Supporting a regional strategy for circular economy in South Tyrol, Italy

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Abstract
The project *Strategy for Circular Economy in the Autonomous Province of Bolzano* aimed at promoting and supporting the transition to a more circular economy (CE) in the region of South Tyrol, Italy. The project focused on the potential synergies between the bioeconomy and the built environment; in particular, it addressed potential opportunities for improving the prevention and management of waste, through the recovery and use of by-products and waste from bioeconomy sectors (namely forestry and agriculture) in construction materials. An integrated approach merging quantitative and qualitative analyses was applied: specifically, the paper addresses the combination of quantitative tools, including geographic information systems (GIS), material flows analysis (MFA) and life-cycle analysis (LCA), with a stakeholder engagement process grounded in semi-structured interviews (SSIs). The integrated approach resulting was oriented to support the public administration in the design and implementation of strategies to enable the transition to a CE in South Tyrol. The findings emerged in terms of (i) harmonizing local legislation and provincial strategies for circularity with market needs of the organizations, (ii) adopting new and improved product design, and (iii) strengthening the inter-sectoral cooperation as far as knowledge sharing, data on material flows and dissemination of good practices are concerned. By combining different tools in an integrated approach, the research contributed with concrete results to supporting the public administration, while also increasing the awareness and the promotion of CE opportunities to key stakeholders - which is crucial to successfully develop and implement effective policies and strategies in the region.

Keywords
Circular economy, regional development, stakeholder engagement, insulation materials, LCA, GIS.

List of acronyms
CE: Circular Economy
CED: Cumulative Energy Demand
C&D: Construction and Demolition
EPS: Expanded Polystyrene
GDP: Gross Domestic Product
GHG: Greenhouse Gas
LCA: Life Cycle Analysis
MFA: Material Flows Analysis
SSIs: Semi-Structured Interviews

1. Introduction

The Circular Economy (CE) focuses on a circular and regenerative use of resources: as stated by the Ellen MacArthur Foundation, the CE is an economy that aims to restore and regenerate products, components and materials, as well as to maintain them at their maximum usefulness and value across time, by distinguishing between technical and biological cycles [1]. As opposed to the traditional linear economic model, CE builds on the principles of closing the loops, keeping resources within our economic system for as long as possible and maintaining their quality and value, or, in alternative, restoring them safely into the environment [2–4]. Having the potential to decouple economic growth from the resource use and its associated environmental impacts, the CE has become a key pillar of sustainable development [2,3].

This paper presents the project "Strategy for Circular Economy in the Autonomous Province of Bolzano", which aimed at promoting and supporting the transition to a more circular economy in the region of South Tyrol, Italy. In brief, the project was carried out in close collaboration with the provincial administration, with the specific goal of providing insight, materials and tools that can support the design, development and implementation of a regional CE strategy. The project included two main components: first, the scientific empirical research on potential opportunities illustrating the use of analytical tools, and providing concrete materials that can be exploited by key organizations and actors in the future development of CE strategies in the region; and second, the involvement of stakeholders to promote awareness and acceptance, identify potential opportunities and barriers and enable a participatory approach, in the design and development of CE strategies. An integrated approach was developed by merging the tools and methods employed in both components, with a focus on two key economic sectors of the region. The paper summarizes the main tools, results and findings of the project and it is structured as follows: in section 2, the scope and strategy of the project are presented, whereas section 3 provides a brief background on integrated approaches to CE studies; the project methodology is presented in section 4, including quantitative and qualitative methods and tools; section 5 presents the main results; and the last section provides concluding remarks, focusing on the integration of tools and methods to support policymaking.

2. The project scope and strategy

The CE is closely linked to the regional and local context, as the design and implementation of circular models should build on the local specificities and opportunities of a territory [5], which determine the availability of resources in the economy, as well as the key socio-economic and environmental aspects [6]. Policymaking for CE, both at the national and European levels, has often been based on principles of territorial cohesion that largely depend on regional assets and specificities, as well as on the "*participatory nature of [local] activities*" [7].

