SUSTAINABLE ALPINE ARCHITECTURE & TOURISM: REIMAGINING THROUGH CIRCULAR STRATEGIES

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ABSTRACT

This research investigates the application of circular building strategies within the context of Alpine Architecture and sustainable tourism. With the Alps as a historically rich laboratory for experimentation, this study positions the region as a testing ground for circular building methods. Austria's Circularity Gap, particularly in the construction sector, reveals significant potential for integrating circular solutions to reduce material consumption, improve resource efficiency, and minimise environmental impact. Conducting a combination of literature study, case study analyses and forming strategic frameworks, this paper identifies actionable approaches to close material loops, prioritising locally sourced, renewable, and reclaimed materials. Case studies highlight the role of design for longevity, energy efficiency, and waste minimisation in achieving circularity. The findings demonstrate the feasibility of aligning architectural practices with Austria's sustainability goals while addressing challenges unique to Alpine environments, such as climate change, fragile ecosystems, and tourism pressures. The research contributes to the broader discourse on the circular economy by offering a regional lens that balances global sustainability objectives with local ecological and cultural contexts. The proposed strategies provide a foundation for architectural interventions that not only enhance the built environment but also promote sustainable tourism practices. This work emphasises the urgency of adopting circular principles as integral components of design processes to create resilient, future-oriented solutions in the Alps and beyond.

KEYWORDS *Circular Building Strategies, Sustainable Tourism, Climate Change, Alps, Austria, Circularity Gap, Material Loops*

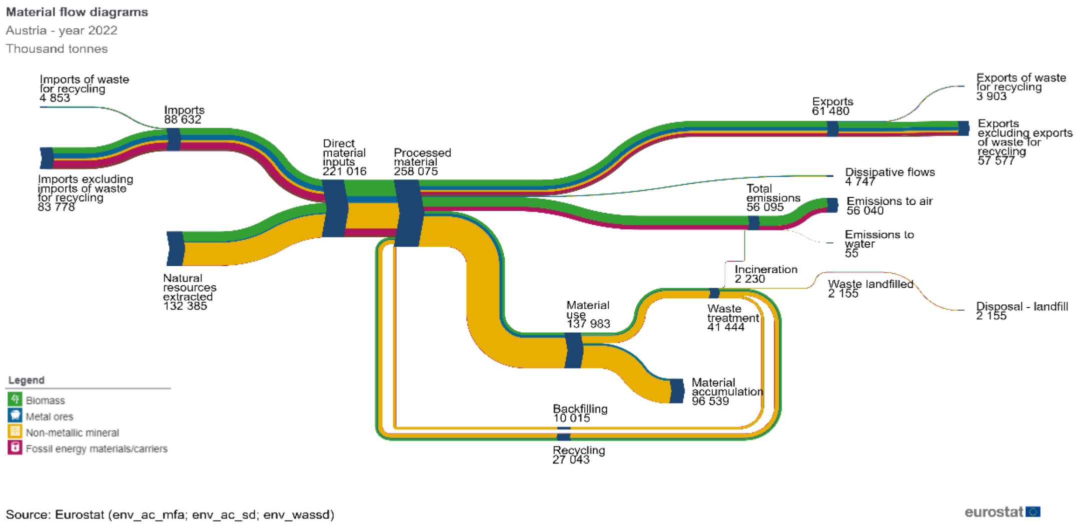
I. INTRODUCTION

Since the 18th century, the Alps have served as a laboratory for various fields of study, such as natural sciences, cultures, and architecture. Constructing structures in the mountains was an impressive accomplishment in the past, given the lack of modern building technologies and accessibility to the region. The challenges in Alpine Regions revolve around climate change, which changes landscapes and has a significant impact on the quality of the Alps and the balance between humans and nature. It is because of this richness in quality, like nature, well-being, winter and summer sports, that many people are drawn to the Alps. Tourism is a major contributor to the economy of these regions. A lot is changing, due to the challenges of climate change. Still, one thing will most probably remain: In the Alpine regions, people will continue to enjoy tourism, striving for health, freedom and unique experiences. This will only be possible in the future in harmony with society and the environment. Therefore, tourism must be developed with low sustainability risks and chances to bring back the qualities of the Alps. Once a Laboratory of Modernism, this research is written with the aim to explore in what way the Alps can be a laboratory for circular building methods and contribute to closing the material loops.

II. CIRCULARITY GAP AUSTRIA ANALYSIS

The transport and building sectors have a significant impact on climate change and are major greenhouse gas emitters. While many strategies to make buildings more sustainable focus on energy efficiency and passive techniques, they often still neglect material circularity or reuse. In 2022, Austria's circularity rate was 13,8% (Eurostat, 2023), higher than the European average of 11,5% but lower than the 27,5% of the Netherlands, the leading country. Austria is, like the Netherlands, committed to reaching a fully Circular Economy (CE) by 2050, indicating the need for accelerating improvement.

Austria has made significant strides in recycling, positioning itself as a global leader with an end-of-life recycling rate of 29,3% and a municipal waste recycling rate of 58% (Circle Economy & ARA, 2019). Despite these achievements, there is an urgent need to move beyond recycling efforts to address the broader Circularity Gap in the Austrian economy. This gap represents the disparity between the current linear economic model and the potential for a fully Circular Economy, where resources are continually reused and recycled.
To close the Circularity Gap in Austria, the report outlines four steps, most of which involve organisational changes. The step of interest for this research is "Developing Decision Metrics and Measurement Framework". In which is stated that Austria requires clear decision metrics and a comprehensive measurement framework to set goals, evaluate progress, and facilitate peer reviews. Such measures are crucial for tracking progress towards global objectives like the Paris Agreement and the UN Sustainable Development Goals. The CE is integral to sustainable development, as it merges economic transitions with environmental conservation and social progress. By minimising resource usage, avoiding pollutants, and reducing waste and emissions, it lowers the overall ecological footprint. This approach contributes to addressing climate change, biodiversity loss, and other environmental challenges.
After the publication of Austria’s Circularity Gap Report (ACGR) numerous convention documents were published outlining the new objectives. The Austrian Circular Economy Strategy (ACES) of 2022 mentions, referring to their Raw Materials Masterplan 2030 (RMM) (BMLRT, 2021), that the crises in recent years have also shown how much the national economy is dependent on international raw material flows. The transition to a CE contributes considerably to the reduction of import dependency and thus to the crisis protection of the Austrian industrial locations, all while the regional creation of value through reuse and recycling activities increases (BMLRT, 2021).



The current state of Material Flow Diagram (2022) of Austria.

2.1 Global Circularity Gap Report

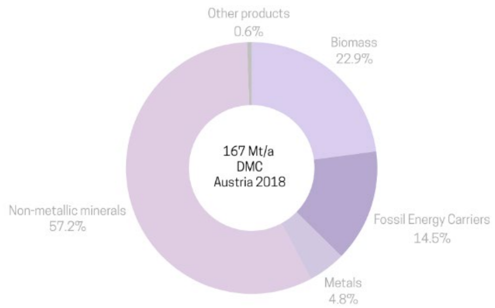
The Global Circularity Gap Report (GCGR) divides certain types of countries by calling them S*hift (*high-income countries in the Global North, as well as in the Gulf, Australia. Member States of the EU, the US, Japan, Canada and Argentina)*, Grow* (Countries in Southeast Asia, Latin America and Northern Africa, as well as those with an economy in transition in Eastern Europe, the Caucasus and Central Asia. China, Indonesia, Brazil, Mexico, Vietnam, Egypt) *or Build* (Sub-Saharan Africa and South Asia such as Bangladesh, Ethiopia, Nigeria, Pakistan and the Philippines) countries. Within this categorisation, Austria can be called a *Shift* Country. Residents of Shift countries lead affluent and comfortable lives and perform well on social measures. However, they consume significantly more than their share of resources, with only 17% of the world's population living there, but consuming one-fourth of global raw materials (Circle Economy, 2024).

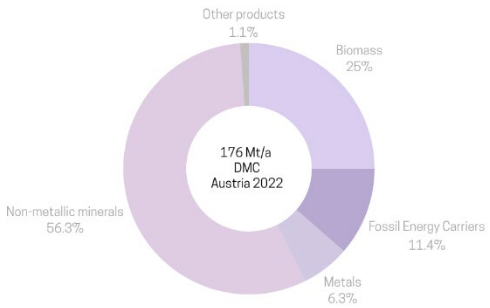
These countries have the highest per capita consumption of non-metallic minerals and fossil fuels, resulting in an average material footprint of 22.6 tonnes per capita, which is 4.6 times that of Build countries and 1.6 times that of Grow countries. Shift countries also account for 43% of global emissions. Their goal should be to reduce material consumption and lessen their impact on planetary boundaries to avoid harming the global majority.

2.2 Material Use in the Construction Industry in Austria

The report on Resource Use (RU) (BMK, 2020) also mentions Austria's Circularity Gap Report (Circle Economy & ARA, 2019) and discusses the recommendations. Implementing a CE related to construction raw materials faces challenges due to the long lifespans of infrastructures, leading to delays in outputs matching resource inputs. Decisions made today in development, design, and waste management will shape the future CE structure. Differentiating between closed-loop, which maintains material quality, and open-loop recycling, which results in downcycling, is essential for effective resource utilisation (p.74, BMK, 2020). The physical constraints of thermodynamics, including energy dissipation and the dispersal of materials, can hinder effective closed-loop processes. Renewable energy sources are crucial for CE processes, although challenges remain due to the competing uses of biomass for energy and material applications.

