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DESIGNING CIRCULARITY
The circular economy for landscape and territory

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ABSTRACT
A farm, a biomedical company and a building materials company, an area with a high landscape value, some agricultural and food waste to be optimised, a team of researchers and a class of design and architecture students. These are the ingredients of the Designing Circularity experience. The article illustrates a field research activity and an educational experiment focused on identifying circularity scenarios for the territory and the development of a project based on the principles of the circular economy, with an appropriate technology approach. The result is that grape marc becomes bricks and hazelnut shells become insulating panels. The experience generated results for all the players involved: the companies strengthened their industrial symbiosis strategies; the university took responsibility for co-processing circularity scenarios and territorial development; the students developed a critical sense and the ability to design in close contact with real 'challenges'.

KEYWORDS
circular economy, appropriate technologies, from waste to resources, industrial symbiosis, territorial development

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The movement towards a circular economy, which is an integral part of the European Green Deal, is one of the key actions that the worlds of research and industry are called upon to address, not only by prioritising the concept of the second life of materials and products, with the consequent implications in terms of industrial symbiosis but also by rethinking processes and designs capable of implementing circularity strategies on the territory, on all scales. The aim of the article is to illustrate Designing Circularity, an experience between research and teaching, conducted in the field, which has made it possible to activate new synergies between stakeholders in a specific context: a small area situated in the Monferrato hills (Piedmont, Italy) which has become the location of practical experimentation with circular processes. The experience described here aims to be part of the debate on some central issues for the transition to a Circular Economy (CE): how to activate/encourage CE practices in a given area? How to accompany those who promote such practices in local contexts? What role can be played by universities and research in these processes of implementing circularity?

The research and teaching approach focuses on two key concepts which form the reference scenario: on one hand, CE, which requires not only the rethinking of the useful life of materials, their second life, but also the (re)consideration of the links between sectors, institutions and local stakeholders; on the other hand, technologies appropriate to the context and the stakeholders. The Designing Circularity project, incorporated into a master's degree in Architecture for Sustainability and in Systemic Design, responded to the needs of real organisations (a farm, a biomedical company and a building materials company) and identified new local circularity scenarios and the development of a project based on the principles of CE. The critical analysis of the results allows us to highlight the limits, potential and prospects of the experience, in terms of the applicability of CE to design and the expressive and communicative possibilities linked to the re-use of materials.

The reference scenario and key concepts | Field research and educational experimentation activities cover two main themes, Circular Economy and Appropriate Technologies, both connected to an idea of promoting local development and optimising a territory's resources. It is possible to identify different principles under the conceptual umbrella of CE (Blomsma and Brennan, 2017; Homrich et alii, 2018), strands of thought, strategies of action. In this context, CE is understood both as a strategy to optimise the use of resources and turn waste into a resource, also on a local scale, and as a form of collaboration between sectors, institutions and local stakeholders, capable of reducing environmental pressures while promoting the socio-cultural and economic development of the territory. The optimisation of resources and the reuse of waste is widely debated in literature and is a crucial element in the definition of the concept of CE, as «[...] economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso-level (eco-industrial parks) and macro-level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations» (Kirchherr, Reike and Hekkert, 2017, p. 229).

At micro-level, with particular reference to the specific context of the research, agri-food waste can play an important role, as most of this type of waste is a by-product that can be potentially used as secondary raw material in a variety of industrial processes (Giordano, Montacchini and Tedesco, 2019). Several studies focused on the development of new building products from agri-food waste, such as hemp, straw, olive waste or other plant fibres, can be found in literature (Madurwar, Ralegaonkar and Mandavgane, 2013; Liu et alii, 2017). These types of waste can be reused for the production of thermal insulation materials (Liuzzi, Sanarica and Stefanizzi, 2017), bricks (Raut, Ralegaonkar and Mandavgane, 2011), plaster or concrete (Prusty, Patro and Basarkar, 2016), etc. A vision of CE that founds the concept of reintroduction and optimisation of underused and/or wasted resources in the current development model can also be a vehicle for the rethinking of new strategies for local land development, thanks to partnerships between sectors, institutions and local stakeholders (Quaranta, Andreopoulou and Salvia, 2018).

