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Systemic Design Methodology applied to hazelnut processing

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The manufacturing sector needs to change its linear production model to provide an answer to sustainability requirements. Systemic Design integrates Systems Thinking in the design approach and it proposes a methodology to design different solutions to move towards Circular and Blue economy. The paper investigates the opportunity to apply the Systemic Design methodology to a case study in agri-food sector in order to produce benefits at environmental and socio-economic level. Outcomes obtained by the application of Systemic Design steps to hazelnut processing in Piedmont Region (Italy) are discussed. The case study presents the limits of the methodology, such as the necessity to holistically mapping the local context and the involvement of many stakeholders in the design process. On the other hand, it highlights many opportunities to transform locally processing residues, producing environmental and economic benefits.

Keywords: Systemic Design, design methodology, sustainable manufacturing, agri-food system, circular economy

1. Introduction

The most of critical decisions related to sustainability of materials and production processes are taken in design phase, precisely "*more than three out of four decisions*" [64]. These decisions have important influences on ecological aspects, but also on economic and social ones [47,64]. Therefore, the design phase becomes crucial to obtain different results and impacts. For these reasons, the field of design for sustainability has emerged, which has evolved from product innovation to system innovation [20], reaching the higher level of the radical innovation provided by this approach [12]. In this context is framed the Systemic Design (SD), a design approach with the goal to reach sustainability at environmental, economic and social level [14]. Applying the Systems Thinking to the design process, this *"integrative interdiscipline"* [40, p. ix] combines systems theory and creativity [40]. Nowadays, the Systemic Design Research Networks is growing and the Systemic Design Association (SDA) was founded in 2018 [62].

A more holistic and ecological view of life has changed the way to see complexity, representing a cultural paradigm shift from the Cartesian and Newtonian mechanism [18]. This last one, the linear thinking, in the industrialization period has produced a linear economy which follows the 'Take-Make-consume-waste/dispose' economic model [29,31,48], today considered by many scholars as one of the enemy of the environmental situation as by [35,48]. The claimed paradigm shift is needed to change the economic model and obtain a Circular Economy (CE), which is based on system-driven innovation to define products and services designing out waste [28]. The CE concept, considering measures as "waste prevention", "ecodesign" and "reuse" could represent both a solution to the environmental problems and to the economic ones: "*could bring net savings of € 600 billion, or 8 % of annual turnover, for businesses in the EU, while reducing total annual greenhouse gas emissions by 2-4%*" [Amec (2013) cited by 31]. An explicit commitment of the European Union since 2014 with the relevant statement *"Towards a circular economy: A zero waste programme for Europe"*[30] has put Europe in a forefront position in fighting waste production and the consequent impact on the climate change thanks to action to reach a CE. The role of Design as an essential building blocks of CE, along new business models, reverse cycles and enablers and favourable system conditions, is recognised by the Ellen MacArthur Foundation, which defines the CE as "*restorative and regenerative by design*" [28]. Also, the EU commission has demonstrated the importance of the design phase as driven for innovation [33] with the "*Action Plan for Design-driven Innovation*" [32] introducing the importance of design in innovation policies.

The transition to a CE affects deeply the manufacturing sector, which indeed will face a revolution in the near future for sustainability issues due to its models related to the old paradigm [35]. Considering production and transformation in the agri-food sector, the primary production is responsible for 9 million tonnes (10%) of food waste [61] while the processing phase of 19%, without considering all the other types of waste (fig.1).

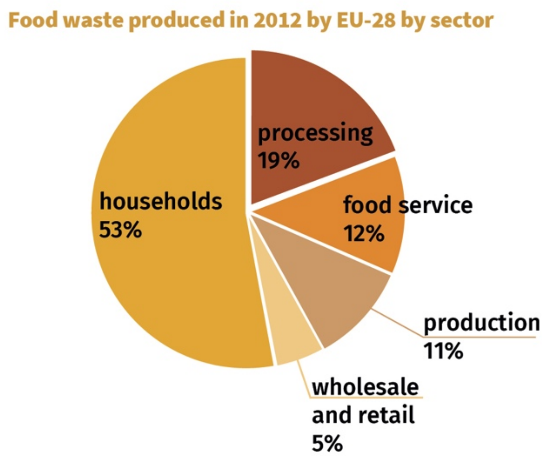

Fig. 1 graph on food waste produced in 2012 by Eu-28 by sector. Based on [61]

Many contributions about sustainability in industrial production processes have fed the debate about the definition of the concept of 'by-products' and the differences between them and "waste". The industrial food transformation is characterized by a high presence of by-products. The potential of the matter that is not used by a particular production process is huge in terms of environmental and economic benefits, as witness by many contributions as [61,49,52]. In line with the definition introduced by Legislative Decree 3 April 2006, n.152, "*Rules on environmental matters*", (or the communication by EU [21]), the by-product is a product of the company which, although not constituting the object of the main production activity, is constantly produced by industrial process and is intended for further use or consumption and, in general, its use is linked to its intrinsic, nutritional, environmental and economic value. By-products of food industry derive mainly from the transformation of agricultural raw materials, characterized by a low environmental impact and a high degree of biodegradability and are mainly used for the followings scope, according to the Italian federation of the food industry [34]: production of animal feed; pharmaceutical and cosmetic industry; fertilizer production; new food ingredients and biofuels.

The SD discipline has developed many different approaches: the one theorized in Politecnico di Torino (Italy) is focused on the energy and production models, following a specific methodology to design open systems. The approach was developed around 5 principal guidelines [14]:

- "*Output–input: The output (waste) of a system becomes the input (resource) for another one;*
- *Relationships: These relationships generate the system;*
- *Autopoiesis: Self-producing systems sustain themselves by reproducing automatically, defining their own paths of action and coevolving together;*
- *Acting locally: The local context becomes fundamental because it values local resources (humans, cultures, and materials);*
- *Human at the centre of the project: A human being is considered connected to its environmental, social, cultural, and ethical context, and its needs become central in design requirements"* [10; p. 3]

Its application permits to design out waste, designing connections between the different production processes and producing sustainability at environmental, economic and social level [14]. This approach was developed in strict relation with the economic paradigm that wants to follow, the Blue Economy (BE). According to it, innovation: follows what happen in nature where waste don't exist for the relationships about the different natural kingdom; responds to basic needs; is driven by physics more than chemistry; wants generate jobs and social capital [53]. SD was also tested in the European RETRACE project (Interreg Europe 1° call) as an effective methodology for the transition of regions to a CE [6].

This article contributes to the research on SD, and specifically wants to validate the SD methodology as an approach to move towards a local CE and BE. According to this research scope, the specific methodology is defined in its current stage. Afterwards it is applied to a specific case study in the manufacturing sector (agri-food), the hazelnuts transformation in Piedmont Region, thanks to the collaboration with a local company. The hazelnut processing is chosen as case study due to its quantitative relevance of the production in the area and the high quality of final products. The study evaluates the application of SD methodology to the case study looking at opportunities and positive benefits created at the environmental and socio-economic level, and also discussing the criticalities and limits of the approach for further researchers.

The paper is divided into four sections: a review of the contributions over the relationships between design and sustainability, SD and the current problems around the food manufacturing sector and waste production (section 1); the definition of the SD methodology (section 2); SD methodology application to the selected case study (section 3); discussion of the application and the validation of the SD methodology as an approach to move towards a local CE and BE (section 4).

2. SD methodology

The SD methodology (fig. 2), that was developed during the years through the application in many projects by the research group in SD and in the 'Open Systems lab' in the Master of Science on 'Systemic Design-Aurelio Peccei' at Politecnico di Torino [8], is composed by eight main steps. The result of each step is the research synthesis in which collected complex data are visualized using the giga-maps [59]. They are used to facilitate the reading of systems' complexity and to promote the dialogue between different partners involved in innovation processes.