The specific case study of the project is the territory of South Tyrol: located in the far north of the Italian peninsula, on the border with Austria and Switzerland, this region possesses unique cultural and geographical characteristics that affect production and other economic activities. Its territory extends over 7 400 km^2 with a population of about 531 000 inhabitants [8]. The entire territory of South Tyrol is considered mountainous: 14% is below 1 000 m altitude, 49% between 1 000 and 2 000 m, and 37% of the territory is above 2 000 m [8]: the area covered by forests and woodlands is quite extended with almost 400 000 hectares, corresponding to about 54% of the whole surface [9]. Gross domestic product (GDP) per capita is 42 900€, and as such it is significantly higher than the EU and Italian averages of 30 000€ and 28 900€, respectively [10].

The project focused on the potential synergies between the bioeconomy (in particular, the sectors of forestry and agriculture) and the built environment. Specifically, bioeconomy can be defined as an economy that uses biological resources from the land and sea as well as waste, including food wastes, as inputs to industry and energy production, by also covering the use of bio-based processes to green industries [11]. The selection of these sectors was based on their relevance in the regional economy, and on their potential for improvement, in the context of a CE. As an Alpine region, the bioeconomy in South Tyrol assumes a particularly significant role: in 2015, the forestry and agriculture sectors accounted for 4.9% of the GDP, compared to 2.3% in Italy [10]. Moreover, the CE in the bioeconomy context can significantly contribute to (i) a more efficient use of resources, (ii) a reduction of dependence in non-renewable resources, and (iii) the mitigation of climate change and other environmental impacts. Concerning the built environment, in South Tyrol (like in many other regions worldwide) environmental sustainability and climate change mitigation have been mostly addressed through operational energy efficiency strategies in buildings. As an example, in 2019 the building sector contributed to 36% of final energy demand and 39% of greenhouse gas (GHG) emissions worldwide [12]. However, decreased operational energy requirements have generally been associated with a trade-off, where embodied requirements acquire a more significant contribution to the overall life-cycle environmental impacts [13]. In South Tyrol, the construction sector (including buildings and infrastructure) generates about 1 million tonnes of construction and demolition (C&D) waste each year [8], almost four times more than the municipal solid waste generated (264 thousand tonnes in 2019) [14]. The analysis of potential synergies between the bioeconomy and construction sectors can provide insights on the potential opportunities to enable collaboration across stakeholders and sectors as well as to improve the circularity of these resources; in particular, within the scope of the project, it was possible to perform an analysis on the potential for recovering by-products and waste materials from the local bioeconomy to use in building materials and components, thus reducing the need for non-renewable imported construction materials. The integrated approach applied in the project builds on mixed methods and a participatory process that are accounted for in the next section.

3. Background: integrated approaches to support the Circular Economy

3.1 Combining quantitative and qualitative methods

Since the multi-faceted nature of CE builds on the interconnections across different actors and production-consumption processes, to support effective decision-making research should address different perspectives and integrate different methods, in a multi-disciplinary approach, to address the complexities, interlinkages and their implications across different economic sectors and spatial scales. The combination of quantitative and qualitative tools can provide a more comprehensive approach to the study of circularity. The definition of mixed methods has varied over the years due to the wide range of potential applications in science, but it is nevertheless based on the practical synthesis between the two main research paradigms (i.e., quantitative and qualitative) by integrating different data inferences and collection techniques so to address the specific research questions in a balanced, inclusive and informative manner [15], which allows for the generation of relevant research questions within complex and multi-disciplinary topics. Mixed methods indicate that questions within research are not to be answered separately but in an integrated way, so that it is possible to coherently check and validate the research outputs [16,17]. Several challenges have been identified in the adoption of mixed methods, such as (i) the need to have a research team that is skilled in both quantitative and qualitative methods necessary to carry out the research activities, (ii) the constant feedback and transparency required between the two methods so not to have misleading or fallacious outcomes, and (iii) the problem arising from the different reliability of quantitative and qualitative methods in terms of data validation.

