Integrating Reversibility in Architectural Practices

Exploring reversible partition walls as a strategy for sustainability

Leon Economidis

Integrating Reversibility in Architectural Practices
Exploring reversible partition walls as a strategy for sustainability

2024, Leon Economidis

Under the guidance of
Corentin Fivet
Stefana Parascho
Célia Küpfer

Ecole Polytechnique Fédérale
de Lausanne

Table of Content

1. Introduction

«We have in Japan an aesthetic of death, whereas you [Westerners] have an aesthetic of eternity. The Ise shrines are rebuilt every 20 years in the same form, or spirit; whereas you try to preserve the actual Greek temple, the original material, as if it could last for eternity.»[1]

This perspective, highlighted by Kisho Kurokawa, underscores the philosophical divergence between a recognition of cyclical renewal and a pursuit of timeless preservation. This contrast serves as a foundation for reflecting on the contemporary building industry's need to embrace change as an inherent reality, aligning design practices with evolving demands and environmental imperatives. In many ways, this principle is already acknowledged, as construction practices are frequently shaped by the pursuit of rapid returns on investment. This economic focus prioritizes cost-efficiency, speed, and immediate functionality. Additionally, production innovations have drastically reduced the cost of materials, rendering reuse economically less viable. The expenses associated with dismantling, refurbishing, transporting, and storing reusable materials increasingly exceed the costs of manufacturing new components. Consequently, the construction industry has shifted toward practices that prioritize efficiency and cost reduction[2].

The critical question lies in how we address obsolescence. Should a building be conceived as a fleeting, temporary entity destined to be replaced, thereby perpetuating cycles of resource consumption and waste generation? Such an approach risks reducing buildings to disposable consumer goods—a notion that is counterintuitive given the significant resources required for their creation. With the growing urgency surrounding climate change, the depletion of natural resources, and the broader question of humanity's impact on the planet, it has become increasingly critical to interrogate the practices of the building industry and the role of architects. Addressing these challenges requires a fundamental rethinking of contemporary construction methods, particularly in terms of sustainability and resource efficiency.

This served as the starting point of my reflection. From there, I turned my attention to the principle of reversibility as a design tool—a concept offering the potential to address evolving needs without succumbing to the environmental toll of constant reconstruction. Throughout this exploration, I encountered numerous questions that underscore the complexity of integrating reversibility into contemporary construction practices. This essay does not claim to provide definitive answers but rather seeks to investigate how, where, and if reversibility can be effectively implemented. By examining the potential of this tool, the discussion aims to contribute to the broader discourse on the construction industry and our roles as spatial practitioners.

1   David Cheshire, *Building Revolutions: Applying the Circular Economy to the Built Environment* (RIBA Publishing, 2016), 22.
2   Michaël Ghoyot, Lionel Devlieger, Lionel Billiet, and André Warnier, *Déconstruction et Réemploi: Comment Faire Circuler les Éléments de Construction* (Lausanne: Presses polytechniques et universitaires romandes, 2018), 29-38.

2. Structure of the thesis

Two primary methods for implementing reuse—selective deconstruction and reversible construction—are outlined in the text *Déconstruction Sélective/Construction Réversible*[3]. Selective deconstruction involves the non-destructive separation of building components, preserving their inherent properties for immediate reuse. For the purpose of this study, the focus will be on the second method: reversible construction. It emphasizes designing buildings with future reuse in mind, incorporating principles such as spatial reversibility (flexible layouts) and technical reversibility (reusable components)[4]. Together, these methods offer complementary approaches to facilitating future reuse.

The first chapter examines spatial reversibility at the building scale, exploring how design strategies can extend the functional lifespan of structures by accommodating changing spatial requirements. This chapter delves into scenarios where reversibility mitigates premature obsolescence, enabling buildings to adapt to evolving user needs and extending their service life. It also considers the practical implications and complexities of implementing spatial reversibility, including the need to balance flexibility with structural performance and address the constraints of various design and construction contexts.

The second chapter shifts focus to technical reversibility at the product scale, analyzing specific building components with significant potential for reuse and adaptability, with particular attention to partition walls. These components exemplify how thoughtful design can enable disassembly, repair, and reuse, offering practical pathways for integrating reversibility into construction practices. This chapter also addresses the challenges and trade-offs involved in designing reversible products, such as material choices, technical specifications, and logistical considerations.