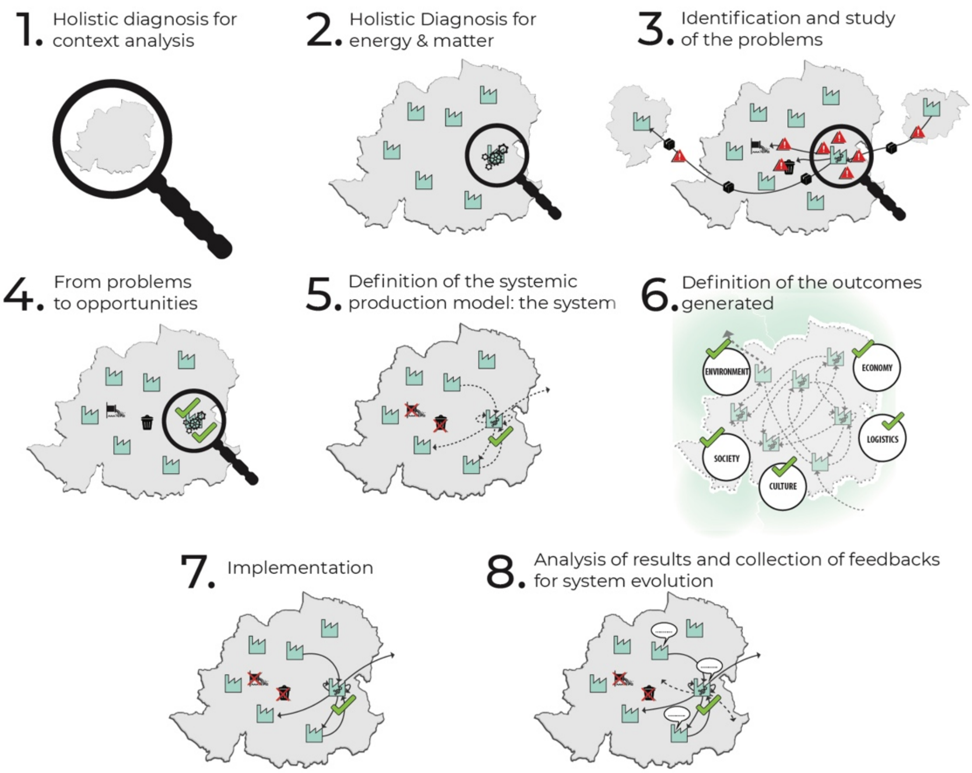

Fig. 2 visual representation of the methodological steps of Systemic Design. Based on the figure presents in [8].

The first step of SD methodology consists in the Holistic Diagnosis (HD): a holistic analysis of the current state-of-the-art and it is performed through field and desk researches [10]. It is divided into two parts that present different goals: *HD for context analysis* (step 1) and *HD for energy and matter flows* (step 2) of production processes. During the first part, the geographical area where the production process is currently located is analysed to highlight geographical, cultural and economic characteristics useful to identify main drivers in the design process. The second step focuses on matter and energy flows analysis of the current production model. It consists on assessing the quality and quantity of raw materials (inputs) that enter into the production processes, and of by-products and waste (outputs) that come out from it. In this phase are also identified all the stakeholders involved in the current linear production model and the typology of relationships already present. The result of HD process are giga-maps that visualize the complexity of the relationships inside production systems, mainly based on material and energy flows.

In the HD process, also the economic situation is analysed. The financial statement that considers assets and liabilities is evaluated. Moreover, a matrix developed by Deloitte in the framework of the SD course, is used to assess the company business's core strategy. It summarizes and visualizes the whole scenario and is based on data combination concerning the company's organization, financial statement, trading relations and market dynamics (fig. 3). After the decision of the different weights, each voice on y-axis is crossed with the x-axis and is defined the strategy based on the percentage weight (the hinted presence area, the attention area, the focus area). The analysis of the situation permits to define the 'linear matrix' which reflects the current strategy

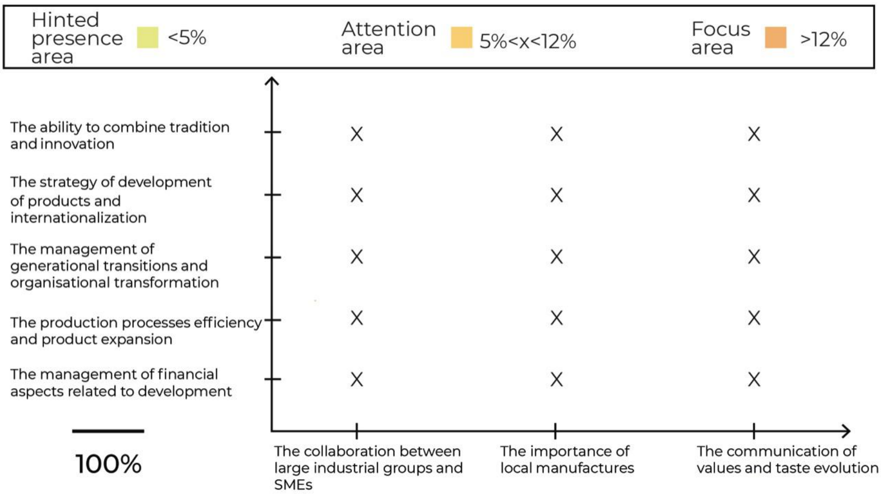

Fig 3. Matrix developed to evaluate the business strategy. In the y-axis the five indicators that describes the philosophy of the company, which in total have to weight 100%, and in the x-axis the three main areas of trading relations that describe the business. After the decision of the different weights, each voice on y-axis is crossed with the x-axis and is defined the strategy: the hinted presence area which is below 5%, the attention area with score between 5% and 12%, the focus area with more than 12%.

After the collection of data about the state-of-the-art, it starts the *Identification of the problems* (step 3) which is enabled by the visualization of the complex situation through HD giga-maps. It is focused on highlighting the complexity criticalities of the linear production models at environmental, economic and social level. Critical aspects are identified during field visits and interviews, and integrated with a desk research online and offline on databases and scientific contributions for an in-depth investigation. The problems identified are considered 'leverages for the change' and turned into potentialities to develop and design a new system – (step 4) *From problems to opportunities*. In this phase, the principal guide-lines of the SD approach, previously described, are taken in consideration. Based on the research of existing case-studies for sustainable technological and social innovation, the goal is to look for solutions to solve the problems identified. The outputs are enhanced as input for the same production processes, or other manufacturing/economic sectors, taking into account their intrinsic quality and their properties. Based on these information and thanks to their creativity, designers are able to design new potential fluxes of matter and energy, but also money, information, .. which become the relationships among the component of the system identified in the HD analysis, obtaining a different open system. More than one possibility for each problem is found, which can be innovative at technological and social level. A particular attention is given to the technologies and practices already presents in the local geographical area which are identified through online and field researches.

All the opportunities found are selected in (step 5) *Definition of the system.* The first selection is based on the context's and company's characteristics assessed in the HD analysis (step 1 and 2). Based on them, the new business strategy to follow is also defined thanks to the visualisation of a new matrix, the systemic one. Afterwards, the opportunities are evaluated based on their feasibility and potential impact, using a qualitative method (fig. 4), inspired by the benchmarking and visualized in a radar chart. The parameters evaluated are four:

- environmental sustainability: based on parameters as the quantity of waste avoided from the landfill;
- technical feasibility: based on the quantity of output-input available, the enterprise know-how and the know-how presents in the local context;
- economic feasibility: based on the type of investment, considering costs and benefits, evaluating if it can be done internally, or within the collaboration of an external company, or completely done by an external company that can create new start-ups;
- the social and cultural impact: evaluated based on the characteristics found in the HD for context analysis.

For each axis is given a score of maximum 3 and the result is a score of maximum 12.