To develop new strategies starting from the territory's own resources, we have to think in terms of Appropriate Technology (Schumacher, 1973). Technology that is appropriate to the context and stakeholders is understood as a tool for (re)designing production processes on a local scale, accessible both economically and operationally to the populations directly involved. In the 'circular' sphere, this means, for example, starting from the most problematic and widespread waste in the reference territory, imagining solutions capable of transforming it into resources for that territory and its inhabitants using processes and technologies that are accessible, economical and entirely manageable at local level. A CE that incorporates the principles of Appropriate Technology consequently becomes a paradigm that brings environmental, social and economic sustainability onto the same level (WCED, 1987).

The specific context and practices of circularity in action | The Designing Circularity experience is part of the activities of the Technology Research Team (RT) of the Department of Architecture and Design (DAD) of the Politecnico di Torino, which has been working in collaboration with small and medium-sized enterprises on the development of technical elements, components and technologically innovative materials for architecture and design for years, with the support of the Innovative Technology Systems Laboratory (LaSTIn). The experience described continues on from the research carried out in the All You Can't Eat cluster, aimed at the optimisation of agri-food waste in the building sector. The aim of the research is not only product experimentation but also the identification of circular and intersectoral supply chain scenarios that can promote the development of local economies at 0 km (Giordano, Montacchini and Tedesco, 2019).

In Designing Circularity, the reference stakeholders – with whom the DAD's RT collaborates within the framework of a Memorandum of Understanding and joint research projects[1] – are three entrepreneurs, responsible for a farm (Azienda Agricola Fratelli Durando), a biomedical company (NobilBio Ricerche srl) and a building materials company (Sarotto Group sas). Three Piedmontese companies, located between the provinces of Asti and Cuneo, in an area of considerable landscape value, rich in resources to be exploited, linked to typical local products, particularly grapes, hazelnuts and wheat. The stakeholders involved, who already operate on the basis of a logic of circularity, are united by their interest in experimenting with new spheres of research and by their desire to support a local network that can generate benefits not only for the activities of each of them but also for the territory as a whole.

The promoter of this project is Azienda Agricola Fratelli Durando in Portacomaro (AT), which operates in the agri-technical sector – specialised in the cultivation and processing of hazelnuts and cereals, and in the production of wine – but also in the field of hospitality and tourist accommodation. Besides being active in sustainable business policies, aimed at reducing the environmental impacts of harvesting and processing and at optimising agricultural waste, the company recognises the benefits of working in compliance with the CE principles, also for the promotion of the local territory, benefits of an economic, environmental and social nature, which it sees as a continuation of its activities. The company sees the CE as a goal to be pursued, but also to be published and disseminated, and the territory becomes the field of action of this idea, the physical space in which and for which circularity takes shape.

Azienda Agricola Fratelli Durando networks with another local company, NobilBio Ricerche srl (Portacomaro, AT), which specialises in the surface treatment of medical devices and in the production of biomaterials, to which it supplies waste from the wine-making process for the study of the properties of molecules of plant origin (grape polyphenols) in the regeneration of bone tissue. Sarotto Group sas of Narzole (CN), a building company that has been working with the DAD's technological research team on the development of eco-compatible building materials derived from agri-food residues for many years now, is an integral part of the network and is currently experimenting with casing elements made of concrete and hazelnut shells supplied by the Durando farm. Local stakeholders see the CE as extremely advantageous and compatible with the reference territory. So how can we support those who promote CE practices at local level?

In this context, Designing Circularity translates into a project with several goals, in which the University takes on the role of 'vector' to support partnerships of industrial symbiosis, leading projects for the promotion of a territory via the optimisation of waste as a resource, and to make the principles of the circular economy visible and communicable through teaching, research and the transferral of knowledge, actions that are tangible and can be used in other contexts.