Mixed methods have been used to explore several social, economic and technical aspects of CE. For example, they have been applied to the analysis of business cycles and practices to cluster industries according to their efforts towards circularity [18], to evaluate the effectiveness of industrial symbiosis [19], and to examine the effect of CE practices in terms of sustainability performance in small and medium-sized enterprises [20]. Regarding waste management, the application of mixed methods has addressed the identification of circular waste flows within food supply chains [21] as well the analysis of consumer behavior when managing packaging and manufacturing waste [22,23]. In general, mixed method approaches have demonstrated that systemic analyses stemming from the integration of quantitative and qualitative tools can reveal important opportunities for circularity to contribute to more sustainable production and consumption patterns [22]. The combination of different methods has also been exploited to assess and monitor the performance of different CE policies and strategies, both at the regional, national and international levels [24].

3.2 Participatory approaches

Mixed-method approaches can include participatory approaches. In recent years, the role of stakeholders and their interests in the CE has been gaining increasing attention as their engagement is essential to understand the state of the art, identify the barriers, and define viable solutions to foster CE. An example is provided by Guerra and Leite [25], who scrutinize CE awareness of some key members of the U.S. architectural, engineering, and construction industry, as well as to disseminate less adopted circular strategies (such as design for disassembly, design in layers, closed-loop recycling) vis à vis more widespread ones (i.e., open-loop recycling, selective demolition, and prefabrication). Nonetheless, most studies have considered a single stakeholder perspective [26], which can overlook the complexity of the entire production and value chain. Indeed, many studies have emphasized that critical factors in implementing CE are mostly related to economic, technological, regulatory, and socio-cultural factors, which often do not occur alone but are rather blended together. Moreover, De Jesus and Mendonça [27] have also highlighted that the transition toward a CE is not typically hindered by one single factor, but rather by a mixture of constraining factors deriving from local context. Therefore, applying participatory methods in research related to CE with the inclusion of different stakeholders provides not only information on the barriers that characterized each sector, but it also allows to collect different opinions from the participants (rather than from the perspective of the researcher [28]), as they tend to see CE from various angles. For instance, Alhola et al. [29] categorized practitioners as developers and intermediaries, stating that developers lack systemic thinking and recognize barriers close to their own development activities. Intermediaries, on the contrary, recognize barriers along the material supply chain. Farooque et al. [30] highlight the lack of cooperation throughout the supply chain as a prominent barrier. Different visions can in some cases lead to a lack of commitment, thus making it difficult to effectively implement CE measures [29]. Participatory approaches are key to identify and overcome barriers, especially those resulting from cultural context and mindset, promoting acceptance to new approaches and coordinated actions. Within participatory approaches, semi-structured interviews (SSIs) are a method to collect and discuss perceptions of different actors, allowing for an open response in the participants ´own words rather than a "yes or no" short type of answer. Longhurst et al. [31] point out that the semi-structured design allows the interviewee to talk more freely and to bring up issues that had not been thought of in the earlier stages of the research process [29]. This type of interview has been successful in investigating the main business practices related to CE to highlight the main divergences across different industries and economic sectors, as well as the perceived barriers and enablers [18].

3.3 Identifying the relevant stakeholders

The involvement of relevant stakeholders in projects and research activities related to the CE requires that the relevant actors are identified. The importance of this phase, according to Reed et al. [32], can be translated into four main moments: (i) defining which social aspects related to the topic of the project are most affected by the decisions and actions of individuals, groups, or organizations; (ii) identifying these actors by understanding how they are affected, in turn, by the implications of the project itself; (iii) establishing a method for ranking them according to their potential role in decision-making processes; and (iv) understanding the potential relationships between them, especially in a well spatially-defined regional context. Among the main frameworks to identify and select stakeholders, the selection of local features investigated in the state-of-the-art phase is usually combined with the widely accepted quintuple-helix approach by Carayannis et al. [33], which divides the main stakeholder groups in five interrelated categories: academia, government, industry, civil society and environment. The quintuple helix is a more inclusive formulation of the original triple helix theory, which included only government, industry, and academia. Such upgrade is necessary when addressing the topic of CE, as it is essential to strengthen ties and engagement with all of society by including the relationship with the ecosystem and the territory as a whole.