Non-metallic minerals (cement, lime, ceramics, glass) are the most used materials for the construction industry in Austria, constituting 57% (95 Mt/a) of total material consumption in 2018 and 56% (99 Mt/a) in 2022 (Eurostat, 2024). These materials are primarily used for construction activities and contribute significantly to expanding and maintaining societal stocks. Although sand, gravel and stone have been freely available until now, they are becoming scarce commodities through the huge scale of demand, shrinking availability of land and the quality of grain structure (p. 93, BMK, 2020). Fossil energy materials/carriers are another category of critical materials used in construction, albeit to a lesser extent of 15% in 2018 (24 Mt/a) and of 11% (20 Mt/a) in 2022 (Eurostat, 2024). Over the period of four years following the publication of ACGR and Austria's strategy documents, there can be seen that there is a decrease in the use of fossil energy carriers, but an increase of 4 Mt/a of non-metallic minerals and 9 Mt/a increase in the total domestic material consumption.





To improve the circularity rate, an integrated approach is needed, in which the effects of a combined approach would be bigger than the isolated effects of individual measures. Combining different strategies—such as reducing the need for new stock additions or recovering materials from these stocks (when more material is needed to maintain), increasing the recycling rate, and maintaining existing infrastructure—can lead to significant increases in Austria's circularity. Design strategies could introduce a decision metric to create an almost completely circular design, contributing to the built environment goals and monitoring progress.

2.3 Tourism Flows

In the context of the Austrian Alps, tourism serves as one of the primary contributors to the national economy, drawing visitors globally for the region's natural beauty, cultural heritage, and outdoor activities like skiing and hiking. However, these tourism flows also present challenges, especially when combined with the effects of climate change and the delicate balance of the alpine environment. Understanding and managing tourism flows in the Austrian Alps is essential for preserving the region's natural and cultural heritage while maintaining its economic vitality. By adopting sustainable tourism practices and fostering collaboration among stakeholders, the Austrian Alps can continue to thrive as a destination for both visitors and local communities. With this goal in mind, various strategy documents were created, such as the monitoring document of the Alpine Convention and those of different municipalities.

Within the Austrian Alps, certain flows regarding tourism impacting local environments, economies and communities can be seen. The document that was published by the Alpine Convention in 2021 was 'designed both as a long-term management tool for any alpine tourist destination wishing to measure its sustainable performance and as an instrument to raise awareness and inspire decision-makers who are intent on transforming these opportunities for rebuilding the tourism sector (post-COVID-19) into a more sustainable model' (p. 2, Alpine Convention, 2021). The report contains certain Environmental, Economic and Social & Governance Issues that can be monitored. In the scope of this research, a few of the Environmental and Economic Issues are interesting to review, to discuss the tourism flows to which (design) solutions can contribute to improvement. In Appendix III, an elaboration of the issues is added.

Interesting issues taken out of Monitoring Sustainability of Alpine Destinations (Alpine Convention, 2021)
Environmental Issues:

- Transport and soft mobility
- Management of energy and resources
- Protection of natural heritage and remarkable and ordinary biodiversity
- Action against the artificialisation and degradation of natural ecosystems
- Natural hazards and erosion management
- Impact of climate change (mitigation and adaptation)
- Waste management

Economic Issues

- Enhancing local production
- Spatial development and land planning
- Seasonality

2.4 Contradiction

The concept of sustainable tourism often seems like a contradiction, especially considering that up to 80% of the industry's CO_2 emissions are generated by travel alone (FRAME, 2018). Travelers are increasingly seeking transparency and accountability, leading to innovations in hotel design and guest engagement. Despite the desire to escape and enjoy the qualities of the mountains, the environmental impacts are undeniable, with emissions from transportation and accommodations contributing significantly to climate change.

Historically, specific buildings for mountain users were absent in the Alps until the nineteenth century. Infrastructures were constructed only for the needs of passing traffic, not for the emerging sport of mountaineering or tourism (De Rossi, 2006). Early mountaineers and tourists lodged in existing buildings converted into inns and hotels, leading to the subsequent construction of purpose-built structures. This colonisation of the mountains by new architecture evolved, with a gradual upward conquest of space and the extension of mountain usage throughout the year. The rediscovery of mountain watering places saw the development of hotels and spas, attracting society's elite and promoting domestic mountain use. Alpine railways played a crucial role in tourism development, with various projects connecting mountain communities and facilitating travel. The new century transformed the mountains, spas and summer watering places into a potential machine for mass consumption regulated by the rhythms of the large cities. First-generation resorts emerged, adorned with new hotels, Art Nouveau villas, and Swiss chalets, alongside infrastructure like roads, railways, and funicular railways (De Rossi, 2006). This transformation often coincided with urban embellishments during tourist seasons.

The global emergence of ecotourism in the 1990s initially focused on sustainable accommodation design, such as ecolodges with rainwater harvesting and solar panels (FRAME, 2018). However, criticisms of greenwashing and carbon neutrality arose, questioning the true environmental impact of these establishments. The shift towards a CE and biomimicry has inspired a new approach to sustainability in the tourism industry. Rather than resisting nature, hotels are learning from it and integrating solutions throughout their supply chains.

One example is the adoption of visible and immersive sustainability practices in hotel design, engaging both guests and residents. Water management systems track consumption, and guests are incentivised to stay within usage limits. Waste materials are repurposed, and local artisans are employed to preserve traditional skills and support the community. Programming also plays a crucial role in fostering a planet-minded culture within sustainable hotels. Offering wellness activities, outdoor spaces, and biophilic design elements encourages guests to engage in healthy and sustainable practices during their stay (Morris, 2024).

In essence, making and communicating local connections - seeing hotels not as sheltered enclaves for tired foreign visitors but as connectors between guest and host – perhaps best describes the task of an accommodation that is part of a global resistance to mass tourism and its impact on the environment (FRAME, 2018). Through innovative architecture and design, these establishments aim to reduce their environmental footprint while enhancing the well-being of surrounding communities.

2.5 Visions and Desired Futures

The GCGR poses the question and desired future of what a circular built environment could look like in *Shift* countries. A circular built environment in Shift countries involves maximising the potential of existing structures through adaptive reuse, renovation, and retrofitting rather than demolition. This approach reduces the need for new materials in housing and commercial spaces. Abandoned buildings can be revitalised, and heritage sites preserved with strategic upgrades. The use of locally sourced, renewable, and recycled materials is emphasised. When new construction is required, circular design principles guide the process. Buildings are designed for repairability and deconstruction, promoting future reuse of components and materials. Additionally, these buildings are energy-efficient and seamlessly integrate with renewable energy sources. In this future circular construction is the norm. Normalising CE practices throughout building regulations creates demand in the market for companies to invest in and compete on CE approaches (GCGR, 2024).

'The long-term goal of the Austrian federal government is to reform the Austrian economy and society into a comprehensive sustainable CE by 2050' (p. 8, BMK, 2022). Next to that, it wants to position itself together with Europe as leading industrial locations for high-quality, resource saving and low CO_2 production. The ACES should drive this transformation forward and significantly accelerate it so that Austria becomes one of the pioneering countries in this area (BMK, 2022).
Vision: "The greenhouse gas emissions are reduced to net zero and the use of raw materials, materials and energy and the volume of waste will be massively limited. The remaining demand for raw materials will be covered largely by biogenic raw materials and by high-quality sustainably acquired secondary raw materials from recycling and thus the anthropogenic materials circuits close. Primary raw materials still required will be acquired sustainably, meaning sparing the ecosystems and regenerating them" (BMK, 2022).

III. CIRCULAR STRATEGIES IN AUSTRIA

3.1 Overview of Circular Strategies

As described in Chapter 1.4, CE principles should be considered in the initial design phase. For this research, it is valuable to know which of them are relevant for architecture in the Austrian Alps. The ACES acknowledges that the Construction and Buildings Industry is one of the areas in which most resources are utilised and stresses the importance of the R-strategies (BMK, 2022). In this report, BMK (2022) mentions that the development phase of construction, which includes conception, planning and procurement, significantly influences the lifespan of buildings and the recycling and reusability of materials. During this phase, the decision to choose materials with a lower environmental impact should already be made to reduce the overall material and ecological footprint. To meet EU targets for avoidance, reuse, preparation for reuse, and recycling, the report sets a few goals and measures in which the construction industry must focus on resource conservation, most of them aligning with the ones applied globally.

The research article of Schützenhofer et al. (2022) provides insights into the selection of materials and circular design principles that have the most potential in Austria. The research claims that the ratio of construction and demolition waste (CDW) to required building materials in Austria is approximately 1:10, indicating a significant potential for substituting primary resources with recycled materials (Schützenhofer et al., 2022). The statement highlights the complexity of comparing data on construction and demolition waste (CDW) and required building materials across different member states. This ratio serves as a reference value for Austria, highlighting the opportunity to enhance resource efficiency by prioritising the use of recycled and sustainable materials in construction projects.

The study acknowledges regional variations in CDW ratios, influenced by factors such as population density, construction activity and waste management practices. The variability in CDW ratios among regions, along with the realistic reference value for Austria, stresses the importance of considering regional nuances in resource management and promoting the substitution of primary resources with recycled materials to advance sustainability in the construction industry (Schützenhofer et al., 2022).

Schützenhofer et al. (2022) stress the significance of CE principles, including Material Reuse and Recycling, Resource Efficiency, Life Cycle Perspective, and Data-Driven Decision Making. Despite these principles being well-established, the study highlights the considerable untapped potential for enhancing CE practices in the Architecture, Engineering, and Construction (AEC) sector.

The study introduces a conceptual framework to assess the sustainable CE potential focusing on environmental sustainability and resource efficiency through demolition, reuse, and recycling practices. This framework, in a way, responds to the solution of the ACGR mentioned in the first chapter about the need to develop Decision Metrics & Measurement Frameworks. The proposal of Schützenhofer et al (2022) calls for a robust digital environment and extensive data for implementation, suggesting simpler, actionable measures to facilitate the transition.

In conclusion, the study underscores the urgency of adopting sustainable and efficient practices in building demolition and construction. It highlights the need for investment in time, money, skills, tools, and technologies to drive the shift towards a more circular and resource-efficient AEC industry. The framework, which incorporates Life Cycle Assessment (LCA) indicators like Global Warming Potential (GWP), Primary Energy Intensity (PEI), and Acidification Potential (AP), provides a structured approach to evaluate building sustainability, aiming to guide decision-making towards more sustainable construction and waste management practices.