The third chapter focuses on methodologies for quantifying the environmental impacts of reversible design approaches. It examines the limitations and uncertainties inherent in life cycle assessment (LCA) and environmental product declaration (EPD) methodologies, particularly in the context of reversible construction. By addressing these complexities, the chapter highlights the challenges of accurately measuring the environmental benefits of designing for reversibility.

Together, the chapters provide an exploration of the broader considerations involved in choosing to design for reversibility.

---

3   Célia Küpfer and Corentin Fivet, *Déconstruction Sélective: Construction Réversible: Recueil pour Diminuer les Déchets et Favoriser le Réemploi dans la Construction* (Structural Xploration Lab, EPFL, Lausanne/ Fribourg: Smart Living Lab, 2021), 4.
4   Ibid., 12.

3. Spatial reversibility

3.1 A targeted strategy

While many buildings maintain their physical integrity over extended service lives, they often become functionally obsolete due to evolving user needs, regulatory changes, or technological advancements[5]. This disconnect leaves building owners with two primary options: demolition and reconstruction or renovation. Renovation can be particularly complex and expensive when extensive modifications are needed, often rendering it financially impractical. Conversely, reconstruction can provide economic advantages under certain conditions, particularly when regulatory frameworks have evolved since the building's original construction[6]. For instance, if updated zoning regulations permit greater density, reconstruction may allow property owners to capitalize on long-term gains by fully exploiting the increased allowable density.

Spatial reversibility presents a promising solution to the challenges of functional obsolescence. By designing buildings to accommodate future changes in use, reversibility minimizes both the environmental and financial impacts associated with outdated functionality[7]. However, while spatial reversibility offers significant potential, it is essential to critically examine its benefits and risks. When improperly implemented, it can lead to increased costs and exacerbate environmental harm[8]. Therefore, identifying effective strategies and contexts that maximize its advantages while mitigating potential drawbacks is imperative.

This chapter explores the concept of spatial reversibility and highlights the importance of targeted implementation of reversible features in buildings. To illustrate these notions, we analyze the Black Swan project in Strasbourg—a case study chosen for its location in a dense, urban area undergoing development. Such environments are particularly well-suited to leverage the benefits of reversibility, as urban centers are characterized by rapidly evolving user needs and high levels of uncertainty regarding future changes. Furthermore, the economic pressures intrinsic to urban areas, including elevated land and rental costs, incentivize property owners to prioritize immediate financial returns. While this case study focuses on urban settings, its conclusions may also apply to rural areas experiencing significant development and densification, where reversibility could serve as a strategic tool to address emerging regional needs.

The case study was also specifically chosen because it focuses on a large-scale building. Multi-story mixed-use developments, in particular, present significant potential for impactful interventions due to their size and complexity.

---

5   David Cheshire, *Building Revolutions: Applying the Circular Economy to the Built Environment* (RIBA Publishing, 2016), 22.
6   Ibid., 42.
7   Luís Bragança et al., eds., *Circular Economy Design and Management in the Built Environment: A Critical Review of the State of the Art, Springer Tracts in Civil Engineering* (Cham: Springer Nature, 2025), 338–339.
8   Ibid., 278.

3.2 The Black Swan project

For the Black Swan project, the competition's shifting functional requirements, including changes to the percentage allocation of each function, directly influenced the decision of the architects to prioritize reversibility in the building's design. To achieve this, they developed the concept of a «Building of Indeterminate Destination» (IDI)[9]. This approach allowed the project team to move away from rigid programmatic definitions, instead embracing a flexible framework. It involved enabling changes in function without substantial interventions to the structure or façade, thereby avoiding technical complexities and maintaining financial feasibility. This approach ensures that the building can adapt dynamically to future needs while minimizing environmental and economic impacts.

By adapting the building to accommodate a variety of functions, the design team focused on identifying key features essential for achieving reversibility. They developed a framework centered on five principal design elements critical to spatial reversibility: Floor Height, Common Grid, Common Core, Open Plan, and Common Envelope[10]. However, achieving this level of adaptability comes with trade-offs. Given the varying demands of different uses, the design inherently prioritizes the function with the most stringent requirements, resulting in a building tailored to meet the highest common denominator of needs. This approach can often lead to compromises that impact time, environmental sustainability, financial costs, and overall quality.

