				5—Exploitation of non-renewable resources for packaging production 6—The end of life of after-consumer packaging 8—The lack of attention to animal welfare 9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products
14	Difficulty of dialogue and confrontation of compa-nies/innovation poles with regional institutions				9—Management and treatment of wastewater from production processes 10—Logistics for the management of waste/organic by-products 11—The low valorization of organic waste/subproducts 13—Individual and little collective effort in executing and promoting circular initiatives

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