The proposed framework is conceptual, and the next steps involve a proof of concept and validation. Practical applications can be derived, such as support for deconstruction management, resource management, and conclusions for planning. Due to a lack of data, data collection and public data provision are essential for applicability. This once again, stresses the implications of incorporating the theoretical studies into practical solutions for the circular building strategies.

3.2 Case Studies
The implementation of sustainable construction methods, material (re)use and bio-based materials in the context of the Alps can be researched by exploring case studies. This will be of value to discover the possibilities and the common practice. See Appendix V for a complete overview of the cases.

3.2.1 OLM Nature Escape – Andreas Gruber Architekten
An exemplary case of sustainable hotel design is the OLM Nature Escape aparthotel in South Tyrol, which achieves energy self-sufficiency. The circular building has earned CasaClima Nature certification for its high construction standards, energy efficiency, and climate protection measures. The project embraces the local rural context by using natural materials sourced from the immediate surroundings. The result is an energy-efficient, self-sufficient structure powered by geothermal and solar energy, making it the first hotel in the Alps with a positive energy balance. Water management systems, including water-efficient fittings, greywater recycling, and rainwater harvesting, were also integrated. Despite complexities due to the building's size and shape, the project demonstrates a commitment to sustainability, innovation, and quality.

3.2.2. SVART – Snøhetta – Concept design
In collaboration with Arctic Adventures of Norway, Asplan Viak, and Skanska, Snøhetta designed "Svart," envisioned as the world's first Powerhouse hotel at the foot of the Svartisen glacier in northern Norway. This project aimed to set a new standard in sustainability by reducing annual energy consumption by 85% compared to modern hotels and generating its own energy, crucial for preserving the Arctic environment. Wooden poles supported the structure, ensuring minimal physical impact and enhancing its transparent appearance in the pristine landscape. Energy optimisation was key, with extensive solar radiation mapping and Norwegian solar panels maximising energy capture. The use of materials with low embodied energy was crucial in meeting the Powerhouse criteria. As part of the Powerhouse collaboration, Svart aimed to generate more renewable energy over its lifecycle than the total energy required for construction, operation, and demolition. Although the project was terminated at the concept design stage in 2019, it remains an interesting example of sustainable and circular design in architecture.

3.2.3 Hotel Ryttergården – 3XN, GXN
Efficient resource utilisation and fabrication are showcased by Hotel Ryttergården in Bornholm, Denmark. This hotel emphasises cross-laminated timber construction for its carbon-sequestering properties. Prefabricated cross-laminated panels were manufactured in a factory using highly accurate computer-controlled techniques, minimising construction time, waste and cost. The inside is based on a 'kit of parts' plan that sees box-like units fill the volume. Rooftop solar cells and water recycling systems further enhance sustainability. Additionally, the standardised design of the units allowed for accurate prediction of material offcuts, which were then repurposed to create furniture items for the hotel, minimising waste. Waste from granite and gas production has been processed locally into new, beautiful products at the hotel. In this way, the building itself is an expression of the hotel's ambition to make green solutions an attractive element for guests (Morris, 2024).

3.2.4 Haus Rauch – Lehm Ton Erde Baukunst GmbH
The residential building in Schlins, Austria, designed by Martin Rauch utilises excavated earth from the construction site itself. The structure and envelope of the building are formed by solid rammed earth walls, adhering to the concept of geobased local mining, where locally sourced earth is employed for construction. Rammed earth offers the significant advantage of being fully recyclable. A constructed wall can be deconstructed, rehydrated, and reused to produce the same quality of building material repeatedly. Any excess material can be returned to the ground without treatment, as it is free

of chemicals. Rammed earth walls also provide excellent thermal mass. This characteristic helps to moderate extreme temperature fluctuations, thereby reducing energy consumption passively. Additionally, these walls can store moisture, creating comfortable indoor environments with optimal air quality and humidity levels.

3.2.5 House K

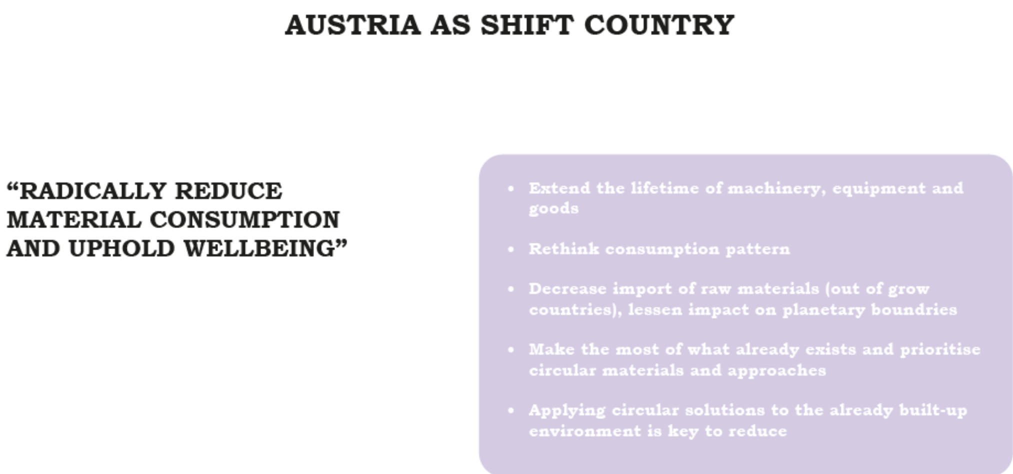
Rammed earth is also used in the project House K of Seilerlinhart Architects. The central development core, constructed from rammed earth sourced directly from its own excavation site, serves as the house's centrepiece, spanning four floors. This core provides a striking, earthy contrast to the bright and spacious rooms surrounding it. Its proximity to the wood-burning stove allows it to efficiently distribute heat gradually throughout the floors while also regulating the humidity levels within the entire house. The exclusive use of wood defines the architectural character of the building. All exterior and interior walls, as well as the roof, are constructed from untreated solid wood elements, eliminating the need for additional insulation materials. The floor slabs are designed as substantial board-pile ceilings. This design approach results in a home free from metal, adhesives, and chemical building materials, relying solely on pure wood.

3.2.6 Office Block in Alpnach – Küng Holzbau. Seiler Linhart Architekten

The Office Block in Alpnach by Seiler Linhart Architekten and Küng Holzbau exemplifies principles highly relevant to sustainable architecture. Its commitment to material simplicity, using only natural timber without adhesives or composite materials, aligns with circular economy principles by ensuring design for disassembly and material reuse. The use of locally sourced silver fir and beech demonstrates an effective integration of local resources, minimizing transport emissions and supporting regional forestry. This project is notable for its exploration of biological material resources in construction, offering an innovative approach to reduce embodied carbon. The sandblasted concrete core integrates functionality (stairs, lift, and fireplace) with durability, while maintaining a minimalist aesthetic that resonates with Alpine vernacular architecture. The absence of insulation layers and reliance on solid timber walls challenge conventional energy efficiency norms, suggesting a climate-specific design strategy. Its emphasis on lifecycle thinking and adaptability provides a valuable case study for material-conscious, resilient architecture in Alpine contexts.

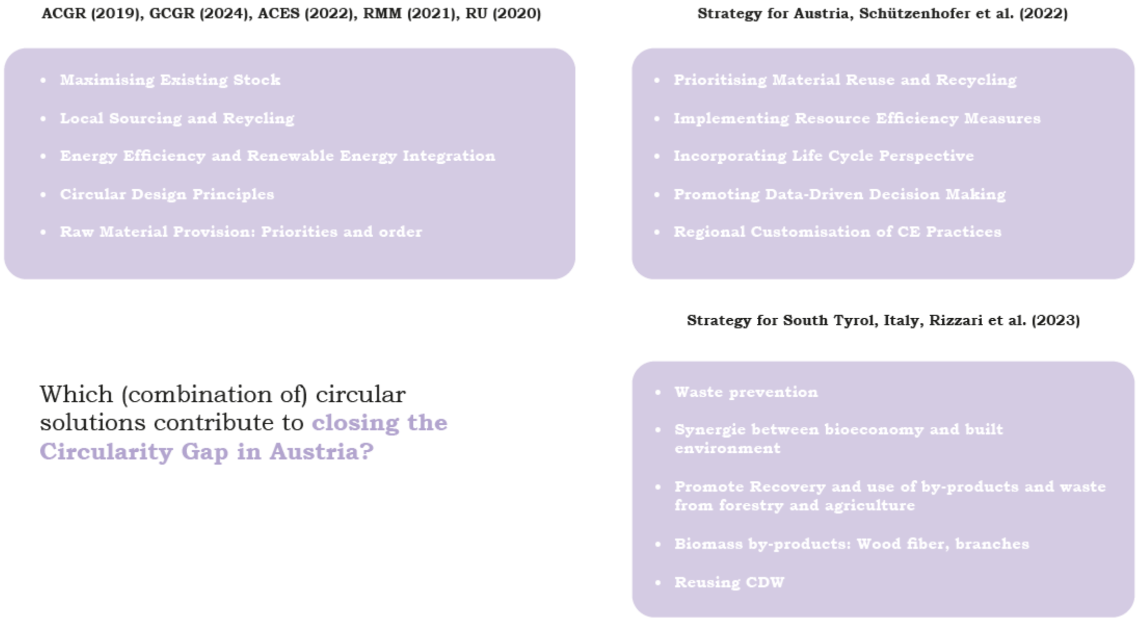
IV. RESULTS

The results of the literature study in chapters one and two can be put in an overview in which the different circular solutions and recommendations can be listed. Austria's Circular Economy Strategy and Tourism strategies outline ambitious goals for transitioning to a sustainable CE by 2050. In the context of the building industry and sustainable tourism, architectural decisions and interventions play a crucial role in realising these goals.