The requirements for floor heights differ significantly between residential and office spaces. In residential buildings, a typical floor-to-floor height is approximately 2.8 meters, while office spaces generally require around 3.5 meters, including a 30 cm slab and a 50 cm technical ceiling to accommodate mechanical ventilation systems (Fig.1). In the Black Swan project, the architects opted for an averaged floor height of 3.3 meters (excluding slab thickness). This decision balances the differing requirements of housing and office spaces, enabling deeper typologies for housing units while slightly reducing the amount of natural light penetration in office spaces[11]. The choice of a 3.3-meter floor height represents a design compromise that accommodates both housing and office uses. However, this approach involves trade-offs that must be carefully evaluated, particularly in multi-use scenarios.

For instance, in the case of an 8-story building with a 50/50 distribution of office and housing floors, using differentiated floor heights would result in a total height of 25.2 meters (4 floors at 3.5 meters and 4 floors at 2.8 meters). By contrast, applying the averaged 3.3-meter height across all floors increases the total height to 26.4 meters, representing a 5% increase. While seemingly small, this increase can have significant implications. In regions where maximum building heights are regulated, it could result in the loss of one floor for every 22 constructed floors. If office and housing distributions vary, the impact on usable space differs proportionally. For example, if two-thirds of the floors are office spaces, one floor is lost every 13 floors, whereas in a housing-only configuration, an extra floor is lost for every 7 floors. Additionally, for housing units, the extra height results in approximately 18% more volume that must be heated, increasing operational energy demands. Increasing floor heights inherently requires more materials for façade panels, partition walls, and interior finishes, raising both environmental
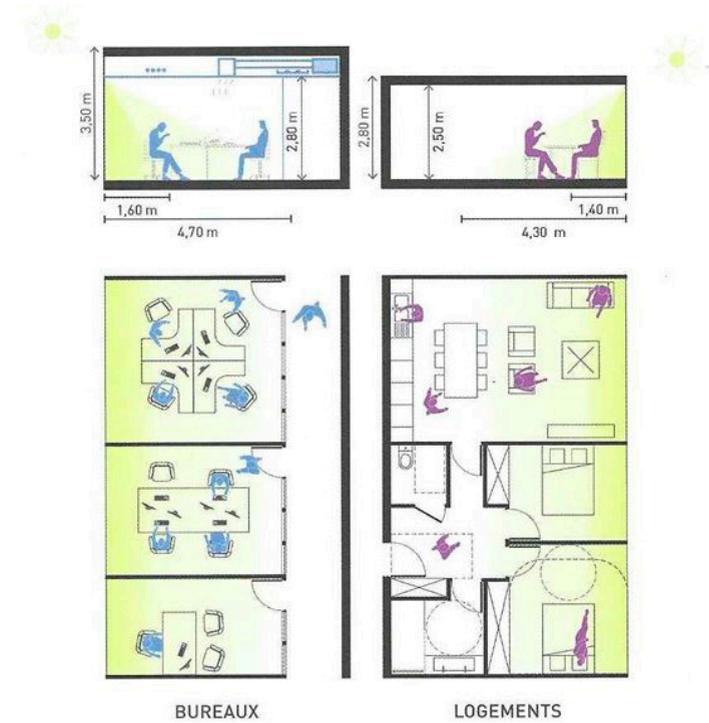

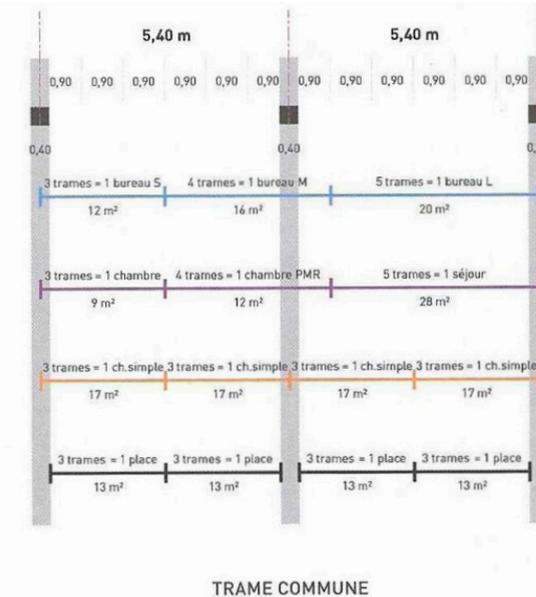BUREAUX   LOGEMENTS

Fig. 1

TRAME COMMUNE

Fig. 2

---

9   Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 45.
10   Ibid., 51.
11   Ibid., 52–53.