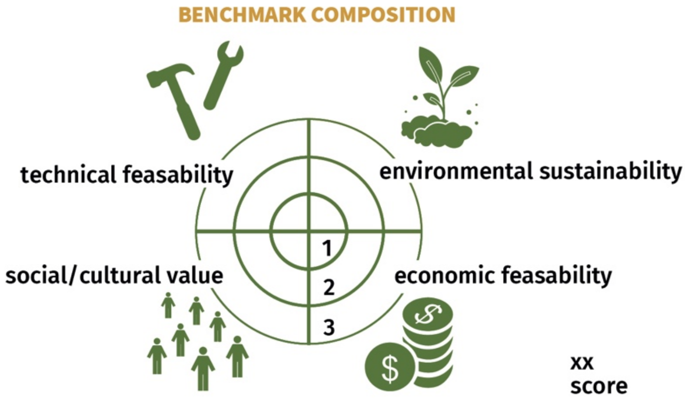

Fig. 4. Qualitative method used for the evaluation of the new opportunities, inspired by the benchmarking and visualized in a radar chart

The total score eases the selection of opportunities, although it requires a strong and active collaboration between the designers/researchers and the company's stakeholders. The 5° step permits to define the new production model, where the fluxes are changed and are included the new feasible one, the new potential actors are considered, passing from a linear to a systemic production model.

The design process ends with the *Definition of the outcomes generated* (step 6) focuses on the preliminary evaluation of the impact and benefit created regarding the economic, socio-cultural and environmental level. In particular, to define the economic impact, a business development plan is studied, defining the financial statement for the first five years of operation.

After this design phase, the process expects the *Implementation phase* (step 7), which involves all actors and stakeholders recognised locally, to realize a final feasibility study and to implement systemic proposals. Further analysis of results and the collection of feedbacks are needed during the implementation phase to improve the project and to allow the discovering of always new opportunities, making the system and the process autopoietic - (step 8) *Analysis of the results and collection of feedbacks for system evolution.*

3. Case study: the application of SD methodology to hazelnut processing in Piedmont Region

A real case-study was chosen for the application of the SD methodology in order to discuss the methodological steps and the main outcomes created. The agri-food sector was selected for its relevance in the local context selected for this research, Piedmont Region (IT), with almost 3.000 food companies considering the total 33.000 companies in the manufacturing sector in 2011 [39], and around 67.000 farms in 2010 for 1.000.000 ha of Useful Agricultural Area (UAA) [38]. In particular, the hazelnut processing was chosen for the quantity of by-products and waste obtained at the end of the processing phase. A SME leader in the Italian hazelnut processing sector, "La Gentile srl" [41], based in Cortemilia, (Cuneo, IT) was involved in the co-design phase. It is operating in the sector of hazelnut shelling and in the preparation of semi-finished hazelnut-based products.

Only the first six steps of the SD methodology are discussed in this study. The application of SD methodology to the selected case study has concluded with the discussion of systemic proposal with the company for collecting main feedbacks and for discussing limitations and possible implementations.

3.1. Holistic Diagnosis of the territory and hazelnut cultivation

The HD method started with the investigation of the context where the company is located: Langhe area (Fig. 5), a strategic and important productive district for the Piedmont Region, especially in the agriculture sector, in Cuneo province which accounts the 37% of regional enterprises [38].

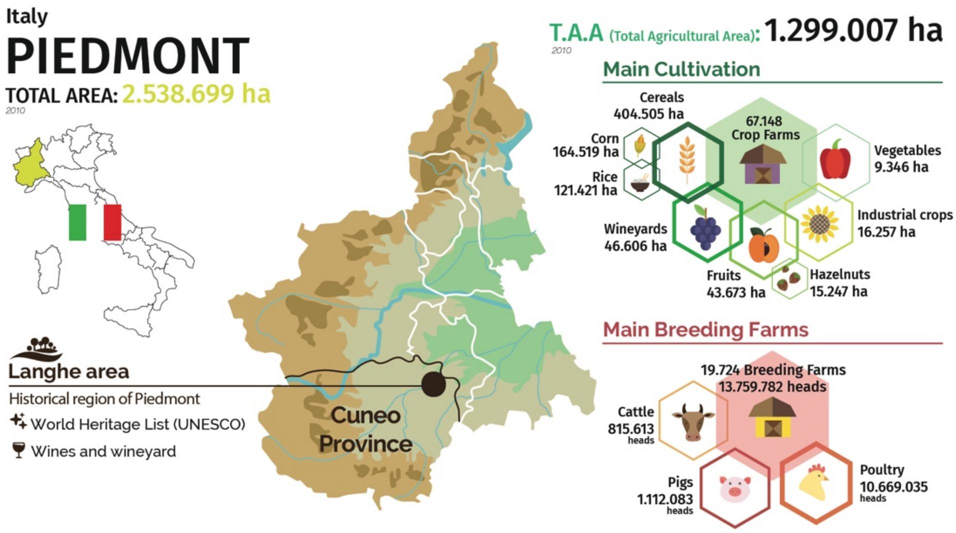

Fig 5. The infographic shows some of more relevant data of Piedmont Region. It is the result of HD carried out on the whole region and on the Lange area. Visualisation adapted from annexes of [9]. Data referred to 2011.

In the region, more than 15.000 ha are dedicated to hazelnuts production with 8.362 companies involved. In Cuneo area the nuts accounts the 20% of enterprises in 2010 and the 3,5% of total U.A.A. [38]. With Campania, Lazio, Piedmont and Sicily, Italy produces almost 100.000 t/year of hazelnut [22], and is one of the leader producers preceded by Turkey, USA and Spain [22]. The “Tonda Gentile Trilobata” (TGT) cultivar variety is the most qualitative representative one of the high part of Langhe area (Alta Langa). In 2015, the TGT hazelnut was cultivated by 784 companies of this specific area, with 3.315 ha and a total production of almost 4.680 tons [42]. It is characterized by specific quality and morphological parameters that differentiate it from other varieties (Fig. 6): spheroidal shape of seeds, easy peeling, excellent taste and aroma of hazelnut fruits after roasting and good quality of shells [42]. It is denominated as “Piedmont Hazelnut PGI” Regulation (EC) n. 1107, 12 June 1996, modified by Regulation (EC) n. 464/2004) and it is highly appreciated in confectionery industry. Like for the other dry fruits, the kernel is the only part that are actually involved in food processing while the perisperms and shells are mainly disposed off.

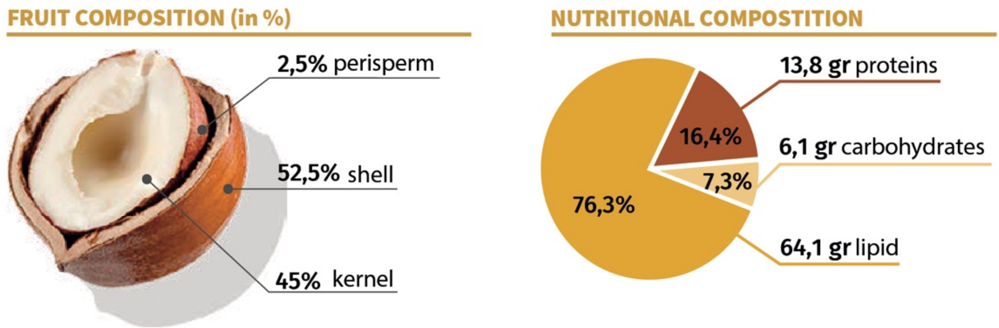

Fig 6. The infographic shows the composition of hazelnut in percentage and its nutritional composition. Images produced by students in Systemic Design master course at Politecnico di Torino, a.y. 2017/2018.

3.2. Holistic Diagnosis of the company and of hazelnut processing

The analysis of the current production model focuses on the collection of quantitative data mainly on the two main company processes: shelling and roasting. The result of HD analysis is a processing scheme that highlights input (raw materials) and outputs (by-products and waste) flows (fig. 7).