4. Materials and methods

The project combined a set of tools to analyze the potential of CE strategies and measures, including desk research, Life Cycle Analysis (LCA), Material Flow Analysis (MFA), geographic information systems (GIS) and SSIs. Specifically, the research approach focused on an integrated analysis of the potential recovery of biomass from agricultural and forestry activities in building insulation, which was combined by the involvement of relevant stakeholders belonging to key sectors in a process of consultation and exploration of good practices, perceived barriers and incentives to CE, and the functioning of local dynamics of waste and by-products recovery. This section provides the description and the integration of these tools and analyses: first, it delineates the quantification and mapping of the residual biomass potentially available from forestry and agricultural activities; second, it estimates the material requirements and potential C&D waste generation with the MFA; third, it briefly assesses the potential environmental benefits of replacing conventional building materials with local bio-based ones in LCA; finally, it explores the opportunities and barriers with the SSIs performed during the stakeholder engagement phase.

4.1 Quantification of residual biomass from forestry and agriculture

The quantitative analysis started with the evaluation of the residual biomass from forestry and agriculture and of its geographical distribution in the territory of South Tyrol. The residual flows coming from forestry and agricultural activities that include orchards, vineyards and rye, barley and wheat cultivations were considered: it basically includes wood-based material cut off from the trees and plants, currently left in the fields/crops/forests. The residual biomass generated by agricultural activities was determined using data on agricultural land use and literature-based coefficients on residual biomass production for different types of crops (e.g., pruning waste and wood produced at the end of the life cycle of the crop), which are reported in Table 1.

Table 1. Residual biomass coefficients of agricultural products [34]

Orchards (t/ha)	Vineyards (t/ha)	Crops (t/ha)
4.2	0.8	1.0

The calculation of the residual biomass coming from forestry activities, instead, was based on data on withdrawals of wood from forests in South Tyrol, building on Notarangelo et al. [35]. In brief, the residual biomass is obtained from the sum of the re-growth volume (coppiced wood), of the firewood that is left in the forest and of the volume of branches and treetops.

$$Residual\ biomass = coppiced\ wood + left\ firewood + branches$$

About 95% of the prescribed annual levy is taken from the forests for commercialization, while 5% are trees that are cut but left in the forests (trees with diameter < 21 cm at 1.3 m from the ground). The total firewood volume is equal to 46% of the annual levy but only 60% is collected while the remaining part is left on-site after the cutting operations. Finally, the volume of branches and treetops is considered equal to 16% of the commercial volume.

4.2 Characterizing construction and demolition material flows

A streamlined material flow analysis of the residential building stock was performed to provide insight on the potential material requirements and waste generation associated with C&D activities. The material requirements and waste generated depend mostly on the level of activity of the construction sector, i.e., on the volume of construction, re-qualification and demolition activities that are carried out in a certain period. Three scenarios were considered: turnover, conservative, and sustainable. The turnover scenario assumes a continuation of the current incentivization policy for the retrofitting of the existing building stock in Italy; the conservative scenario simulates the end of the incentivization scheme (and absence of state support) for the requalification and construction of buildings; finally, the sustainable scenario represents a solution that foresees the continuation of the policies on fiscal incentives that boost the retrofitting interventions (particularly those using renewable and/or low carbon materials) while discouraging new construction. Basically, the calculation methodology builds on the existing residential built surface (or volume) and makes use of renovation rates and material density parameters to estimate the total amount of C&D waste generated annually. The material flows were then determined as a percentage of the total. The parameters used in the calculations were derived from literature and technical reports on C&D material and waste flows [36,37], and are summarized in Table 2.

Table 2. Parameters used for the evaluation of C&D waste (sources: [36,37])

<table>
<tr><th>Scenario</th><th>Renovation rate</th><th>Material density</th><th>Material composition</th></tr>
<tr><td>Turnover</td><td>1,20% retrofits
0,30% demolitions
1,00% new buildings</td><td rowspan="3">Retrofitting:
320 kg/m²