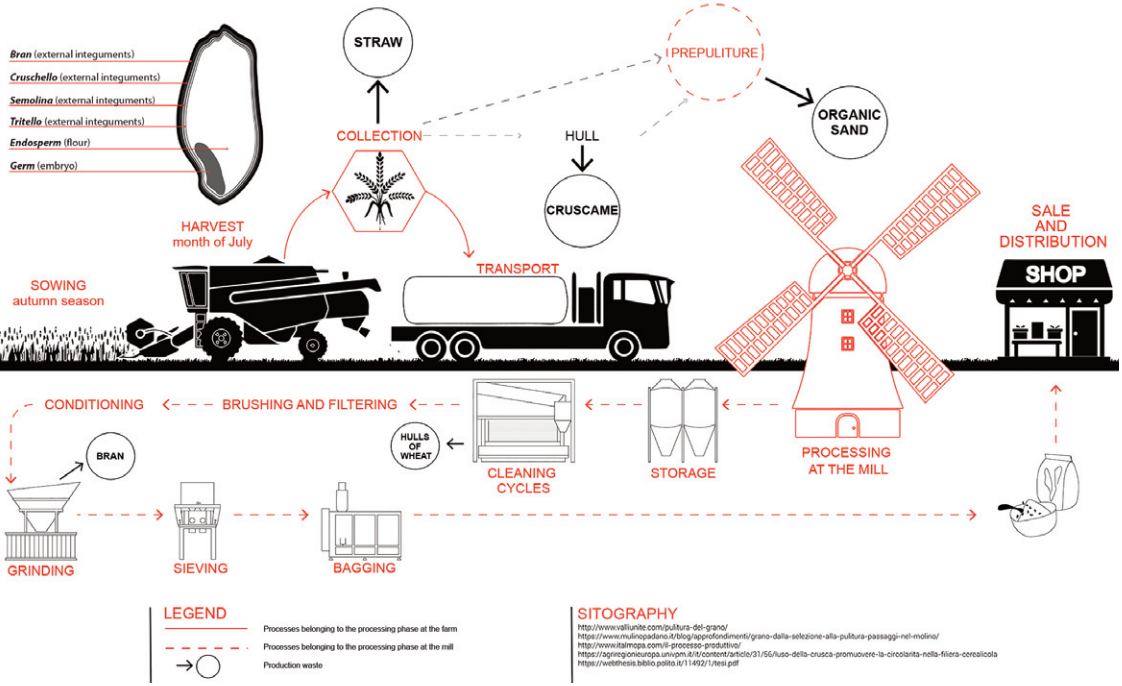

Fig. 1 | Example of a supply chain analysis of wheat flour production (credit: S. Roggia, M. Ronco and M. Salomone).

Designing Circularity, between didactics and experimentation | The Designing Circularity project has been incorporated into a Master's Degree Course for Architecture and Design students[2] focused on the development of the CE in design disciplines. The course has been conceived to develop knowledge of principles, methods and tools related to the CE both from a theoretical and an applied/experimental point of view. Designing Circularity has given students the opportunity to tackle the direct application of CE theories, working on a real case at micro-level, with businesses within the territory that are already linked by practices of circularity and interested in implementing local circular economy processes. The course has provided an opportunity to explore issues related to the varying needs of the stakeholders, such as exploring possible new synergies between the three companies and other local activities in terms of CE, with the aim of consolidating and expanding the network of 'circular' players; designing a micro-architecture to optimise the landscape and as a symbol of the promotion of local circularity practices and sustainable innovation. These needs, expressed by the stakeholders within the area, combined with the different educational goals envisaged as part of the course, have become the focus of two exercises proposed to the group of students.

Fig. 2 | View of the Monferrato hills during the visit to F.lli Durando with a group of students.

Developing circularity scenarios for the territory | The educational aim of the first activity was to develop the capacity to promote new business models based on the idea that one company's waste becomes another's resource (closed-loop), while keeping the value of the material at the highest possible level (EMF, 2015). This aim intersected with the need of local companies to explore new possibilities for synergies and stimulate networking between new local players. The decision was made to focus the research activity on the three agri-food production chains (wine, hazelnuts and wheat) in which the F.lli Durando company operates. The methodological approach was taken to the study of the supply chains of hazelnuts, wheat, and grapes for the production of wine, with the aim of understanding the phases that usually characterise 'linear' production, i.e.: without processes aimed at recovering and recycling the material: from the field, to harvesting, to processing, to the finished product. Investigation into the processes that generate waste, identifying the type, percentage and quantities potentially available (Fig. 1), was crucial in this sense. In order to estimate the availability of waste at regional level, based on the average production of finished product, data from ISTAT (the Italian Institute of Statistics) and ENAMA (the Italian Agency for Agricultural Mechanisation) and data obtained by searching for keywords (e.g.: waste, by-products, yields per hectare hazelnut/vine/rice, etc.) online were used as reference.