Austria as a shift country – ACES, 2022

RESULTS LITERATURE



Overview recommendations literature

The overview in the image presents the results in their key aspects. For a deeper explanation of the recommendations, a summary is added to appendix VI.
By following these strategies, according to the researched literature, Austria can significantly enhance its resource efficiency and sustainability in the construction sector, aligning with broader CE principles and reducing the environmental impact of building activities.

The results of chapter three provide an interesting overview into the sustainable and circular principles that are most commonly applied in practice up until now and in what way they contribute to closing material loops and reducing energy resources. Based on the case studies discussed, it can be seen that in Alpine countries and rural locations, this is mainly done with the use of local, natural materials such as wood, earth and natural plasters and stone. In this research, no case study was found (yet) where materials are reused or reclaimed. The case studies gave a better insight into the practical interventions of the possible and common principles and were assessed with the CE principles that came out of the Circularity Gap report in mind. By learning from these examples, future developments can further refine and expand sustainable practices, contributing to a more sustainable built environment.

An overview of the categories and their circular solutions researched in the case studies:

Material Sourcing and Use
- Local and Natural Materials
- Elimination of Chemical Additives

Energy Efficiency and Renewable Integration:
- Self-Sufficiency
- Design for Energy Optimization

Circular Design Principles:
- Design for Longevity
- Efficient Use of Resources

Repurposing Waste
Water Management
    Innovative Water Systems
Rammed Earth and Thermal Mass
    Rammed Earth
    Thermal Mass and Humidity Regulation
Efficient Space Plans
    Maximising Space Efficiency
    Multifunctional Design Elements

V. CONCLUSION & DISCUSSION

5.1 Conclusion

To contribute to closing the Circularity Gap in Austria and promote a more sustainable and circular economy, the results of this research contain a combination of circular solutions that can be implemented. They aim to maximise resource efficiency, reduce waste generation, and promote the reuse and recycling of materials. The information was found in strategy documents, concerning Austria, but the list of key strategies could apply to other countries. The regional customisation of CE Practices should be taken into account. For Austria, this means, as seen with the case study analysis, that this mostly contains locally sourced wood (certified) or other natural materials and implementing renewable energy sources. Based on resource use in Austria, the most significant reductions can be made in non-metallic minerals and fossil energy carriers.
The research of Schützenhofer et al. (2022) provided insights into the selection of materials and circular design principles that have the most potential in Austria. This article forms the second part of the list of possible circular solutions together with the solutions advised in the strategy documents. With the explanation of the CDW ratio per region in the article of Schützenhofer et al., it could be concluded, why the circular design principles of reuse and reclaimed materials are not conventional (yet) and not found in the case studies situated in Alpine countries.
As seen in the first chapter, discussing the strategies of ACGR, GCGR, ACES, RMM, there is a great potential to elevate the Circularity Rate of Austria. Schützenhofer et al. (2022) even call this a significant untapped potential for increasing the CE of Austria. The strategies the sources come up with are fairly similar. The framework Schützenhofer et al. (2022) propose, is still conceptual and needs proof of concept and validation to be applicable. Data collection and public data provision are essential for applicability. This is also why almost all strategy documents stress the importance of digital tools, like Building Information Modelling (BIM) and material passports (MP). Which will eventually also help with efficiently implementing the strategies.

With the found solutions in case studies, the more practical question about the optimal integration of circular solutions in the design (process) can be answered. The results provide a list in which form (and maybe also the 'how') they can be integrated. For 'the how', there can be concluded that the circular solutions were the starting point in the design process of the case studies and not an afterthought.
Next to the proven high potential of improving the circularity rate of Austria, improving the sustainability of Alpine tourism could also help significantly in the problems climate change causes for Austria. Prioritising certain (material) flows is crucial to minimise environmental impact, promote resource efficiency, and support the well-being of local communities. This regards waste management, energy and resource efficiency and solutions in transport. Within the tourism sector, flows that should be considered are water use practices, local sourcing and food production, and promoting sustainable transport.

In conclusion, the research provided a lot of insights and gave an overview of the circular solutions and integration in the context of the Austrian Alps. With the results and sub conclusions an answer to the thematic research question can be formed. The most suitable circular solutions should be researched for the specific design location (in the context of the Austrian Alps), from the beginning of the design process and kept in mind. When designing a project that enhances the Sustainability of Tourism, the flows of water use, local (material) sourcing, food production and waste management should be prioritized. This research started with the aim to explore in what way the Alps can be a laboratory for circular building methods and contribute to closing the material loops. It ends with the conclusion that for the Alps to be a laboratory for circular building methods, people should make the most of what already exists and prioritise circular materials and approaches.

Based on the conclusions of the literature review and the case studies, a framework could be created in which design inputs and potentials of a given circular solution could be linked. This created a practical strategy for implementation (from the case studies) and a strategy based on possible solutions researched in the region-specific literature focused. This strategy (added on the next pages) forms a basis grounded in research for the design phase.

STRATEGY LITERATURE

SOLUTION - INPUT - POTENTIAL

Circular Solutions	Design Input	Potential
Maximising Existing Stock	Prioritise adaptive reuse, renovation, and retrofitting of existing buildings to preserve resources and cultural heritage.	Reduces demand for new materials, decreases waste, and maintains historical and cultural continuity.
Local Sourcing and Recycling	Use locally sourced, renewable, recycled, or reclaimed materials in construction.	Promotes resource efficiency, reduces transportation emissions and offshore environmental impacts
Energy Efficiency and Renewable Energy Integration	Incorporate energy-efficient features and renewable energy sources into building designs.	Reduces energy consumption, minimises reliance on fossil fuels, and contributes to a positive energy balance.
Circular Design Approaches	From the initial design stages apply modularity, material transparency, and lifecycle thinking.	Ensures efficient resource use throughout the building's lifecycle, facilitating future reuse and recycling.
Prioritising Material Reuse and Recycling	Emphasise the reuse of materials and recycling of construction and demolition waste (CDW).	Substitutes primary resources, reducing environmental impact.
Implementing Resource Efficiency Measures	Adopt practices that minimise waste generation and optimise material use.	Enhances sustainability by reducing resource consumption and environmental impacts.
Incorporating Life Cycle Perspective	Consider the entire lifespan of buildings, using Life Cycle Assessment (LCA) indicators to evaluate environmental impacts.	Provides a holistic understanding of a building's sustainability, informing better design and material choices.
Promoting Data-Driven Decision Making	Develop digital environments for data collection and analysis, implement Material Passports (MPs) and Building Certification systems.	Enhances transparency and informed decision-making in resource management.
Regional Customisation of CE Practices	Tailor CE strategies to regional specifics, considering local construction practices and waste management systems: bioeconomy (forestry, agriculture) and by-products.	Addresses unique regional needs, improving the effectiveness of CE strategies.

STRATEGY CASESTUDIES

Practical examples of implementation

Category	Circular Solution	Design Input	Potential
Material Sourcing and Use	Local and Natural Materials	Use wood, earth, natural plasters, and stone.	Promotes sustainability and reduces environmental impact.
	Elimination of Chemical Additives	Avoid adhesives, composites, and chemical materials.	Reduces pollution, ensures healthier living environments.
	Rammed Earth	Use for its thermal mass properties, regulating indoor temperatures and humidity.	Provides natural temperature and humidity regulation, reducing energy consumption.
Energy Efficiency and Renewable Integration	Self-Sufficiency	Implement geothermal, solar, and other renewable energy systems.	Achieves energy self-sufficiency and reduces reliance on fossil fuels.
	Design for Energy Optimisation	Use design strategies that maximise energy efficiency and minimise consumption.	Lowers energy consumption and operating costs.
Circular Design Approach	Design for Longevity	Ensure durability and long-term performance of buildings.	Extends building lifecycle and reduces need for frequent replacements.
	Efficient Use of Resources	Optimise space and material use to minimise waste.	Enhances resource efficiency and lowers costs.
	Repurposing Waste	Reuse material offcuts and other waste in construction or furniture.	Reduces waste and promotes a circular economy.
Water Management	Innovative Water Systems	Integrate water-efficient fittings, greywater recycling, and rainwater harvesting.	Enhances water conservation and reduces utility costs.
Efficient Space Plans	Maximising Space Efficiency	Plan spaces to optimise functionality and minimise material use.	Ensures efficient use of space and materials, reducing waste.
	Multifunctional Design Elements	Incorporate elements that serve multiple purposes to enhance efficiency.	Increases functionality and reduces the need for additional materials.

5.2 Discussion

The questions posed in this research could, in principle, be answered through the results obtained. The study primarily focused on specific literature tied to the context of Austria and other Alpine regions. However, during the process of gathering results, addressing the questions, and forming conclusions, the findings were often articulated in more generic terms. This gives the impression that the research is of a more generic nature, with outcomes centred on identifying generalised solutions. Nevertheless, many of these solutions are directly derived from recommendations by Austrian ministries and research papers specific to the particular region of the Alps.
While circular principles are universally applicable, their implementation often requires region-specific adaptations. Achieving a fully circular economy at a national level is challenging due to the complexities of import and export, yet identifying and applying the most relevant circular economy (CE) practices on a regional scale is feasible. This broader articulation may come from the fact that many regionally specific documents themselves are based on insights drawn from more general frameworks. As shown, Austria is not a pioneer in circularity rate, and it is possible that the development of policies, papers, and recommendations relied on generic examples, reflecting the broader state of circularity in the region. Although it seems more generic, the results and conclusions were valuable for this research and its objective to develop a strategy for the design process. It does, however, indicate that further specification and integration of circular interventions can still be explored and implemented during the design phase, allowing for a more tailored approach to sustainable solutions at the specific design location.