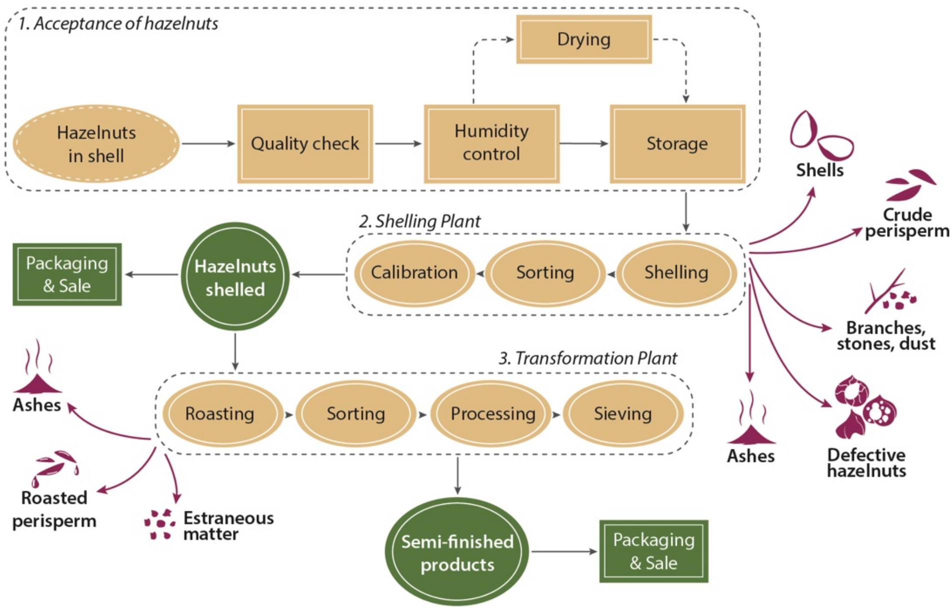

Fig 7. Simplified flow chart of hazelnuts processing that shows main by-products and waste obtained.

In the shelling plant, the hazelnuts in shell are more than 3.100 t/year provided by almost 300 direct lenders, farmers, traders and cooperatives both local, national or international suppliers. The peeling process takes place according to high quality standards during the months immediately after the hazelnut harvest (in Piedmont Region between August and September). The hazelnuts are cleaning using vibrating screen to remove stones, branches, dust and soil which are almost 7 tons and are disposed as soil reinforcement by local farmers. After this phase, the quality check is carried out to discard defective fruits, such as bug-wound, damaged, wrinkled and mouldy hazelnuts that do not meet the quality regard hygienic and aesthetic standards required for food use (CAC/RCP 1-1969, Rev. 4-2003; Reg. CE 852/2004; FSSC 22000; Reg. UE 2017/228). Hazelnuts which do not meet required standards are around 2-3% in the best years and they can reach the maximum limit of 20% of total production during the worst year, for example in 2018 they were about 60 tons. Hazelnuts are subsequently shelled, and they are discarded by perisperm. Shells are the largest percentage of by-products, with almost 1.633 t/year of outputs. The second important by-products are fragments of hazelnut perisperm that is almost the 2% of the total hazelnut weight. Ashes obtained by the combustion of hazelnut shells, almost 9 t/year that is almost the 3% of total shells weight, are disposed of by qualified company. Part of raw perisperm cuticles, almost 16 tons, is collected and sold to breeders. After shelling process, kernels are separated into entire hazelnuts and scraps. A part of them are sent to the semi-finished processing plant, almost 60 t/year, and the other part, more than 1.250 t/year, is packaged and sold.

Roasting process produce toasted kernels and roasted perisperm. Roasted perisperm, rich of polyphenols [13, 24, 25], is currently sold for feed production thanks to its high nutritional value [23]. The Fig. 8 summarizes main outputs obtained per year by shelling and roasting process with their approximate quantities and current uses.

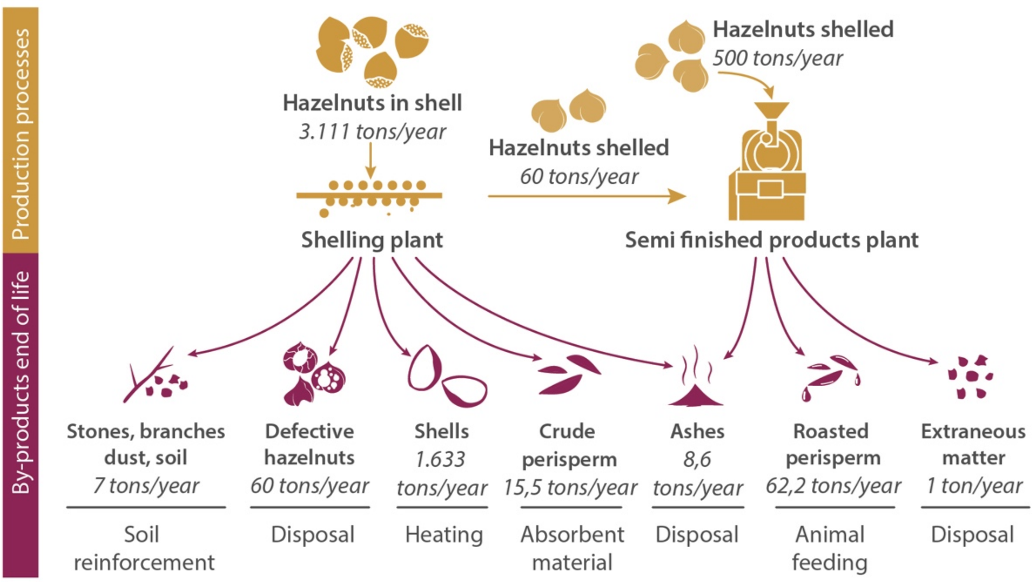

Fig 8 The scheme shows main by-products and waste produced by hazelnuts shelling and roasting. The current end-of-life and uses are indicated for each of them (data refers to the period 2017/2018).

3.2.1. Analysis of current economic condition

The core business of the company is focused on providing high quality products which requests significant investments in market strategies and technological innovations. They are responsible of an increase in annual turnover, almost 27%. Otherwise, the hazelnut market is characterized by high instability, due to annual production yield and to international competition that define hazelnuts price. The linear matrix (Fig. 9) shows that the focus area is mainly oriented towards improving the positioning of its products on the international market. This purpose is hindered by the strong international competition with other countries in the Mediterranean area, especially Turkey. Another important issue that define the company's business strategy is related to the innovation of machineries and processes towards the improvement of production efficiency and the reduction of waste.

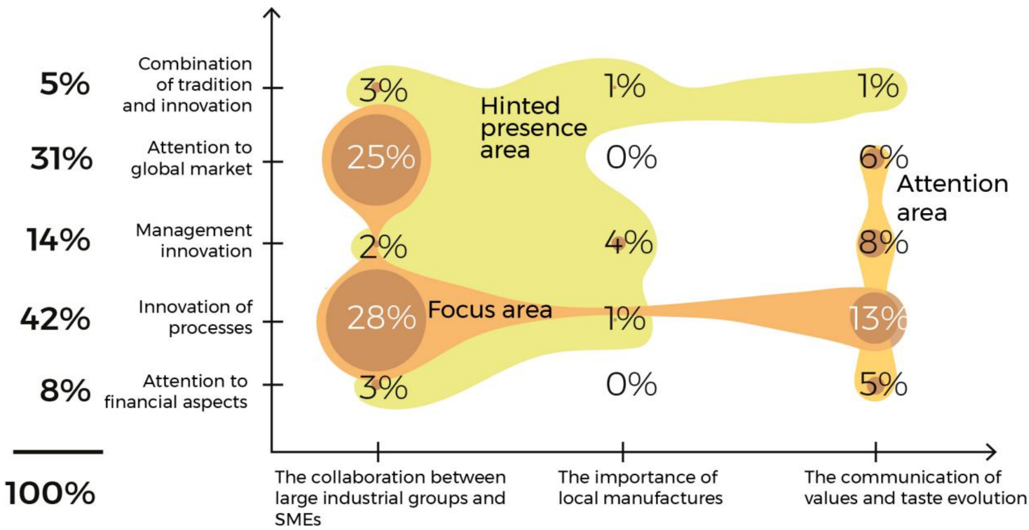

Fig 9. Linear matrix obtained from the analysis of the company status and of main goals of the core business strategy.