Demolition:
573 kg/m³

New buildings:
580 kg/m³</td><td rowspan="2">C&D waste: concrete 17%, bricks 8%, mineral materials 58%, wood 8%, insulation materials 8%, metals 0,5%, glass0,5%.
New buildings: concrete 50%, bricks18%, mineral materials 23%, wood 3%, insulation materials 2%, metals 2%, glass 2%</td></tr>
<tr><td>Conservative</td><td>0.60% retrofits
0,15% demolitions
0,50% new buildings</td></tr>
<tr><td>Sustainable</td><td>1,50% retrofits
0,20% demolitions
0,75% new buildings</td><td>C&D waste: concrete 17%, bricks 8%, mineral materials 58%, wood 8%, insulation materials 8%, metals 0,5%, glass0,5%.
New buildings: concrete 51%, bricks18%, mineral materials 20%, wood 5%, insulation materials 2%, metals 2%, glass 2%</td></tr>
</table>

4.3 Life-cycle energy and GHG analysis of building insulation materials

Among the methodologies that evaluate the effectiveness of CE, Life Cycle Analysis (LCA) is a very useful methodology to be applied as it addresses quantitatively the determination of a series of environmental impacts that are classified in mid-point and end-point categories. A life-cycle (LC) energy and GHG analysis was performed to quantify potential benefits of replacing conventional insulation with local bio-based materials. Specifically, a common panel in Extruded Polystyrene (EPS) was compared with locally produced wood fiber board. The selected functional unit was the insulation of a 1 m^2 surface with a thermal resistance of 1 m^2K/W across 50 years. The analysis considered a cradle to gate approach (i.e., including raw material extraction, material transport, processing and production of the insulation) and a service life of 50 years. In the case of the wood fiber, two scenarios were considered in the production, one using the Italian electricity mix, and the other using hydroelectric power – the dominant electricity source in South Tyrol. The LC model is built on *ecoinvent*, a widely used life-cycle inventory (LCI) database. Primary non-renewable energy was calculated using the Cumulative Energy Demand (CED) model [38], and GHG emissions used the IPCC 2013 model, with a 100-year time horizon [39]. The main characteristics of the panels compared are shown in Table 3.

Table 3. Characteristics of the panels compared

Material	Thermal resistance R [Km^2/W]	Density ρ [kg/m^3]	Thermal conductivity λ [W/mK]	Thickness [m]	Mass [kg]
EPS	1.0	30	0.0375	0.037	1.125
Wood fiber	1.0	140	0.0400	0.040	5.600

4.4 The stakeholders' involvement

The stakeholder engagement activities started with the identification of relevant and interested actors to be involved in a process of knowledge and experience sharing, strategic discussion and co-creation process concerning CE in South Tyrol. Starting from the quintuple-helix approach [33], eight stakeholders were selected representing private and public organizations which belong to the bioeconomy and construction sectors. After the outreaching phase, semi-structured interviews (SSIs) were conducted separately each stakeholder. The flexibility of the SSIs has allowed for: (i) the investigation of unanticipated aspects of their activities, (ii) the access to supra-personal and organization-level knowledge, (iii) the discovery of the role within the community and of existing connections to other sectors [32,40]. The interviews were designed so to have dedicated macro-aspects to investigate, as shown in table 4. After introducing the project to the interviewees, the investigation focused on the current knowledge and practices of the organisation regarding the topic of CE, and on their needs, barriers and improvement opportunities, as well as on the availability of data and possible local strategies to implement. From these interviews, it has been possible to gather all the insights and outputs into macro-categories (which are illustrated in section 5.4) covering the relevant factors contributing to the promotion or to the slowdown of CE in South Tyrol. At the end, the interviewees were brought together in a workshop where the main project results were presented and discussed, together with future research and actions toward the development of regional CE policies and strategies.

Table 4. Characteristics of the panels compared

Macro-areas	Topics to investigate
Current knowledge of CE and related practices	Information, prior knowledge, possible initiatives, best practices, tools and opinions regarding the concepts of sustainable development and CE from stakeholders Familiarity with the concept of CE and sustainability Current prevention and waste management practices Material flows and production processes associated with the organization
Reflections and insights	Factors promoting or hindering the implementation of circular economy actions in the reference sectors (agriculture, forestry and construction) Data concerning flows of organic byproducts or C&D waste (respectively for organizations belonging to bioeconomy or to the building sector) Expected cost from the establishment of CE practices in South Tyrol
Expectations from SEC	Understanding which of the strategies and potential benefits of CE are of most interest to business and the community