The potential for optimising waste with a view to extending its useful life of waste was subsequently explored, both in terms of technological and biological optimisation (Bocken et alii, 2016). Several fields of application were considered, including construction and design. The survey outlined a framework of examples of reuse and recycling, classifiable in two categories: on the one hand, commercial products and implemented solutions, and on the other hand, experimental materials, the result of studies and research. The tools used for the survey were virtual libraries (e.g.: Matrec, Material Connexion, etc.) and the main platforms for scientific dissemination (e.g.: ScienceDirect, Google Scholar, etc.). Lastly, using one or more types of waste from the supply chain assigned as a reference, concepts of technical elements and materials for architecture or 'products as services', functional to the activities carried out by Durando, Nobil Bio and Sarotto, were developed, imagining new links between the three companies and other possible players.

The students' proposals were varied. Grape marc and lees, by-products of the winemaking process, were turned into bricks, textiles for screening the sun, dyes for the construction industry, photovoltaic panels and bioplastics, paper for leaflets, labels and packaging, as well as food supplements. Hazelnut shells and cuticles were transformed into soundproofing panels, building blocks and outdoor furniture, while hazelnut twigs and branches obtained from pruning were turned into thermal insulation panels. As far as wheat is concerned, straw was used to imagine insulating elements for the building industry or wrapping for the packaging sector. Germ and bran were reused in the cosmetics sector. In other cases, the reuse of waste was planned as part of recreational/experiential workshops for the self-production of low-tech handcrafted products such as coloured pencils made from lees and marc, soap made from hazelnut shells and sponges made from straw.

The design concepts represent different scenarios for the optimisation of waste or products that have reached the end of their life and indicate the possible closed cycles of their circulation among different companies in the area. The proposals represent a circularity linked not only to materials but also to the specific know-how of each company, with a view to collaboration and industrial symbiosis. While continuing to be purely hypothetical, the concepts reveal the multiple potential of recirculation of resources, outlining possible new circular business models (Linder and Williander, 2015), and are representative of the possible experiments that can be activated among local players.

Circularity applied to the enhancement of the landscape | The didactic goal of the second exercise was to develop an architectural project in compliance with the principles of circular design (Moreno et alii, 2016) applied to the construction sector (Benachio, Freitas and Tavares, 2020), using an Appropriate Technology approach, optimising and offering visibility to the use of local materials and waste from the agri-food supply chains and other manufacturing companies in the area. The practical case of application responds to the intentions of F.lli Durando and NobilBio to create a viewpoint on a piece of steeply sloping land owned by F.lli Durando, offering an extensive view of the Monferrato hills, accessible from the provincial road that runs alongside the land. The idea of the viewpoint originated from the desire of the companies to provide a public place where people can stop and enjoy the local panorama, appreciating the rural landscape (Fig. 2). Aimed at the local community, tourists who are passing through and customers of the farm, the viewpoint also intends to symbolise a bridge between agricultural tradition, care for the land and sustainable, circular innovation.

A number of architectural design circularity criteria were identified for the design of the viewpoint, based on the five phases of the life cycle of buildings identified by Benachio, Freitas, and Tavares (2020): Project Design, Manufacture, Construction, Operation, End of Life. Particular attention was requested in relation to: 1) the Manufacture and End of Life phase phases, envisaging the use of by-products and waste materials (Nußholz, Nygaard and Milios, 2019) or at least materials that are recycled and recyclable at the end of their life (Sanchez and Haas, 2018); 2) the Project Design phase, reasoning in terms of Design for Disassembly (Leising, Quist and Bocken, 2018) and design by modules (Kyrö, Jylhä and Peltokorpi, 2019); 3) the Construction and Operation phase, designing in terms of waste reduction and reasoning on the durability of materials and components, encouraging their replacement with a view to preventive maintenance (Adams et alii, 2017).

Other design indications were taken from the circular design principles of Moreno et alii (2016), the result of a combination with the principles of Design for Sustainability defined by De los Rios and Charnley (2017): Design for Resource Conservation, Design for Reliability and Durability, Design for Extending Product Life and Design for Resource Recovery. Indications were also given with regard to design in terms of Appropriate Technology (Amirante and Gangemi, 1988), particularly in relation to the use of accessible technologies that did not require the use of advanced instrumentation for the processing of semi-finished products (cutting, drilling, foundations) and the assembly of components. Other design indications refer to fundamental criteria such as accessibility, usability and safety, in compliance with the logic of Inclusive Design and Design for All. Lastly, some landscape enhancement requirements were indicated. The project had to respond to the need to be a distinctive element and visual attraction, while being integrated and harmonised with the context, the environment and the landscape, enhancing and supplementing the view of the Monferrato hills and establishing an emotional link with them.