Making, for example, the summary of BMK (2022) on Raw Material Provision and order in priorities (see Appendix VII), which is part of the strategy, more specific to architecture in the Alps there would need to be a priority on Sustainable Secondary Sources. Making reuse strategies important, even though these processes are not specifically found in the context of this research. This would make it interesting to research during the design phase, which materials could be reclaimed in the context of the Alps. Given the most used materials are wood, stone and concrete, sourcing these materials from structures to minimise the need for new materials is probably what will happen. Sustainable Renewable Sources would be certified timber. Utilising timber from sustainably managed forests close-by, certified by bodies such as FSC or PEFC, ensures responsible forestry practices that promote ecological balance and biodiversity. Or using bamboo and other rapidly renewable materials. Incorporating materials that regenerate quickly and can be sustainably harvested, reducing the pressure on slower-growing resources. Then finally there should be no (or limited) use of Non-Renewable Sources, only if necessary. For example eco-friendly insulation materials, like wool, cellulose, or hemp should be chosen over non-renewable options, balancing thermal performance with sustainability. And finally if non-metallic minerals are really needed, for essential non-renewable resources such as limestone for cement, the focus should be on sourcing from operations that adhere to high ecological and social standards, minimising environmental impact through careful resource management and rehabilitation efforts.

The part that is not discussed thoroughly in this research, but which is part of the research question is how the circular design principles can be efficiently implemented in the context of the Austrian Alps. Research about certain practical design strategies is not researched as a subject of its own, but almost all sources dealing with the circular strategies, stress the importance of a proactive and holistic approach from the start of the design process and an early engagement of all stakeholders. This phase should entail a life cycle assessment (LCA), a clear overview of the selection of materials and their sourcing and other circular design aspects. It is this realisation that is important at the start of the design phase, but researching the different practical steps of the design process could be a research topic on its own. In the scope of this research and the following design objective and assignment, this (efficient) implementation can be researched 'by doing/design' as follow-up on this literature and case study research.

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Appendix I - Glossary of Terms

- Circularity Gap

  The circularity gap refers to the difference between the current level of resource use and waste generation in an economy and the level needed to achieve a fully circular economy. In a circular economy, resources are used efficiently, waste is minimised, and materials are continuously reused, recycled, or repurposed. The circularity gap measures how far an economy is from this ideal state, possibly highlighting areas where more sustainable practices are needed to close the gap and improve resource management and waste reduction.

- Flows of Tourism

  Flows of tourism refer to the movement and distribution of all activities related to tourism within a specific region, encompassing both the quantity and patterns over time. This includes factors such as the origin and destination of tourists, travel routes, duration of stay, and peak visiting times. But also the resources, such as energy (sources), building materials and food production that are needed to provide for all activities related to tourism. Understanding these flows is essential for planning and managing tourism sustainably, ensuring that the region's attractions and amenities can accommodate tourists without causing undue strain or negative environmental impact.

- Sustainable Tourism

  Sustainable tourism is an approach to tourism that seeks to minimise its negative flows that impact the environment, local culture, and society while maximising its positive contributions to the well-being of local communities and economies. This approach involves responsibly managing natural, cultural, and heritage resources to ensure their preservation for future generations. By balancing economic, environmental, and social goals, sustainable tourism aims to provide enriching experiences for visitors while protecting and enhancing the destinations they visit.

  In the context of the Alps, sustainable tourism focuses on protecting the fragile alpine ecosystems, landscapes, and biodiversity while providing quality experiences for visitors. This includes managing the pressures of seasonal tourism, such as winter sports and summer activities, like hiking, while also striving to shift toward year-round tourism to decrease the impact of climate change on the economy. All of this in a way that respects the capacity of the environment and local communities. Sustainable tourism in the Alps aims to maintain the main source of income and at the same time the preservation of natural and cultural heritage, ensuring the region remains a viable and desirable destination for future generations.

Appendix II - Alpine Architecture – A history, summary interesting parts of Antonio De Rossi's book

The introduction of Antonio De Rossi's book starts with a statement of Swiss architect Bruno Reichlin, in which he says that Alpine Architecture represents a diverse array of technical, material, formal, and ideological approaches, making it a laboratory of architectural modernism (De Rossi, 2006). Beyond architecture, the transformation of the Alps since the eighteenth century serves as a litmus test for societal attitudes towards nature, tradition, identity, and modernisation. Anthropologist Mondher Kilani suggests that the interaction between local and global influences in the Alps provides insights into modern values and practices, highlighting both the unique characteristics of mountain communities and their connections to broader societal structures. Alpine architecture and landscape serve as windows through which we can observe and understand the evolution of cultural and societal concepts over time.

Alphonse Daudet recognised the simultaneous modernisation and preservation inherent in the development of Alpine regions. In his work "Tartarin on the Alps" (1886), he humorously portrays 'how the 'Disneying' Processes of the Alps are not just a contemporary prerogative but were already present during the phases of their discovery and invention' (p. 11, De Rossi, 2006).

De Rossi (2006) also mentions Federico Sacco's book "Geologia applicata della Città di Torino" (1907), in which he analysed the materials of the built village as though it was a geological formation. The image of the mountains physically and visually entering the city was even stronger, with Alpine stone transported via railways overlaying the city's clay layer of buildings, symbolising a close relationship between village and mountain.

Historically, specific buildings for mountain users were absent until the nineteenth century. Infrastructures were constructed only for the needs of passing traffic, not for the emerging sport of mountaineering or tourism. Early mountaineers and tourists lodged in existing buildings converted into inns and hotels, leading to the subsequent construction of purpose-built structures. This colonisation of the mountains by new architecture evolved over time, with a gradual upward conquest of space and the extension of mountain usage throughout the year.

The rediscovery of mountain watering places saw the development of hotels and spas, attracting society's elite and promoting domestic mountain use. Alpine railways played a crucial role in tourism development, with various projects connecting mountain communities and facilitating travel.

The eclectic style of alpine architecture, exemplified by buildings like hydroelectric power stations designed as castles using local materials, continued well into the twentieth century. These structures, along with chalets, villas, and grand hotels, reflected the era's fascination with picturesque mountain living and the late romantic tastes of urban middle classes.

The new century transformed the mountains, spas and summer watering places into a potential machine for mass consumption regulated by the rhythms of the large cities. First-generation resorts emerged, adorned with new hotels, Art Nouveau villas, and Swiss chalets, alongside infrastructure like roads, railways, and funicular railways. This transformation often coincided with urban embellishments during tourist seasons.

These constructions, whether nestled in panoramic locations or adjacent to villages, stood in stark contrast to the rugged mountain landscape, sparking marvel and wonder. Villas and gardens, set against the backdrop of alpine peaks, embodied an idealised microcosm within nature.

This vertical expansion of the territory, while initially representing a sophisticated interpretation of the mountain environment, revealed its negative aspects during the era of mass tourism in the 20th century. Despite embodying urban perceptions of mountain living, the structures' sectional relationship with the terrain and their gradual detachment from the built environment showed the complex interplay between development and natural morphology.

Appendix III - Alpine Convention, Monitoring Tabel Sustainable Tourism

The issues that are interesting concerning this research are taken out and summarised. To see the whole monitoring table:

Alpine Convention. (2021). *Measuring the tourism sustainability of mountain destinations in the Alps*. Retrieved April 16, 2024, from https://www.alpconv.org/fileadmin/user_upload/Topics/Measuring_tourism_sustainability_of_mountain_destinations_in_the_Alps_2021_en.pdf

Environmental Issues:

- Transport and soft mobility

The alpine topography complicates travel, leading to reliance on road transport which causes environmental impacts like air pollution, noise, and traffic jams. These issues can be exacerbated by tourism activities during high season. Two types of transport are identified: trans-Alpine (from outside the alpine area) and intra-Alpine (within the alpine area), with a good intra-Alpine transport system potentially benefiting the local economy.

- Management of energy and resources

The European Union aims to be more energy self-sufficient and climate-neutral by increasing the use of renewable energies and improving energy efficiency, targeting 32% renewable energy by 2030 and carbon neutrality by 2050. The main energy consumption is related to heating needs, transport, and electricity. Currently, 80% of heating demand in the EUSALP territory is met by non-renewable sources, with the remaining 20% covered by locally generated renewable energy (biomass and biofuels).

- Snowmaking and the management of large facilities

The impact of snow scarcity on tourism is manageable until at least 2050 with 45% snowmaking coverage. Artificial snow production, however, leads to water loss (10-30%) due to evaporation and seepage. With every 1 ºC increase in temperature, the snowline rises by about 150 meters. Sustainable water management strategies, including efficient use of water resources and addressing conflicts regarding water uses, are necessary, especially in the context of artificial snowmaking in ski resorts.

- Protection of natural heritage and remarkable and ordinary biodiversity

Alpine flora is impacted by human activities, global warming, and tourism infrastructure. Protected areas cover 30% of the Alpine Convention territory, but protection levels vary. Global warming causes species to move to higher altitudes, replacing specialised high-altitude plants with more competitive lower-altitude species.

- Action against the artificialisation and degradation of natural ecosystems

In spatial planning, it's crucial to consider the territory's loading capacity, soil waterproofing, and landscape preservation. An environmental approach should be integrated for all constructions, with inhabitants encouraged to participate. Artificialisation of soils, defined as the transformation of natural, agricultural, or forest soil for urban or transport functions, should be carefully managed.

- Natural hazards and erosion management

Residual risk from natural hazards remains even after implementing protection measures. Winter sports and tourism in the Alps, especially skiing, significantly impact fragile Alpine soils and ecosystems. Increased winter sport activity and infrastructure development contribute to avalanche risks. Global warming is causing more frequent rock falls, affecting alpinism activities and necessitating changes in itineraries.

- Impact of climate change (mitigation and adaptation)

Global warming in the Alps has surpassed 1.5°C over the last century, double the global average. The EU's climate-energy targets aim for a 20% reduction in greenhouse gas emissions by 2020 and 40% by 2030. In the Alps, emissions stem from transport, energy, heating, construction, and tourism. Climate change leads to rising temperatures, altered precipitation, and more extreme weather events like heatwaves and droughts. These changes affect mountain ecosystems and landscapes, with permafrost thawing and increased risks of rockfalls. The Alpine Climate Target System 2050 aims for climate neutrality and resilience. The Alpine Convention's Climate Action Plan includes measures for the tourism sector to address these challenges.