5. Main results

5.1 Residual biomass from forestry and agriculture

According to the estimates, about 79 688 t of residual biomass are annually produced from orchards, 4 235 t are generated from vineyards and 4 044 t from crops in South Tyrol. A large part of the agricultural biomass available is currently burned by the landowners for domestic heating purposes [41]. However, if forestry activities are considered (see Figure 1), the estimates showed that about 227 410 t of residual wooden biomass is left in the forests of South Tyrol. It should be noted that residual biomass is important in soil and forest management. This trade-off on the regrowth time should be accounted for by considering that not all the biomass available in the forests can be collected for other purposes (e.g., the fabrication of building insulation panels).

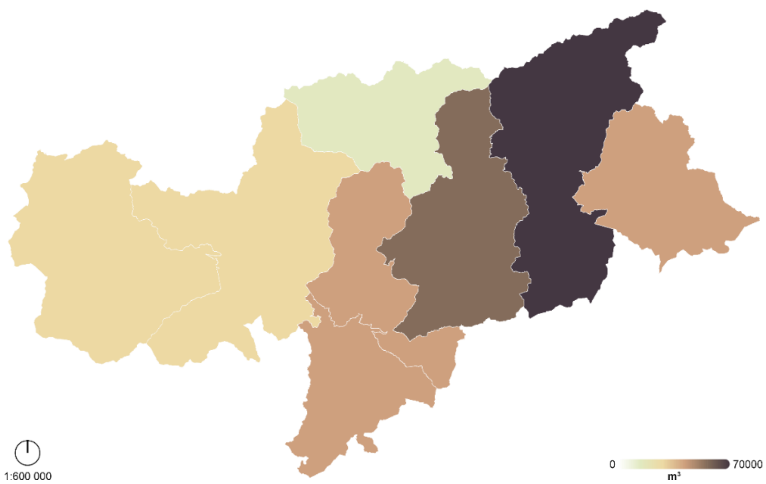

Fig. 1 Evaluation of residual biomass from forestry activities (aggregation by forest inspectorate)

5.2 *Construction and demolition material flows*

The implementation of a MFA model permitted the quantification of the inputs and outputs of materials characterizing the construction sector. The results obtained are reported in Figure 2 for each one of the scenarios considered.

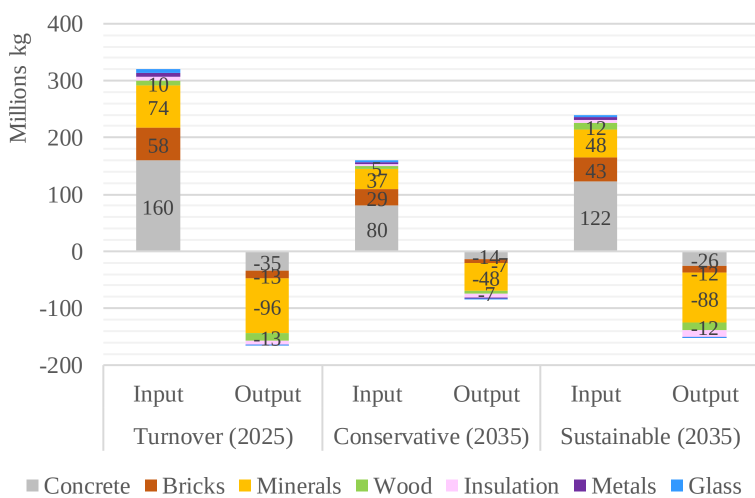

Fig. 2 MFA of the residential construction sector in South Tyrol.

5.3 Life-cycle energy and GHG analysis of building insulation materials

In the LC energy and GHG analysis, the EPS panel was associated with 108 MJ and 4.8 kg CO_2 eq; and the wood fiber alternatives had considerably lower results. The wood fiber produced with the Italian electricity mix showed a reduction of 42% and 15% in non-renewable energy (NRE) and GHG emissions respectively. Additional benefits can be obtained if hydropower-based electricity is used in the manufacturing process: in this case it had a further reduction of 35% and 34% in NRE and GHG respectively, comparing with the panel produced with the national electricity mix. The results confirm that bio-based insulation materials, derived from the recovery of wood residues, have significant potential to lower embodied energy and GHG emissions associated with construction materials.