Based on these requirements of circularity, sustainability, functionality and expressiveness, a call for bids was drawn up in agreement with the partners of the Designing Circularity project. The designs presented at the end of the course were judged by the partners according to the criteria defined in the call, particularly favouring formal expressiveness, technical feasibility and adhesion to the landscape restrictions imposed by the region. The design selected will be realised by the companies involved in collaboration with the winning group of students (Fig. 3). The 19 resulting designs are very different from a formal and expressive point of view, but several common features emerged in relation to the choice of construction materials, the technologies required for the processing of the semi-finished products, the systems used for anchoring to the ground and the joints between the elements (Figg. 4, 5). Comparing the projects with respect to the principles of circular economy applied to the construction sector by Akhimien, Latif and Hou (2021), some recurring circularity aspects and some critical issues emerged.

The design choices most in line with the Principles of Circularity (PoC) suggested by Akhimien, Latif and Hou (2021) concern the use of accessible and reversible connections between the different elements, favouring the choice of nuts and bolts over welds, glues and nails. This facilitates assembly and disassembly processes and simplifies the reuse of individual components and elements. Also, in terms of connections, standardised components were largely preferred to specific custom-made components. The modular design approach was also favoured, facilitating the possibility of reusing components at the end of their life and minimising waste. Another recurring element, in line with the PoC, concerns anchorage to the ground, with a preference for reversible screw foundations.

A more critical element concerns the choice of building materials. Generally speaking, the load-bearing structures proposed were made of wood or steel, with laminated beams and posts made of deal, poplar, maple, beech, larch and oak, or recycled and new steel girders. In some cases, the short supply distance of these raw materials was mentioned as an important element in terms of sustainability. Materials made from industrial waste were used only for railings and roofing or flooring and, to a minimal extent, for the padding of some seats. The materials proposed are pallets, disused vineyard posts made of wood or corten, twigs and branches from the pruning of hazelnut trees and vines. In one case, the reuse of disused wine barrels was proposed. In two cases, straw and hazelnut shells were used for seating. In only one case were hazelnut shells used for the production of bricks and, in another case, rice husk panels were used for flooring. In only one case was a recycled material used as the predominant material and this was a recycled plastic fabric used for seats. In general, only 50% of the designs succeeded in incorporating by-products from local production chains into the project. Only in two cases were hypotheses explicitly indicated for the reuse of end-of-life materials.

The analysis of the design proposals reveals a further consideration that combines dimensional and expressive aspects. On one hand, most of the designs tended to propose solutions involving the use of a large amount of material in proportion to the function required, i.e.: that of offering a shortstop next to a panoramic viewpoint. The micro-architectures show a tendency to be oversized. This prompts us, as researchers/teachers and designers, to place more emphasis on one of the key principles