3.3. Identification and analysis of critical issues

The third step of SD methodology focuses on the analysis of critical aspects regarding environmental and economic issues.

3.3.1. Environmental issues

The analysis of the hazelnut processing highlights that main environmental issues are related to the management of organic waste. By-products are the 52-58% of the total hazelnuts' weight, more than half of the whole fruit. Shelling process is the most critical step because it produces shells, perisperm, failed fruits, ash and other impurities. Shells are the largest part of the organic waste, while raw perisperm cuticles and roasted perisperm are the second ones. The classification of these outputs as "organic waste" is outlined by regulations and hygienic quality standards prescriptions (CAC/RCP 1-1969, Rev. 4-2003; Reg. UE 2017/228). A considerable part of outputs must be treated in landfills that delete the opportunities offered by their quality. The real transition toward a more sustainable approach in agro-food systems consists in considering outputs from food processing as "*by-products*" and no longer as "*waste*". Currently, the company has already adopted some solutions to enhance a part of these organic outputs (Fig. 8). Shells and perisperms cuticles are involved in energy valorisation cycles, however it contributes consistently to the production of ashes (8,6 tons per year) that must be treated as "non-hazardous special waste" in landfills. A part of shells is used for plant's heating system (288 tons per year) and the other part (181 tons per year) are sold for private heating. However, during the harvest period, between August and September, there is a peak in the production of shells that is difficult to sell and to store. The saturation of stock capacity of silos occurs during summer when the private heating requirements is very low. Because of that, the company must sell them low price or dispose them. All these actions are aimed at the partially enhancement of by-products, but they present some critical aspects. Indeed, defective hazelnuts (bug-ridden, mouldy and wrinkled), that don't satisfy quality standards, and other organic by-products, such as part of crude and raw perisperm are still collected and disposed.

3.3.2. Economic issues

Environmental critical issues have relevant consequences on the company's financial statement. Although the company is sensitive to innovative strategies towards the CE, critical issues of by-products' and waste's end-of-life still remain. Producers are responsible for the disposal of waste that requires a significant economic investment by the company itself (Table 1).

Waste	**% of total weight**	**t/year**	**€/kg**	**TOT**
Remaining shells	37,5	1.164	0,21	244.440 €/year
Defective hazelnuts	2	60	0,21	12.600 €/year
Ashes	0,3	8,6	0,21	1.806 €/year
Extraneous matter	0,05	1	0,21	210 €/year
TOT	**39,85**	**1.233,6**	**-**	**259.056 €/year**

Table 1. The table shows cost to dispose each type of waste calculated for 3.111 tons of hazelnuts in shell. Data refers to the 2017 and they are provided by the company's manager.

Shells for private heating, crude hazelnut perisperm and roasted perisperm are sold with the main purpose to eliminate costs for disposal, but without obtaining any relevant revenue. They are sold at very low price: such as roasted perisperm, a by-product with very interesting properties, the cost is around 0,25 €/kg. The analysis of the current production process and of the output's management highlights the need to define new opportunities for outputs to generate positive environmental and economic impacts.

3.4. Identification of new opportunities for using by-products

The investigation of new opportunities to use outputs as inputs mainly focuses on chemical-physical properties of the main outputs currently produced by the process: shells, raw perisperm and roasted perisperm, ashes and defective hazelnuts.

3.4.1. Opportunities provided by hazelnut shells and defective fruits

Hazelnut's shells, the largest by-product of shelling process, are mainly composed of about 30% hemicellulose, 27% cellulose and 43% lignin [65]. Thanks to these characteristics, shells are used for industrial and domestic heating. Hazelnut shells present a calorific value between 17,21 MJ/kg and 18,42 MJ/kg, a moisture content between 5,78% and 6,79% and a low percentage of ashes production, depending by hazelnut varities [37]. An increasing trend consists in transforming hazelnut shells in pellets. They have a higher calorific value than hazelnut shells not pelletized [27], almost 20,88 MJ/kg, and they also present lower moisture content, almost 3%, and lower ashes production from combustion, almost 1%. Furthermore, hazelnut shells can be mixed with olive stone to obtain most performing biofuel. Olive stone is a lignocellulosic material, with hemicellulose, cellulose and lignin as main components [57]. It is characterized by relatively high calorific value [7], almost 20 MJ/kg, that increases performances of mixed biofuels. Nowadays, hazelnut shells potentials are well known for mulching and for composting, especially for the high content of lignin and cellulose. They represent a valid alternative to plastic mulching that protect plants' roots against frost and drought thanks to retaining moisture ability. During composting, they provide porosity to the manure, in order to allow the circulation of oxygen [43]. They can be used especially for correcting water excesses thanks to their high hygroscopic properties at low temperature [2]. As hygroscopic material [45] can be also used as litter for pets and especially for equine breeding. Hazelnut shells and other dried fruit shells can be also used to produce abrasive for sandblasting on soft materials such as wood. This mixture of vegetable shells low abrasive powder is suitable especially for cleaning, polishing and finishing of moulds, plastic products, electrical components and electric motors. It is also used as filler in PLA-based green composites [5].

3.4.2. Opportunities provided by raw perisperm cuticle and roasted perisperm

The hazelnut perisperm is the 2.5% of weight of the whole fruit and it is in form of raw perisperm cuticles and roasted perisperm. They are rich of dietary fibre, fat-soluble bioactive and antioxidant polyphenols compounds that are important for human health [23,44,50], but they present different opportunities [63]. During roasting processing, hazelnut perisperm loses hygroscopic property and it becomes water-repellent. For this reason, roasted hazelnut perisperm is not suitable for animal litter for the high content of fat soluble, but it can be enhanced by animal feed, pharmaceutical products and food industry. Pelvan et al. [54] demonstrate that roasted hazelnut perisperm is an excellent source of phenolics and antioxidant compounds if compared with natural and roasted hazelnuts (Fig. 10).

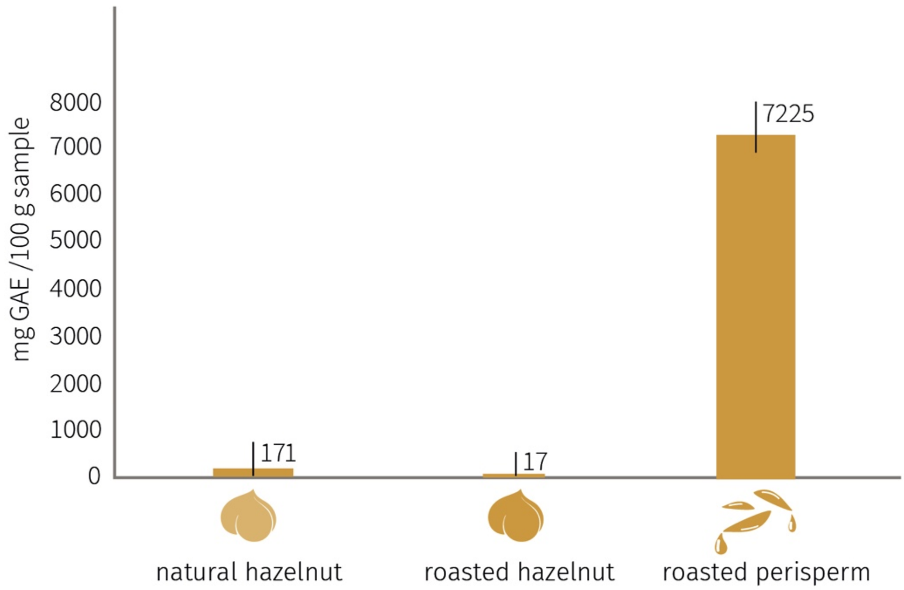

Fig 10. The graph shows the content of Gallic Acid Equivalent (GAE), measures in mg, in natural hazelnut, roasted hazelnut and roasted hazelnut perisperm. Representation by students in SD master course at Politecnico di Torino, a.y. 2017/2018. Data retrieved from [54]