5.4 The stakeholders' involvement

As mentioned in section 4.4, the outputs of the qualitative analysis have been summarized in Table 5 according to five macro-categories: economic, cultural, spatial, bureaucratic and technical aspects. The engagement process revealed the importance of inter-sectoral cooperation and alignment across industries that are interested and proactive; in cases already implementing individual CE actions. However, a systemic and integrated vision is required for an efficient provincial strategy, building on existing practices, perceptions and opportunities. While economic incentives were identified as the main tool to make circularity attractive for firms, business models and normative aspects are also needed to enable the transition to a CE, such as simplified norms and procedures to use recycled construction and demolition materials, and a more widespread tracing of material flows across local supply chains, with the support of digital tools. In summary, it is possible to point out three crucial aspects that emerged from the stakeholder engagement process, namely: (i) the necessity to raise public awareness and acceptability on the reuse and valorisation of waste; (ii) the creation of a network of trust between relevant actors who can cooperate to increase efficiency and circularity of material flows; and (iii) the challenges in developing innovative products from by-products and waste, which can be context specific.

Table 5. Outputs emerging from the SSIs during the stakeholder involvement phase

Macro-categories	**Outputs of the interviews**
Economic aspects	• Highly fragmented and small-scale local supply chains hinder the re-use of waste and byproducts • Infrastructure, soil and transportation costs influence firms' preferences of import over local purchases • Public incentives are welcome, but they should make organizations capable of autonomously growing in the long run
Cultural aspects	• A stronger attitude for intra-sectoral cooperation (especially within agriculture) emerges if compared to the inter-sectoral one in terms of waste and by-products reuse as well as of data and knowledge sharing • Role of intra-industry cooperatives as crucial aggregators for local firms and producers • Virgin materials, when it comes to building products such as concrete, are still preferred over recycled ones
Territorial and spatial aspects	• Proximity of actors can be exploited for an exchange of byproducts across sectors • Mapping local material flows and C&D waste (differences between rural and urban buildings in terms of material used over the years) is vital to suggest new locally relevant laws and guidelines • Important role of specific types of crops for the local economy (grapes and apples) and of wood-based biomass to power the local district heating system
Bureaucratic aspects	• The role of environmental laws is paramount in the reuse and recycling practices, but more harmonization is required between the provincial and national/European level • Examples of normative adaptation should target the facilitation of the re-use of certain types of recycled concrete and the adoption of ashes as fertilizers • Digitalization of administrative processes concerning CE should be increasingly fostered

Technical aspects	• Disagreement exists about the technical features of South Tyrolean wood as far as its use in the building sector is concerned • Rethinking the design of products is crucial as the mixture of chemicals and metals applied on C&D materials and wood-based materials make separation and disposal complicated • The high rate of reuse of bio-based byproducts within the local energy, food and agricultural industries does not incentivize their application in the building sector

6. Discussion of results, recommendations and future research

The results of the quantitative analyses showed significant potential and benefits, in terms of non-renewable energy (-42% in comparison with EPS) and GHG emissions (-15% in comparison with EPS), if bio-based materials were used to replace conventional materials. The recovery by-products from the bioeconomy to produce building insulation panels can be preferable to direct energy recovery (through incineration) in district heating power plants, since it maintains the economic value of the biomass resources higher. Moreover, the fabrication of insulation panels with biomaterial can have environmental benefits deriving from the substitution of conventional insulation materials of fossil origin. In this way, the use of bio-based waste as secondary raw material for building insulation and other construction products can be an interesting solution to tackle operational energy efficiency with local resources, while avoiding increased embodied requirements. At the Province scale, this type of CE strategy can have significant benefits. Considering the turnover scenario, the annual requirement for insulation materials for residential buildings in South Tyrol accounts for 6 400 t. If this volume was composed only of EPS, it could be replaced by about 31 850 t of wood fiber. This quantity represents only 10% of the residual biomass estimated, confirming the potential sustainability of the process. Several limitations should however be mentioned: (i) the two panels have similar thermal performance but different behavior in terms of interaction with fire and water, for example, which were not addressed; (ii) the physical performance of materials from bioeconomy residues is difficult to determine (the analysis considered literature-based values); (iii) only EPS is considered for comparison, but other materials can have lower embodied energy and GHG [42]; (iv) the use/maintenance and end-of-life phases of the two panels are not modelled. Further analyses should be performed to assess the potential benefits and impacts of redirecting wood-based biomass as a secondary raw material rather than energy recovery, including the energy sources that may be used as alternative.