- Waste management

Tourism activity generates significant waste, particularly in accommodation and catering facilities during peak seasons. Reducing food waste is a priority for European countries to decrease greenhouse gas emissions, pesticide use, and economic costs. The European Union aims to recycle 55% of municipal waste by 2025, 60% by 2030, and 65% by 2035, with specific targets for product packaging. Waste contamination from mountain treks and expeditions is a concern, highlighting the need for improved waste collection infrastructure and tourist education.

Economic Issues

- Enhancing local production

Encouraging regional production and consumption in the Alps is vital for fostering a green economy. Local authorities play a key role in promoting regional production cycles to support sustainability. By encouraging consumption of sustainable regional products and services, communities can foster connections between producers, service providers, vendors, and consumers. External investments can further support sustainable economic development in the Alps, particularly in the tourism sector, by promoting natural resources and high-quality services.

- Spatial development and land planning

The Alpine region faces challenges in spatial planning and sustainable development due to limited space, rising land prices, and competition from tourist accommodation and second homes. The construction of second homes brings wealth and employment but also leads to economic, social, and environmental issues. Measures are needed to balance accommodation prices with local incomes, manage the underutilisation of tourist lodgings, and ensure respect for the territory's capacity and economic balance. This could involve anticipating land needs for tourist accommodation and limiting urbanisation and second homes.

- Seasonality

Supporting the local economy and promoting year-round tourism in mountain destinations are essential for reducing dependence on the winter season and meeting evolving guest expectations. Diversifying tourism offerings throughout the year is crucial for economic development and employment in these areas. This requires developing non-skiing activities, facilitating split stays, and maintaining services year-round. Seasonal fluctuations pose challenges for destinations, such as managing infrastructure during peak times and dealing with low revenue and workforce during off-peak seasons. Promoting four seasons tourism leads to more stable revenue, enabling investment in local amenities and enhancing the overall appeal of mountain destinations. Progress can be made through diversifying and adjusting offerings, attracting new markets, and revitalising the mountain's image beyond winter sports.

Appendix IV - Questions & Answers Email Contact Andreas Gruber Architekten – OLM Nature Escape

Welche Baumaterialien wurden genau verwendet und woher stammen sie?
Südtirols Bauwerke im ländlichen Kontext sind vorwiegend von einer natürlichen Material Wahl geprägt. Diese Haltung leitet sich davon ab, dass man die Materialien vom Ort und der unmittelbaren Umgebung bezogen hatte. Diese Haltung haben wir auch im Falle des Projektes Olm Nature Escape übernommen. Prägende Materialien sind natürlich mineralische Oberflächen in Form von natürliche putze und stein Oberflächen sowie naturbelassene Hölzer. Großzügige Glasflachen verknüpfen innen und außen räume miteinander.

Das Bauwerk wurde in einer Zeit (2019-2023) entwickelt und realisiert, in der es global gesehen, zu geschichtlich einschneidenden Ereignissen gekommen war. Diese Gegebenheiten haben wir wie so oft als Herausforderung angenommen und diese Erkenntnisse in ein einzigartiges Bauwerk übertragen. Entstanden ist ein energieeffizientes autarkes Gebäude, gespeist mit Erdwärme und Sonnenenergie. Kenner der Branche beschreiben es als erstes Hotel Gebäude mit positiver Energiebilanz, in den Alpen und vermutlich auch etwas darüber hinaus. Wichtig war für uns auch das Wasser Management durch wassereffiziente Armaturen, graues Wasser Recycling und Regenwassernutzungssysteme.

Die Verwendung von lokalen und recyclebaren Materialien stellt ein weiteres wichtiges Element bei der Umsetzung des Projektes dar. Mineralische Oberflächen oder naturbelassenes Lärchenholz für den Innenausbau werden dieser Anforderung gerecht. Sehr oft wird auch die Langlebigkeit eines Bauwerkes mit dem Thema der Nachhaltigkeit gemessen. Die Einfachheit und Flexibilität von Olm Nature Escape unterstützt ebenso diesen Aspekt.

Welche Art von Energiestrategie wurde verwendet?

Erdwärme mit 150 Sonden a 125m tiefe. Auf einer Fläche von ca. 15000qm

800kw pv Anlage

Wurden bestimmte architektonische Interventionen gezielt eingesetzt, um einen Beitrag zum nachhaltigen Tourismus zu leisten?

Die Idee ein rundes Gebäude zu schaffen, entstand aus der Verknüpfung von vielen Parametern, welche mit dem entsprechenden architektonischen Entwicklungsprozess einher gingen. Im Vordergrund stand stets die respektvolle Haltung gegenüber dem Landschaftsbild, die Bedürfnisse des gastes als zukünftiger Nutzer als auch der architektonische Anspruch nach Innovation und einer hohen qualitativen Lösung für innen und außen Räume.

Die Planung und Realisierung einer kreisrunden gebäudeform erfordert eine hohe Verknüpfung der Kompetenzen zwischen Planungsteams und praktischer Umsetzung. Dieser Herausforderungen haben wir uns in einer exzellenten Zusammenarbeit angenähert. Olm Natur Escape verfügt über üppige Glas Fassaden, um die entsprechenden Qualitäten der Landschaft auch in die Innenräume zu übertragen. Dies erfordert beispielsweise, dass sämtliche statische Strukturen nach innen verlagert werden. Schlitze und Decken Durchbrüche für Haustechnik und Automation sowie Brandverhütung birgen bestimmte Komplexitäten. Man bedenke, dass das Bauwerk einen außen Durchmesser von ca. 95m ausweist und eine Bruttogeschossfläche von gut 4200m² umgesetzt wurden. Ein wesentlicher Aspekt war die effiziente Raum Nutzung und Planung des Gebäudes aus Sicht des Betreibers, welche dann schlussendlich ein wesentlicher Indikator für die Wirtschaftlichkeit des Bauwerks darstellt.

Translation
South Tyrol's buildings in a rural context are predominantly characterised by a natural choice of materials. This attitude derives from the fact that the materials were sourced from the location and the

immediate surroundings. We have also adopted this approach in the Olm Nature Escape project. Characteristic materials are natural mineral surfaces in the form of natural plasters and stone surfaces as well as natural wood. Generous glass surfaces link interior and exterior spaces.
The building was developed and realised at a time (2019-2023) in which, from a global point of view, historically drastic events took place. As is so often the case, we accepted these circumstances as a challenge and translated these insights into a unique building. The result is an energy-efficient, self-sufficient building, fuelled by geothermal and solar energy. Experts in the industry describe it as the first hotel building with a positive energy balance in the Alps and probably even beyond. Water management through water-efficient fittings, grey water recycling and rainwater harvesting systems was also important to us.

The use of local and recyclable materials is another important element in the realisation of the project. Mineral surfaces or natural larch wood for the interior fittings fulfil this requirement. Very often, the longevity of a building is also measured in terms of sustainability. The simplicity and flexibility of Olm Nature Escape also supports this aspect.

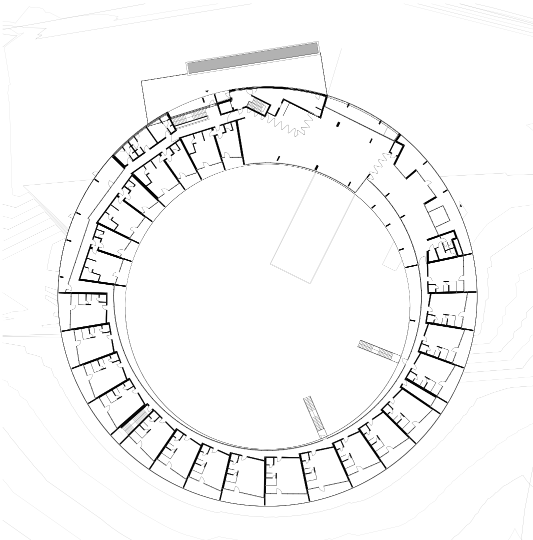
Geothermal energy with 150 probes, each 125 metres deep. On an area of approx. 15000 square metres

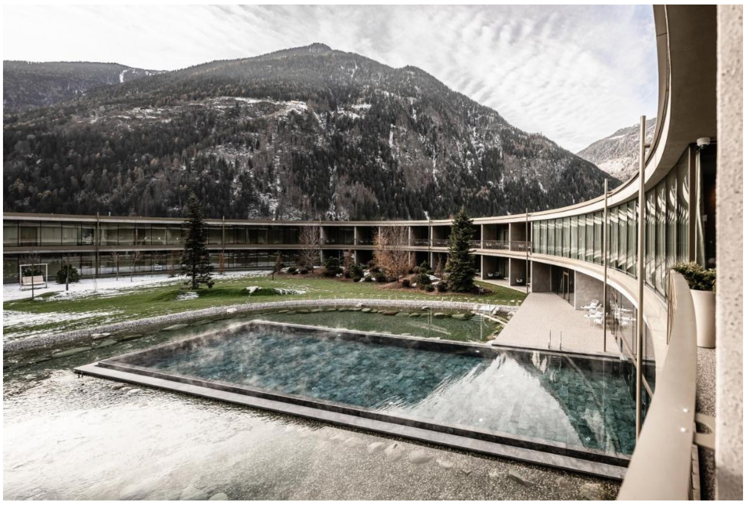
800kw pv plant

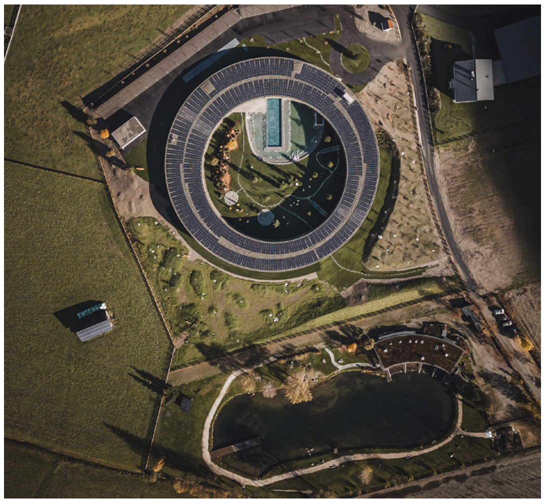
The idea of creating a round building arose from the combination of many parameters that went hand in hand with the corresponding architectural development process. The focus was always on a respectful attitude towards the landscape, the needs of the guest as future user and the architectural demand for innovation and a high quality solution for interior and exterior spaces. The planning and realisation of a circular building shape requires a high level of interlinking of skills between planning teams and practical implementation. We approached this challenge through excellent collaboration. Olm Nature Escape has opulent glass façades in order to transfer the corresponding qualities of the landscape to the interior spaces. This requires, for example, that all static structures are relocated inwards. Slots and ceiling openings for building services and automation as well as fire prevention harbour certain complexities. Bear in mind that the building has an external diameter of around 95 metres and a gross floor area of a good 4,200 m². A key aspect was the efficient utilisation of space and planning of the building from the operator's point of view, which ultimately represents a key indicator for the economic efficiency of the building.