Roasted hazelnut perisperm is an excellent source of fibre and antioxidants and therefore it has a great potential to be used for food and nutraceutical applications. Roasted perisperm shows high quality of prebiotic activity. It could provide positive effects on human health by regulating cholesterol, triglycerides and non-esterified fatty acids [63]. Research projects, undertaken by the University of Turin, are experimenting potential provided by roasted hazelnut perisperm in dairy sector. Perisperm cuticles of TGT are firstly grinded and screened, and then they are added to yogurt and milk. Preliminary results highlight the possibility to obtain dairy products enriched with fibre (almost 3%) [11, 66], following current European regulation (Reg.Ce 1924/2006). Recent researches [46,65,55] also highlight the possibility to extract natural antioxidant phenolic for pharmaceutics, cosmetics and food industry.

3.4.3. Opportunities provided by ashes from shells combustion

Ashes from shells' combustion are currently disposed of and treated as non-hazardous waste from biomass burning, following Italian regulation (Legislative Decree no. 152/2006). On the other hand, biomass ashes present great properties for agronomic practices. They contain phosphorous and other nutrient, such as potassium, magnesium and calcium, that are useful for plant growing [58]. They can be also used as liming agents and as stimulator of microbial activities and mineralization processes of soil, improving chemical and physical characteristics [26]. As consequence, ashes as soil improvers have positive consequences on its chemical parameters as pH and acidity [15].

Biomass ashes are considered excellent additives for manure and compost. Chemical properties of ashes are also useful for the re-discovery of traditional techniques in cleaning products. They contain important quantities of potassium and sodium peroxide and they are used to obtain lye, an alkaline solution used since ancient times for saponification. Following soap-making tradition, lye is an important component of soaps thanks to high cleaning and detergent ability.

3.5. Definition of alternative model for enterprise through systemic approach

The research of new opportunities for by-products highlighted a set of potential applications for creating new relationships with other economic activities at local scale or creating new products (fig. 11).

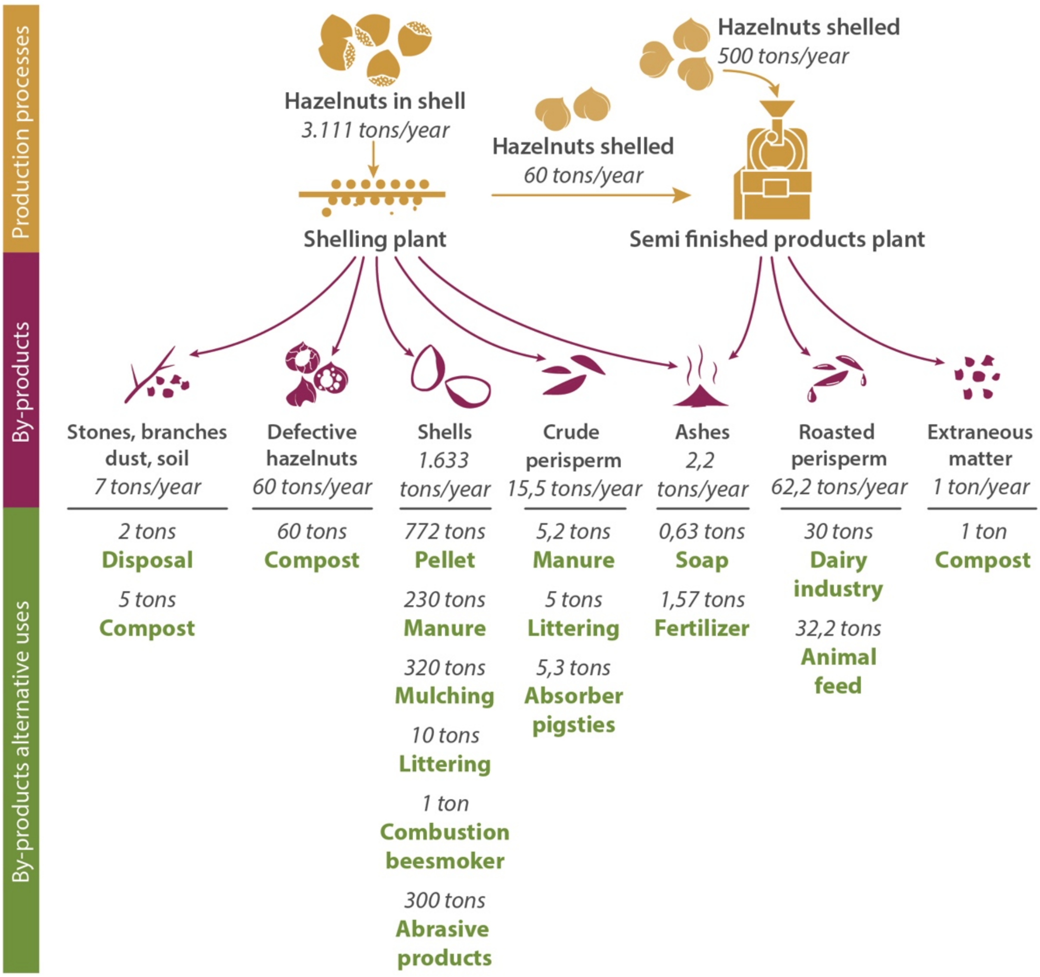

Fig 11. The scheme shows alternative uses and possibilities for hazelnut's by-products based on their specific properties.

The radar chart was used for qualitative evaluation of the most suitable innovation to apply for designing the systemic model for the company (see the column ‘benchmark evaluation’ of table 2). Information and data collected during the HD allow to identify new strategic partners that could use hazelnut’s by-products as resources for other activities (Table 2).

New opportunity	**By-product used**	**Quantity of by-product used**	**Partner**	**Benchmark Evaluation**
Compost	Branches, defective hazelnuts, extraneous matter	66 tons	CAP Nord Ovest	
Matrix for manure	Shells and crude perisperm	235 tons	Agrindustria	
Mulching	Shells	320 tons	Local nursery plant	
Litter for animal	Shells and crude perisperm	15 tons	Agrindustria	
Beesmoker combustion	Shells	1 ton	Aspromiele	
Abrasive product	Shells	300 tons	Agrindustria	
Animal feed	Roasted perisperm	30,2 tons	CAP Nord Ovest	
Pellets	Shells	772 tons	Agrindustria Tecco srl	
Absorbent substrate	Crude perisperm	5,3 tons	Local farmers	

Dairy industry	Roasted perisperm	30 tons	Caseificio Alta Langa	
Soap	Ashes	0,63 tons	Educational workshops	
Fertilizer	Ashes	1,57 tons	CAP Nord Ovest	

Table 2. The table shows the new activities defined based on the opportunities provided by each by-product. Potential partners already active at local scale are identify as collectors and user of hazelnut's by-products

Results of the preliminary benchmark evaluation were discussed with the company to assess the feasibility of proposals. For example, the hazelnut shells pelletizing is a process already considered by the company, but it is not economic feasible due to significant investments for machineries. However, it can be performed by an external actor, Agrindustria Tecco srl [1] located nearby. In this case, La Gentile srl ensures itself in revenue by selling part of the shells to Agrindustria Tecco srl and to have back fuel in pellets that produces less ash, reducing costs for disposal. The partnership with this leader company located in Cuneo city that processes agricultural by-products to obtain raw material for industry uses, can play a key role also in collecting and processing hazelnut shell and part of crude perisperm to produce manure, litter for horses breeding, abrasive products for industry. The combustion of shell pellets strongly reduces the ashes produced (from 8,6 to 2,2 tons per year). A part of these ashes can be sold to CAP Nord Ovest [17], an agricultural consortium located in Villafalleto in Cuneo province, to produce fertilizers and the other part can be used for the organization of soap workshops by La Gentile srl. Moreover, the roasted perisperm can be used to produce cheese and yogurt by local dairy companies which are important presence in the territory of Alta Langa, as Caseificio dell'Alta Langa [19] just 7 km faraway. At last, the shells for mulching activity can be distributed both among the many plant nurseries around Cortemilia which are three in less than 20 km, and among the local farmers.