The potential of bio-based materials was confirmed by stakeholders during the interviews stage, although some obstacles (especially the limited inter-sectoral cooperation) make it difficult to establish robust patterns of material flows exchange in the short run. To exploit this almost untapped potential, it seems clear that balanced strategies should be put in place by considering the local specificities of South Tyrol, by starting from the outputs of the qualitative analysis. The social and economic fabric of the region has unique characteristics due to the history, ethno-linguistic and cultural diversity. Thus, the local dimension of interconnectedness among the various socio-economic groups in the region requires special governance approaches that aim to strengthen relationships across the territory [43]. Coordinated initiatives must be supported by continuous feedback and monitoring activities, as this is crucial for firms and organizations to structure patterns of industrial symbiosis [44], as well as to try and overcome different perceptions of roles along the supply chains [45]. Key lessons learned in these terms concern the facilitation of circular processes: expanding dissemination activities and working closely with regional, national and international partners to harmonize legislation, upscaling and transferring good practices are crucial actions to be achieved. However, the public administration should not impose a top-down approach. Since the need for more cooperation and knowledge sharing is the main aspect to be improved, collective and co-creation processes are to be enabled and kicked off by firms, cooperatives and industrial associations that have CE embedded in their own strategic vision. Undoubtedly, allowing for more bottom-up and organization-driven actions gives more leeway to market-based aspects by considering CE as a source of competitive advantages and innovation along the supply chains [44]. Circularity is to be seen as complementary (and not antagonist) to economic development and competitiveness. Thus, it is necessary to acknowledge local-specific limiting and enabling factors to CE, which may need tailored approaches to be tackled properly. Moreover, it is important to go beyond improvements in the supply chain and address the consumption side of the economic system, in order to boost the reuse of materials and the extension of product life cycles, for example. The potential synergies identified within the bioeconomy and building sectors in South Tyrol need to be further explored; in particular, by developing more robust analyses, implementing indicators for monitoring and improving data collection, and by establishing further discussions across key stakeholders on specific hotspots, such as: (i) the technical qualities and features of local wood, (ii) the role of financial investments that could prevent the potential of biomass to be exploited in other sectors (for instance, by incentivizing the reuse as fuel in the energy sector instead of its employment in the building sector), and (iii) the definition of clearer sustainable development strategies that take into account trade-offs and counterintuitive implications across key economic sectors, as illustrated by the competitive use of land between forestry and tourism [46].

7. Conclusions

This paper presents the integrated approach, combining qualitative and quantitative methods, developed and applied within a CE project in South Tyrol, northern Italy. Considering the local context and developing context-specific research approaches is crucial to support effective policy- and decision-making. The project focused on the bioeconomy and the construction sectors, due to their relevance and importance within the region. A set of empirical tools and methods were combined to address the potential of material reuse of local biomass into the building sector. This was complemented by a qualitative approach consisting of stakeholder involvement activities, which has investigated how such potential resonates with current good practices, sectoral cooperation, and perceived obstacles as well as incentives to CE in South Tyrol. The two approaches turned out to be crucial for supporting the Autonomous Province of Bolzano: by targeting the key aspects identified by stakeholders, with applied research and analyses, the project provided knowledge and tools, tailored to the actual needs of the province and other stakeholders across an important set of sectors. Moreover, involving key actors contributed to increased awareness and acceptability, and promoted an active discussion process on CE measures, which is essential to bring research into practice with effective and successful results. The project highlighted an uncharted potential that can be exploited by managing flows of agricultural and wood by-products and waste and enabled through stronger collaboration among economic sectors and actors.

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