OLM Nature Escape – Andreas Gruber Architekten

Location	Sand in Taufers, South Tyrol, Italy
Year	2019-2023
Maximising Existing Stock	No, newly built
Material Resources	Biological, Technical materials
Local Sourcing – distance to site	Larch wood (2nd most common tree in South Tyrol)
Energy Efficiency and Renewable Energy Integration	Self-sufficient: 126 geothermal probes (125 m deep, 15000 m^2), solar energy systems (800 kW PV)
Circular Design Principles – Design Approaches	Design for Longevity
LCA: Skin, Structure, Services, Space plan, Stuff	Skin: natural mineral surfaces in the form of natural plasters and stone surfaces Structure: static structures (solid wood) are relocated inwards (the circle). Services: Slots and ceiling openings for building services, fire prevention. Water management through water-efficient fittings, greywater recycling and rainwater harvesting systems. Space plan: efficient utilisation of space & planning of the building.
Label/Certification	CasaClima Nature





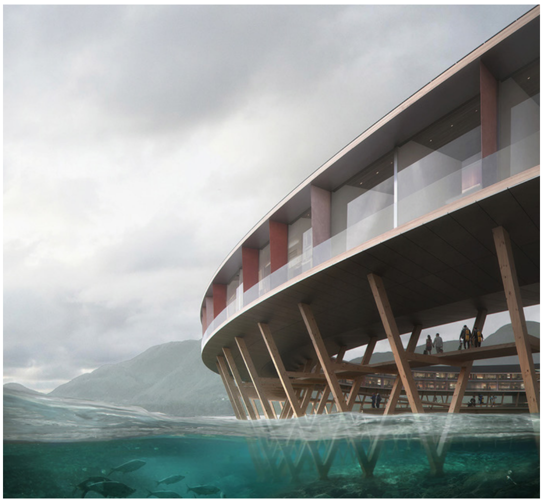


An exemplary case of sustainable hotel design is the OLM Nature Escape aparthotel in South Tyrol, which achieves energy self-sufficiency through 126 geothermal probes and solar energy systems. The circular building has earned CasaClima Nature certification for its high construction standards, energy efficiency, and climate protection measures. It is circular in its form and function.
The project embraces the local rural context by predominantly using natural materials sourced from the immediate surroundings. These materials include natural mineral surfaces like plasters and stone, as well as natural wood, with generous glass surfaces connecting interior and exterior spaces. Developed and realised between 2019 and 2023, during a period of significant global events, the project aimed to overcome challenges and translate insights into a unique building. The result is an energy-efficient, self-sufficient structure powered by geothermal and solar energy, making it the first hotel building in the Alps with a positive energy balance. Water management systems, including water-efficient fittings, greywater recycling, and rainwater harvesting, were also integrated.

Local and recyclable materials were prioritised in the project's realisation, contributing to its sustainability and longevity. The simplicity and flexibility of Olm Nature Escape further enhance its sustainability. The circular building design was chosen to align with landscape considerations, guest needs, and architectural innovation, requiring close collaboration between planning teams and practical implementation. The building's opulent glass facades capture the landscape's qualities, while efficient space utilisation and planning from the operator's perspective ensure economic efficiency. Despite complexities in construction and infrastructure due to the building's size and unique shape, the project demonstrates a commitment to sustainability, innovation, and quality in both interior and exterior spaces.

Svart – Snøhetta (Concept)

Location	Svartisen Glacier, Norway
Year	2017-2019
Maximising Existing Stock	No, newly built, still concept
Material Resources	Biological, Technical materials
Local Sourcing – distance to site	unknown
Energy Efficiency and Renewable Energy Integration	Self-sufficient. Aim to reduce 85% of energy consumption. Norwegian solar panels produced with clean hydro energy. (Solar mapping determined form of design)
Circular Design Principles – Design Approaches	Design for Longevity, Regenerative Design
LCA: Skin, Structure, Services, Space plan, Stuff	Skin: predominantly Glass Facades Structure: Wood (minimal footprint), Concrete? Services: no details Space plan: multifunctional design elements (e.g. boardwalk & structure) efficient utilisation of space & planning of the building.
Label/Certification	-



In collaboration with Arctic Adventures of Norway, Asplan Viak, and Skanska, Snøhetta designed "Svart," envisioned as the world's first Powerhouse hotel at the foot of the Svartisen glacier in northern Norway. This project aimed to set a new standard in sustainability by reducing annual energy consumption by 85% compared to modern hotels and generating its own energy, crucial for preserving the Arctic environment.
The circular design of Svart, inspired by local vernacular architecture in the form of the "fiskehjell" (A-shaped wooden structure for drying fish) and the "rorbue" (a traditional type of seasonal house used by fishermen), extended into the Holandsfjorden fjord, minimising its environmental footprint. Wooden poles supported the structure, ensuring minimal physical impact and enhancing its transparent appearance in the pristine landscape. Energy optimisation was key, with extensive solar radiation mapping and Norwegian solar panels maximising energy capture. Secluded terraces and large windows utilised natural thermal energy, reducing the need for artificial cooling and heating. The use of materials with low embodied energy was crucial in meeting the Powerhouse criteria. As part of the Powerhouse collaboration, Svart aimed to generate more renewable energy over its lifecycle than the total energy required for construction, operation, and demolition. Although the project was terminated at the concept design stage in 2019, it remains a pivotal example of sustainable and circular design in architecture.

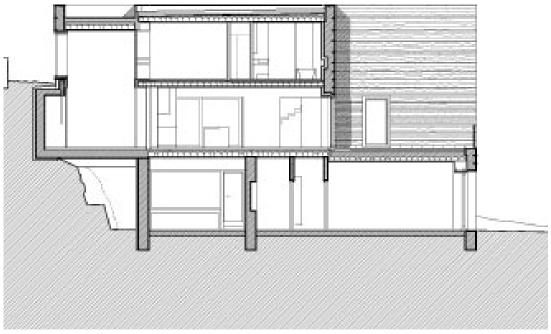
Hotel Ryttergården – 3XN, GXN

Location	Bornholm, Denmark
Year	2021
Maximising Existing Stock	No, newly built
Material Resources	Biological materials
Local Sourcing – distance to site	CLT prefabricated, tiles of upcycled glass from local sources
Energy Efficiency and Renewable Energy Integration	Rooftop Solar Cells
Circular Design Principles – Design Approaches	Design for Longevity, Design for Standardisation, showcase for material innovation
LCA: Skin, Structure, Services, Space plan, Stuff	Skin: Timber Cladding Structure: CLT Services: Natural ventilation, Solar cells, water recycling Space plan: Standardisation of units, efficient utilisation of space & planning of the building.
Label/Certification	-

Efficient resource utilisation and fabrication are showcased by Hotel Ryttergården in Bornholm, Denmark. This hotel emphasises cross-laminated timber construction for its carbon-sequestering properties. Prefabricated cross-laminated panels were manufactured in a factory using highly accurate computer-controlled techniques, minimising construction time, waste and cost. The inside is based on a 'kit of parts' plan that sees box-like units fill the volume. Rooftop solar cells and water recycling systems further enhance sustainability. The design leverages the precision and repeatability of computer-controlled fabrication to deliver custom solutions at a lower cost than traditional methods. For example, elegant grills for natural ventilation are cut directly into the CLT panels, showcasing the advantages of a holistic design approach that integrates design, manufacturing, and performance. Additionally, the standardised design of the units allowed for accurate prediction of material offcuts, which were then repurposed to create furniture items for the hotel, minimising waste. Waste from granite and gas production has been processed locally into new, beautiful products at the hotel. In this way, the building itself is an expression of the hotel's ambition to make green solutions an attractive element for guests (Morris, 2024).

Haus Rauch – Lehm Ton Erde Baukunst

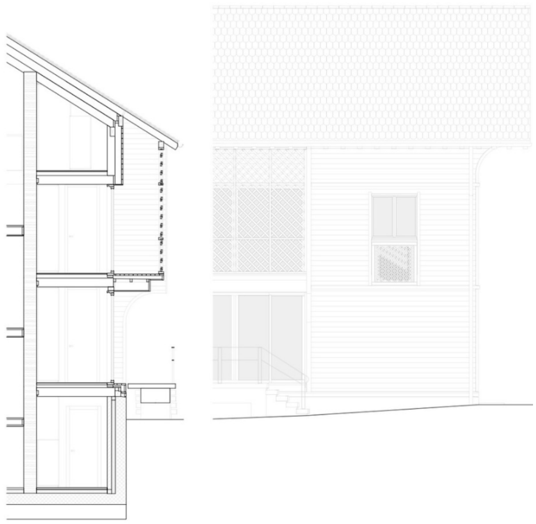
Location	Schlins, Austria
Year	2005-2008
Maximising Existing Stock	No, newly built
Material Resources	Biological
Local Sourcing – distance to site	Own excavation pit, 0 km
Energy Efficiency and Renewable Energy Integration	Thermal mass, acts as heat buffer
Circular Design Principles – Design Approaches	Design for Longevity, Regenerative Design
LCA: Skin, Structure, Services, Space plan, Stuff	Skin & Structure: Solid rammed earth Space plan: Efficient, Rectangular
Label/Certification	-



The residential building in Schlins, Austria, designed by Martin Rauch utilises excavated earth from the construction site itself. The structure and envelope of the building are formed by solid rammed earth walls, adhering to the concept of geobased local mining, where locally sourced earth is employed for construction. Rammed earth offers the significant advantage of being fully recyclable. A constructed wall can be deconstructed, rehydrated, and reused to produce the same quality of building material repeatedly. Any excess material can be returned to the ground without treatment, as it is free of chemicals. Rammed earth walls also provide excellent thermal mass, acting as a heat buffer by absorbing heat during the day and releasing it during cooler nights. This characteristic helps to moderate extreme temperature fluctuations, thereby reducing energy consumption passively. Additionally, these walls can store moisture, creating comfortable indoor environments with optimal air quality and humidity levels. In Austria and Switzerland, there are multiple examples of projects of Lehm Ton Erde Baukunst GmbH in which rammed earth is used.