The company has welcomed with interest the organization of educational activities concerning the alternative use of by-products that involve local citizens, children and local schools. A potential workshop to organize is for the use of ashes to produce soap. For these activities become fundamental the partnership with the Aspromiele Association [4], the regional association of beekeepers that can provide beeswax for making handmade body creams and cleaning products.

These solutions provide a new scenario for the company based on research and innovation at local scale (fig. 12). All the new partners are maximum 100 km faraway from Cortemilia.

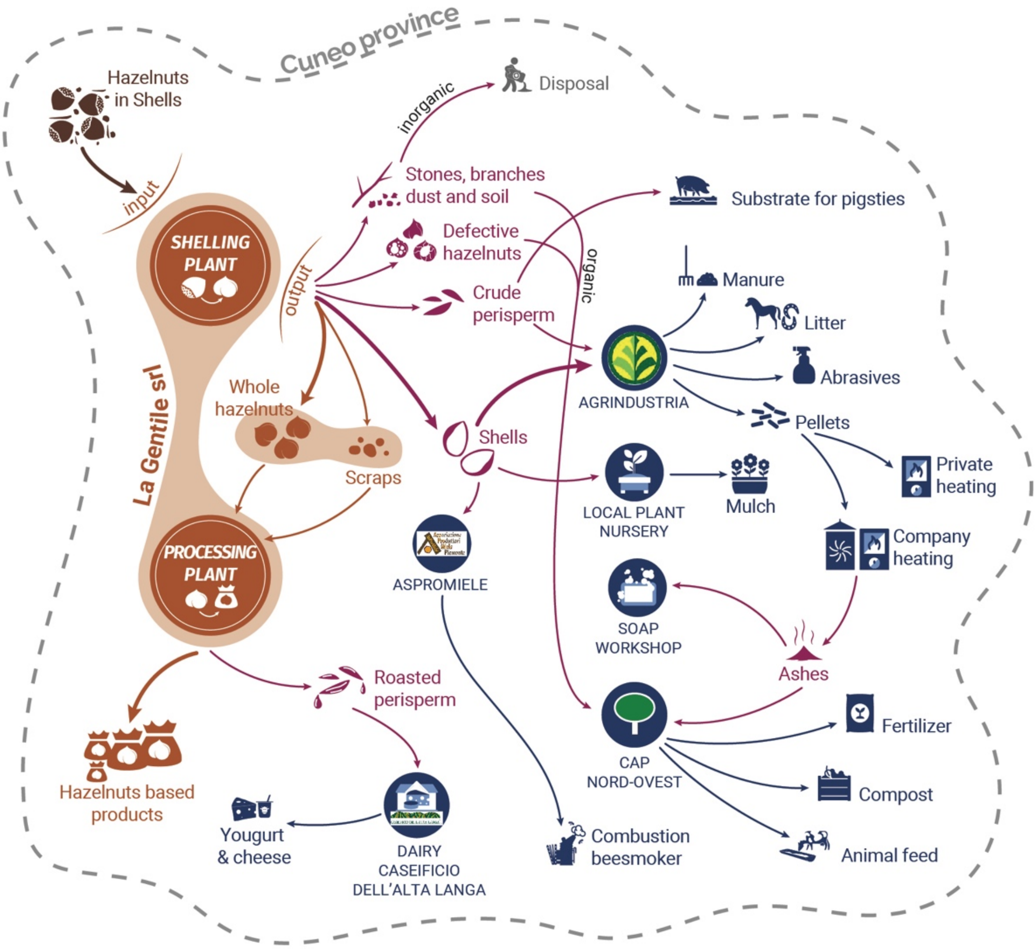

Fig 12. The graph shows the systemic model proposed for the company. The scheme enhances the network of enterprises active at local scale. The systemic network is created by partnerships between companies based on opportunities provided by hazelnut's by-products.

The application of systemic approach highlights opportunities for the transition from the linear production model to a systemic one, that focuses on creating strong partnerships at local scale and on enhancing traditional know-how, as decided in the creation of the new business strategy reflected in the systemic matrix (Fig. 13).

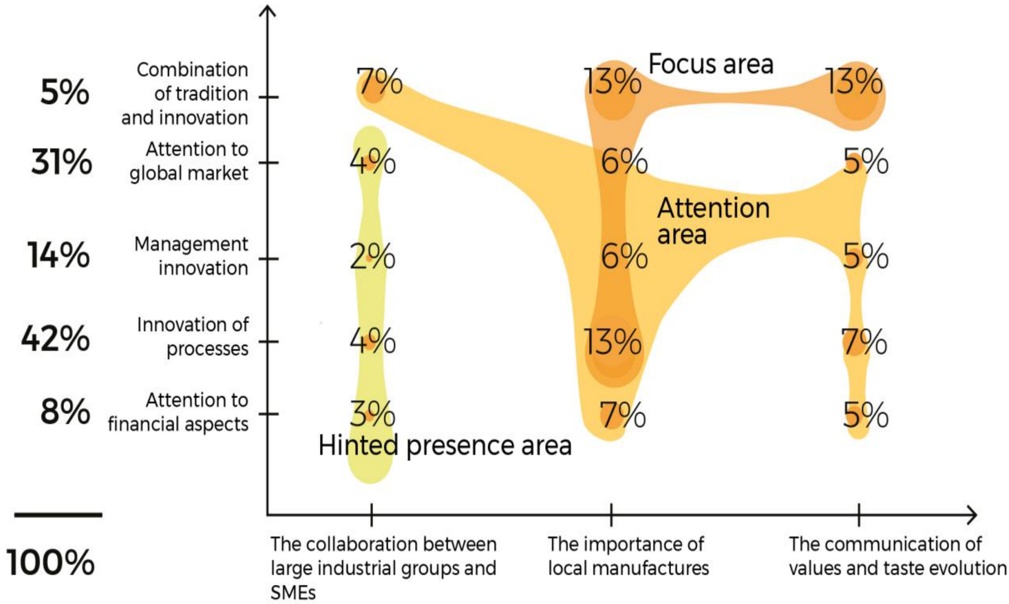

Fig 13. Systemic matrix which reflects the new business strategy obtained by the application of the systemic approach that focuses on enhancing hazelnut's by-products and on creating partnerships at local scale.

3.6. Potential outcomes obtained by the application of the systemic production model

The application of systemic approach created a network of enterprises that operate in synergy towards CE model (Fig. 12).