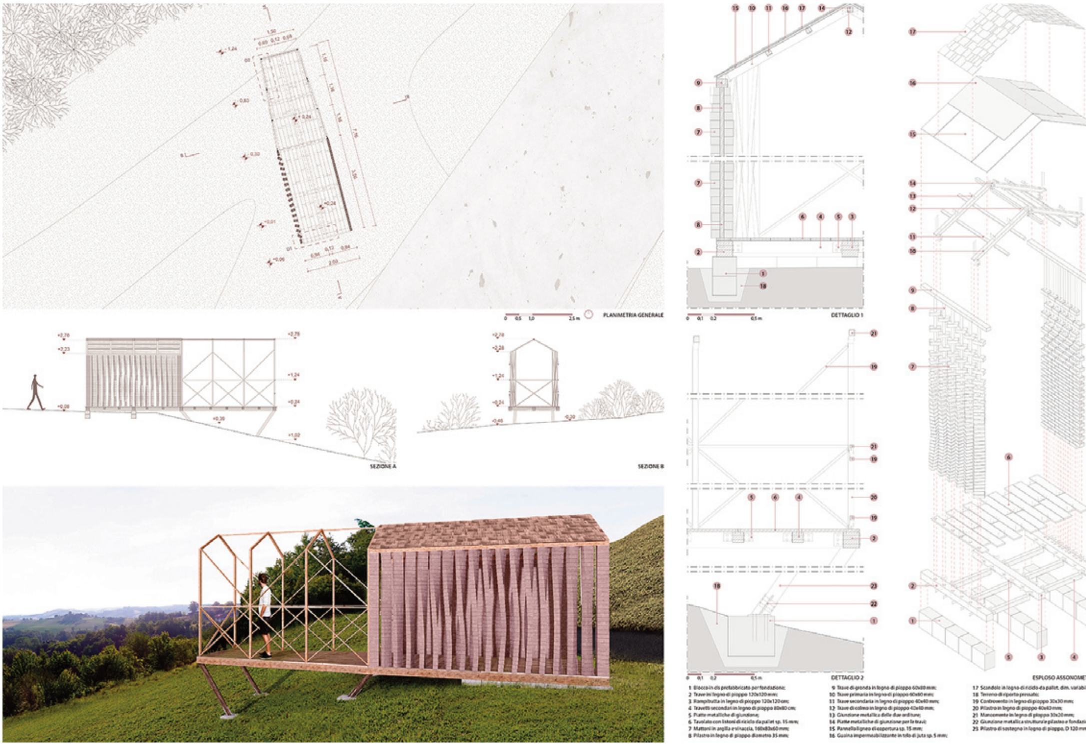

Fig. 3 | Design board of the viewpoint proposal of the winning team (credit: M. Gherardi, C. Goia, A. Marchesi, M. Puglielli and W. Tonelli).

Next page

Figg. 4, 5 | Comparison tables of the viewpoint design concepts (credits: see note 2).

of the CE, which is to design with a reduction in the consumption of material from the concept phase. This oversizing is undoubtedly linked to the need to draw attention to the viewpoint, making it visible, because the idea of the project partners requires it to be seen as an attractive element, acting as a sort of totem, representing the idea of environmental sustainability and promoting circularity.

In this sense, a general overview of the designs allows us to see whether and to what extent they have succeeded in explicitly conveying the principles of sustainability and circularity. While, as noted, the designs were developed in line with many of the principles of circularity from a technological point of view, this circularity was hardly ever explicit from a compositional/aesthetic/expressive point of view. In a sense, the waste from the supply chain, where used, has been so well integrated into the architecture as functional elements that its expressive and representative charge of circularity has taken a back seat. Consequently, this design experience opens up a


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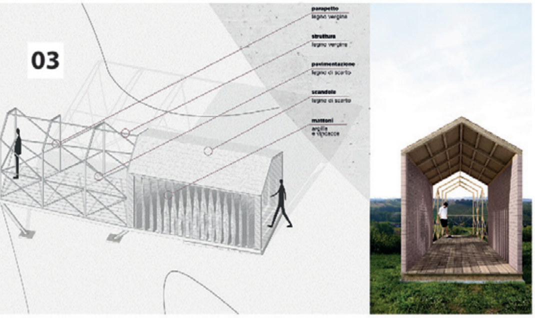
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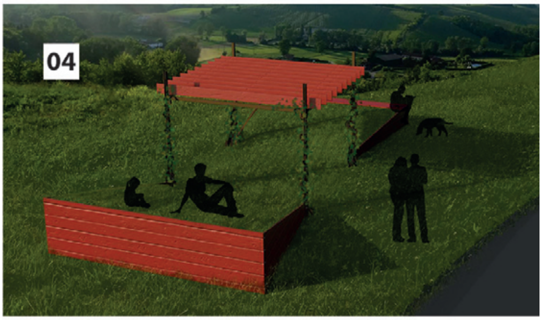
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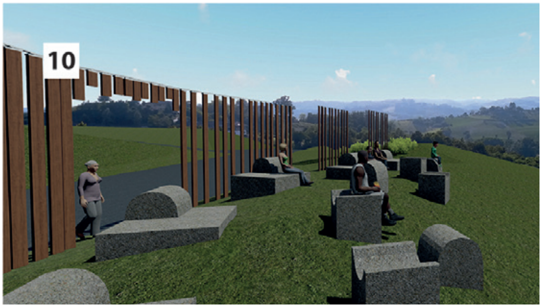
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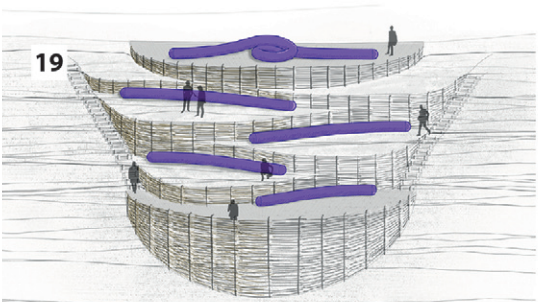

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number of reflections on the 'visibility' of circularity. If the aim of the project, as in this case, is also communicative, it could be effective to emphasise the fact that the materials are living a second/third/fourth life, perhaps trying to 'tell' more about their history, their origin.