House K - Seiler Linhart

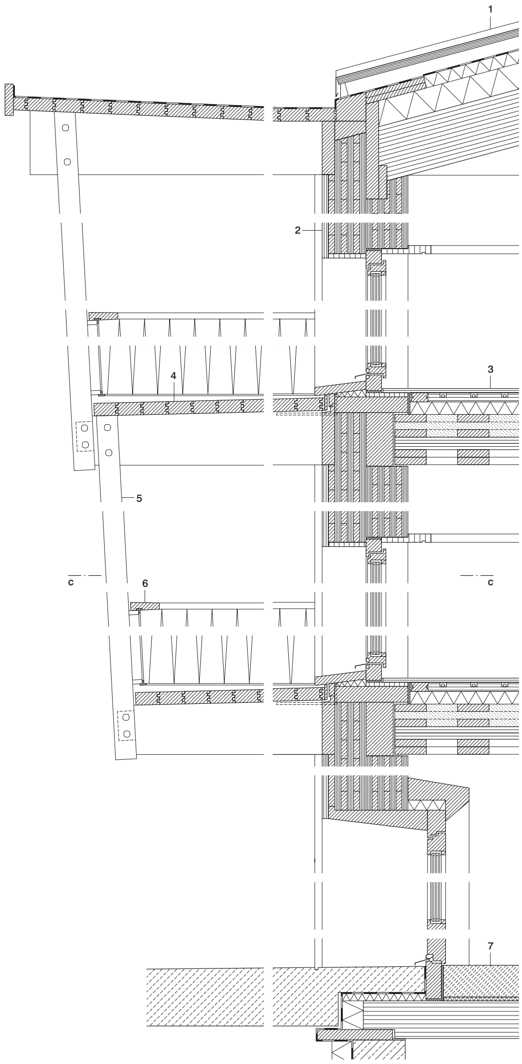
Location	**Alpnach, Switzerland**
Year	2018
Maximising Existing Stock	No, newly built
Material Resources	Biological
Local Sourcing – distance to site	Earth, own excavation pit, local spruce/silver firs
Energy Efficiency and Renewable Energy Integration	Thermal mass, heat distribution, wood-burning stove
Circular Design Principles – Design Approaches	Design for Longevity, Regenerative Design, Disassembly
LCA: Skin, Structure, Services, Space plan, Stuff	Skin: Untreated solid wood elements Structure: Solid wood, Rammed earth, concrete pedestal (reinforced with bamboo) Services: Stove Space plan: Efficient, Rectangular, Open around core
Label/Certification	-



Rammed earth is also used in the project House K of Seilerlinhart Architects. The central development core, constructed from rammed earth sourced directly from its own excavation site, serves as the house's centrepiece, spanning four floors. This core provides a striking, earthy contrast to the bright and spacious rooms surrounding it. Its proximity to the wood-burning stove allows it to efficiently distribute heat gradually throughout the floors while also regulating the humidity levels within the entire house. Complementing the natural material palette, Tadelakt is used for the walls in wet areas, and casein is applied to the floors in both the entrance and bathroom areas. The house is built on a sturdy concrete pedestal reinforced with bamboo, providing a robust foundation. Rising above this base is a three-story timber structure, crafted entirely from the company's proprietary solid wood system (HolzPur). The exclusive use of wood defines the architectural character of the building. All exterior and interior walls, as well as the roof, are constructed from untreated solid wood elements, eliminating the need for additional insulation materials. The floor slabs are designed as substantial board-pile ceilings. This design approach results in a home free from metal, adhesives, and chemical building materials, relying solely on pure wood.

Office Block – Küng Holzbau. Seiler Architekten

Location	**Alpnach, Switzerland**
Year	2021
Maximising Existing Stock	No, newly built
Material Resources	Biological
Local Sourcing – distance to site	Local silver fir, Beech
Energy Efficiency and Renewable Energy Integration	
Circular Design Principles – Design Approaches	Design for Disassembly
LCA: Skin, Structure, Services, Space plan, Stuff	Skin: Silverfir Structure: Solid timber, sandblasted concrete core Space plan: Efficient, Square, Open, Core
Label/Certification	-



The Office Block in Alpnach by Seiler Linhart Architekten and Küng Holzbau exemplifies principles highly relevant to sustainable architecture. Its commitment to material simplicity, using only natural timber without adhesives or composite materials, aligns with circular economy principles by ensuring design for disassembly and material reuse. The use of locally sourced silver fir and beech demonstrates an effective integration of local resources, minimizing transport emissions and supporting regional forestry.

This project is notable for its exploration of biological material resources in construction, offering an innovative approach to reduce embodied carbon. The sandblasted concrete core integrates functionality (stairs, lift, and fireplace) with durability, while maintaining a minimalist aesthetic that resonates with Alpine vernacular architecture. The absence of insulation layers and reliance on solid timber walls challenge conventional energy efficiency norms, suggesting a climate-specific design strategy. Its emphasis on lifecycle thinking and adaptability provides a valuable case study for material-conscious, resilient architecture in Alpine contexts.

Appendix VI – Explanation Recommendations Result / Summary of Literature

Explanation Recommendations ACGR (2019), GCGR (2024), ACES (2022), RMM (2021), RU (2020)

Maximising Existing Stock: Architectural interventions should prioritise adaptive reuse, renovation, and retrofitting of existing buildings over demolition. This approach reduces the need for new materials and preserves cultural heritage.

Local Sourcing and Recycling: Emphasising the use of locally sourced, renewable and recycled or reclaimed materials in construction promotes resource efficiency and reduces environmental impact. Buildings designed for repairability and deconstruction facilitate future reuse of components and materials.

Energy Efficiency and Renewable Energy Integration: Sustainable architectural design includes energy-efficient features and seamless integration with renewable energy sources. By reducing energy consumption and reliance on fossil fuels, these interventions contribute to closing the circularity gap.

Circular Design Principles: Buildings should be designed with circular design principles, such as modularity, material transparency, and lifecycle thinking from the start of the design process. This ensures that materials and resources are used efficiently throughout the building's lifecycle, from construction to operation and eventual decommissioning.

Raw Material Provision: Priorities and Order: First sustainable Secondary Sources, Sustainable Renewable Sources and then only the rest from Non-renewable Sources.

Explanation recommendations out of research by Schützenhofer et al. (2022)

Prioritising Material Reuse and Recycling:

Emphasise the reuse and recycling of CDW. The study highlights a 1:10 ratio of CDW to required building materials, indicating a significant potential for substituting primary resources with recycled materials. Promote deconstruction methods that facilitate the reuse of materials rather than traditional demolition.

Implementing Resource Efficiency Measures:

Adopt design and construction practices that minimise waste generation and resource consumption. This includes optimising material use and selecting sustainable materials with a lower environmental impact. Enhance resource efficiency by integrating principles such as Life Cycle Assessment (LCA) to assess the environmental impacts of materials and processes used in construction.

Incorporating Life Cycle Perspective:

Integrate a life cycle perspective in the planning and execution of construction projects. This involves considering the entire lifespan of buildings, from material extraction to end-of-life disposal.

Use LCA indicators like Global Warming Potential (GWP), Primary Energy Intensity (PEI), and Acidification Potential (AP) to evaluate the environmental impacts throughout the building's life cycle.

Promoting Data-Driven Decision Making:

Develop and maintain a robust digital environment to facilitate data collection and analysis. Accurate and comprehensive data are crucial for assessing the sustainability and CE potential of buildings.

Implement Material Passports (MPs) and Building Certification systems to track material usage and enhance transparency in resource management.

Regional Customisation of CE Practices:

Acknowledge and address regional variations in CDW ratios and construction activity. Urban areas, for instance, may exhibit different waste generation patterns and resource needs compared to rural areas. Tailor CE strategies to regional specifics, ensuring that local factors such as population density, construction practices, and waste management systems are considered.

Appendix VII – Summary BMK (2022) Raw Material Provision, Priorities & Order

Interesting take on resource use and raw material provision in the circular economy

Our society depends on resource use for sustenance and daily needs, including energy for human and animal metabolism and material consumer goods. To ensure sustainable resource utilisation, we must fully leverage closing material loops within environmental and social limits and adopt lifestyles and social practices that reduce resource consumption.
Even in a CE, there cannot be an entirely closed system, in particular from a local perspective, due to import and export flows. Food and energy are inherently linear. Even with careful use, things become waste at some time. Therefore, raw materials will still be needed in the future. Their sustainable acquisition must thus be as high a priority as the retention of our natural capital.
"*The following principles apply to raw material provision in the circular economy: The demand for raw material should be covered with sustainable secondary sources as a priority, then from sustainable renewable sources and only the rest from non-renewable sources. In this way, priority is given to raw material sources that meet the high social, humane and ecological standards that apply in Austria" (BMK, 2022).*