The systemic production model designed can generate positive outcomes for the company at environmental, social and economic level. New partnerships between enterprises define alternative uses of hazelnut by-products that create environmental value, extend their lifecycle and avoid negative effects of waste disposal. Outputs of hazelnut process are not anymore considered as waste, but as resources for other activities. The interest demonstrated for the organization of educational activities is important to increase the awareness regards environmental issues among people. These activities strengthen relations between potential partners and disseminate good practices concerning by-products uses. The identification of potential partners at local scale can be important to preserve and enhance traditional know-how of the Piedmont territory, as the production of cheese and honey. Alternative uses of by-products also have positive effects at economic level. Costs for disposal are reduced and opportunities provided by selling by-products and secondary activities, as workshops, generate positive incomes. The Table 3 compares costs and revenues of linear model and systemic one. Prices for disposal are defined collecting data directly from La Gentile srl and selling prices for by-products are established based on Italian trends [16]. It shows a significant decrease of costs for waste management (-100%) and important increase in revenues obtained by selling by-products (+197%) that are currently considered waste, such as exceeded shells.

	Current Production Model		**Systemic Model Proposal**	
	Costs (€/year)	*Revenues (€/year)*	*Costs (€/year)*	*Revenues (€/year)*
shells	244.440	28.960	-	112.840
crude perisperm	-	3.410	-	3.410
roasted perisperm	-	15.550	-	15.550
ashes	1.806	-	-	330
defective hazelnuts	12.600	-	-	9.600
extraneous matter	210	-	-	160
stones, branches, dust, soil	-	-	420	800
	259.056	**47.920**	**420**	**142.690**

Table 3. The table shows costs and revenues referred to by-products in the linear model.

4. Discussion and conclusion

The involvement of the company has allowed the research to be placed in a real context. This has made possible to highlight limits and benefits produced by the application of the SD methodology in the transition to a CE and BE. Moreover, to understand with concrete examples the benefits created at environmental and socio-economic level by this project. And the systemic strategies that a linear company in the sector of hazelnuts processing can adopt to innovate, considering the implications of a complex and well-defined production and geographical context.

This study also highlights how the systemic approach adopted to change this linear production model, if applied on a large scale in the manufacturing sector in Piedmont area, would produce considerable advantages on the economy of the Region.

4.1 Review on SD methodology application to the case-study

Retracing all steps of the SD methodology considering its application to the case-study, the HD of the territory is the most critical part to understand from an external point of view over the designers' team. In this case, the HD for context analysis has been adapted to the goal of the research [10] and conducted mainly on both the territorial characteristics, especially regarding cultural and economic aspects, both the scenario of hazelnut market and its importance in the Piedmont Region.

Afterwards, the HD of energy and matter flows is the most critical stage for the part regarding the data collection which depends mainly by the availability and collaboration of the company analysed. Field visits is an essential activity that complete the general overview of the company analysed, if it is conducted by experts to capture more information as possible on the entire production process especially on the quality and quantity of inputs and outputs. In this case, the request of analysis has not been made by the company as the result of problems found in daily processes, but it was voluntarily action of the research team involved. Nevertheless, the company CEO has shown a very high openness without having constraints in sharing confidential data, that usually it is an obstacle in many projects of interventions toward CE model as stated by [56]. Regarding the single data, some difficulties occurred in receiving precise quantities related to some matters or energy consume, because there are outputs that currently are not considered relevant by the company and are managed as waste. Indeed, the data referring to stones, branches, dust and soil contained in the organic waste is given in total and without a precise quantity, even if it is a small one. This limits the possibility to use this output, but can be an element to stimulate further laboratory researches conducted by experts to better understand these outputs' quality. Another aspect regarding the HD, is the utility of the visual representation of energy and matter flows through giga-maps. It becomes an important tool for discussing with the company regarding the current production situation, problems and further steps of analysis. It is essential also during following stages of analysis to highlight important data.

The stage related to problems identification was conducted with an active contribution of the company. The identified problems regard not only the specific wastage of quality of the shells in the waste management process but also the lack of recovery of secondary by-products. The identification of new opportunities is focused on desk researches to find real cases of technological and social innovation at local and international scale which can open and enlarge the possibilities on a specific case. The desk research is carried out on scientific databases and on informal websites. It is also a critical phase for the need to find a balance within opportunities discovered and creative solutions proposed by the designers, which can open new possibilities and research fields. This research phase required the integration of information collected during the HD, regarding the presence on the territory of enterprises and potential stakeholders with specific know-how that can become project partners.

New opportunities find need to be evaluated and chosen to design a project that is feasible. The benchmarking method proposed try to provide a tool to support these challenging decisions making process. However, it presents some limitations: one is the subjectivity of the evaluator for the not setting of specific and defined criteria. Moreover, for the multiple elements involved, it needs specific background studies which requires the involvement of multiple experts for assessing the sustainability and the feasibility. In addition, the selection phase requires the involvement of the company's decision makers to evaluate their interest for the solutions improvement which depends also to their inclination towards sustainable aspects. These meetings are also essential to discuss the value and potential benefits provided by solutions and to collect decision makers' feedbacks. Some opportunities may be discarded due to several problems, such as limitations imposed by regulations on waste and by-products management. However, they can also open new scenarios for new business opportunities both inside the industrial reality analysed both for innovation research projects or new joint ventures between enterprises.

Finally, the application of the SD methodology can be useful to build awareness of the situation outside the company in itself, allowing a better comprehension of the impact of the following project over all the region. For example, if potentially extended to every hazelnut processers it can boost the local economy and prevent environmental problems, as the waste of useful resources as hazelnut shells or the high use of energy from fossil fuel for the roasting phase. Moreover, it can also boost the creation of new entrepreneurial activities, along the lines of Agrindustria' plants due to its needful role for the transformation of various by-products.

4.2 Future challenges for improving SD methodology

To conclude, the article highlighted some limits of the SD methodology applied to a real case study. It suggests the need to map in detail the local current situation in order to identify main stakeholders that could be positively involved as experts and partners in the implementation phase. However, SD methodology presents some useful tools to move towards innovation processes:

- HD is an essential tool to map the current situation and to define the analysis of qualitative and qualitative data and relationships between local stakeholders;
- Giga-maps, as results of research synthesis, facilitate the management and communication of systems complexity to people involved in research stages, although with different background and technical languages. They are useful tools to collect immediately feedbacks;
- the systemic approach guides in designing a bigger picture of the state-of-the-art, perform an holistic diagnosis, and deliver innovation at system level;
- the technological and social innovations found in the research phase are critically evaluated based on the SD guidelines and resized thanks to the feasibility studies and the comparison with the company decision-maker. They are considered in the complex system, how they can modify material and energy flows and relationships between system's components;
- SD guidelines suggest how to overpass environmental issues that consequently have positive effects at the economic level;
- The increase of local partnerships based more on collaboration than competition can have positive consequences on the economic development of the territory.

Evaluating pros and cons regarding the application of the SD methodology, some recommendations are expressed to face the challenges for the improvement of SD application toward CE and BE and define further researches. This research is the first attempt to validate this methodology, and some tools, such as the linear and systemic matrix and the benchmarking, need to be better assessed as quantitative and qualitative methods. Moreover, step 4 'form problems to opportunities' would be facilitated by the use of IT systems that could support the transition from linear to CE models. Online regional database, with all the technologies present locally, or databases that provide information regard the quantity of outputs produced or inputs required by local companies, could promote the use and transformation of by-products in regional area.

In addition, considering the entire process, it requires the involvement of more experts in different fields to evaluate the real feasibility and the impact produced by the opportunities found due to the multiple aspects considered in the research phase and in the project development. Further researches should focus on the definition of the multidisciplinary team required to conduct a SD project, defining the role of the designer.

Another limit can be found in the SD principles which needs to be expressed more in detail with a new definition of SD guidelines, to provide the transferability of the methodology application to other research teams and other economic sectors.

Moreover, the limitations found in the projects development and implementation can be considered as the starting point to reflect on future policies. According to the need to develop policies to support the transition towards circular models, designers and policymakers should collaborate, sharing competencies and knowledge. Another aspect which requires further studies is the potential of this SD approach to create innovation in business models and in the creation of new entrepreneurial realities (joint ventures between enterprises, start-ups, spin-offs…)

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