This activity highlights how the transition towards a circular economy requires the development of new technologies for architecture and better processes for optimising materials and resources, opening up the possibility of new business models that encourage collaboration and the exchange of resources and skills between companies operating in very different sectors. At the same time, however, it is necessary to work on making the potential of this approach understandable, both socially and culturally, in order to respond to the need to use the resources of our planet more responsibly. As we all know, the challenge of circularity also, and most importantly, begins with the design activity. In this sense, it is important to consider methods and approaches for transmitting and experimenting with these principles in the training courses of those who are going to be designing the environment we live in tomorrow.

Final considerations and possible future developments | The experience brought results for all those involved: the university 'open to the territory' has taken on the responsibility of co-processing circularity and territorial development scenarios together with other local stakeholders; the companies were able to draw on diversified knowledge, with the final result of opening up new prospects for circularity and industrial collaboration; the students developed a critical sense and the ability to design circular economy scenarios in close contact with real 'challenges', global challenges promoted at international level and, at the same time, supported by local actions. The paper highlights how new projects based on the principles of circularity may be able to activate or strengthen networks of producer-stakeholders interested in stimulating virtuous development dynamics in an area rich in resources and characterised by a significant landscape value that has not yet been fully exploited.

The paper deals with a very topical issue, at the heart of the actions promoted by the 2030 Agenda (optimising local resources, rethinking the concept of waste, promoting low environmental impact architecture). The results of the research show how 'small-scale' intervention can promote local development, with results that can also be transferred to other contexts. The article provides ideas to fuel the scientific debate on the transition to alternative socio-economic models to those currently adopted, capable of directing actions towards closer interaction between the parties involved, optimising the use of resources, promoting synergies between production processes and cultural and social contexts. The article also looks at how to transmit this knowledge and the principles of circularity from an educational point of view, a debate that is as necessary and urgent as ever in order to equip future planners with new tools suitable for a circular transition.

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Notes

1) Examples of the same partnership include: CIBUS (CIrcular economy in the BUilding Sector from agri-food waste), research developed within the framework of the Bando Talenti della Società Civile (Civil Society Talents Call) promoted by Fondazione Giovanni Goria and Fondazione CRT, aimed at investigating the effects of the circular economy model on the design of innovative cross-sectoral processes between agriculture and building; Monferrato – Nut...urally – Mon-Nut, a research project within the framework of the 2014-2020 EAFRD programme, which aims to optimise hazelnut waste in the food, biomedical, cosmetic and construction sectors.

2) Students and Work Groups: G1_ J. Barbero, B. Benanchietti, R. Giannuzzi, A. Peluso; G2_ E. Campana, R. Cito, L. Clemente, L. Sanzo, S. Vialardi; G3_ M. Gherardi, C. Goia, A. Marchesi, M. Puglielli, W. Tonelli; G4_ S. Degiacomi, M. G. Pozzo, G. Mana, C. Morani, O. Palazzolo; G5_ K. Babenko, A. Barra, F. Calorio, C. Finotti, G. Fiocca; G6_C. Oceane Sido Lasseur, A. Perucchietti, L. Sanz Allona, Z. Emre Silan; G7_ R. Biondi, M. Leo; G8_C. Rampa; G9_ S. Candido, L. Cassina, E. Deffacis, E. Ferrero, G. Ferrero, V. Schio; G10_ D. Fossà, L. Gallinati, I. Giubellino, F. D. Moldovan, M. Troppino; G11_M. Barbirato, F. Innocenti, V. Nallo; G12_ B. Aimar, G. Autretto, J. Bono, G. R. Latina, M. Martina; G13_ A. Benigno, S. Biancifiori, F. Iacoboni, C. Massucco, A. Parvis; G14_ A. Barbato, A. Farina, T. Uriel Monteu Cotto, C. Patti, S. Valentini; G15_ B. Armano, M. C. Capocotta, M. Di Mauro; G16_ S. Roggia, M. Ronco, M. Salomone; G17_ E. Cerra, S. Fasano, V. I. Fissor, L. Insinna, V. Martone; G18_ A. Cavallini, S. Cavallini, R. Morgoni; G19_ C. Campolmi.

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