5,40 m   5,40 m

BUREAUX

LOGEMENTS

HÔTEL

Fig. 3

● Plan théorique
  Coursives ≥ 0,70 m

● Application pratique
  • Déformation horizontale/
    verticale du plan théorique
    selon le contexte
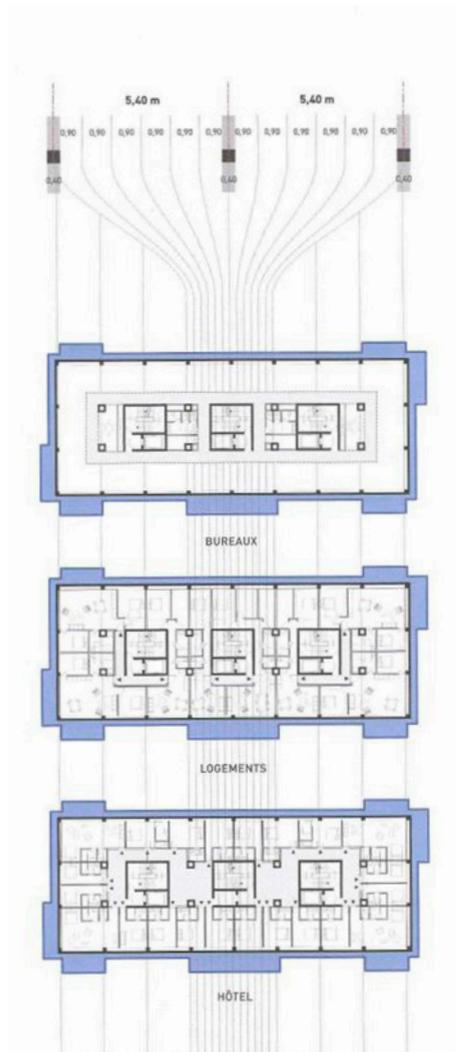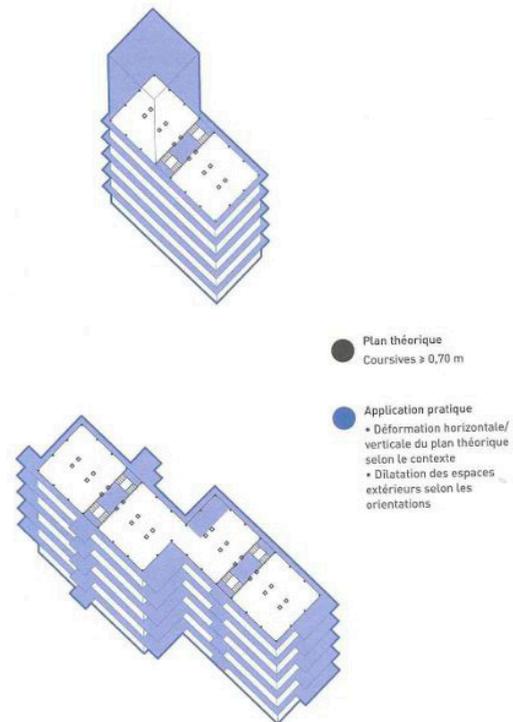 • Dilatation des espaces
    extérieurs selon les
    orientations

Fig.4

impact and construction costs. In the Black Swan example, each floor requires approximately 192.5 linear meters (ml) of façade. For a floor height of 2.8 meters, the façade area is 539 m² per floor. With a 3.3-meter height, the façade area increases to 635.25 m², representing an 18% rise in material use. This additional material use also affects structural requirements, as increased weight necessitates stronger support systems. Moreover, if this strategy becomes increasingly common and floor heights for housing are raised to accommodate potential future changes to office use, but such transformations do not occur, it would result in a general increase in housing floor heights without any functional benefit.

Centralized cores play a critical role in enhancing adaptability by consolidating technical voids and circulation systems, such as elevators and staircases, near the core. The inclusion of external cores in the S-typology reduces operational energy demands during use but divides the structure into three entities, posing logistical challenges[12]. While larger circulation areas improve adaptability, they reduce rentable space and increase material use, construction costs, and energy requirements for non-habitable zones. Open-plan layouts complement this adaptability by employing a peripheral structural system that eliminates central columns and load-bearing walls, enabling flexible interior reconfigurations[13]. However, the success of open plans depends heavily on the adaptability of interconnected systems, such as HVAC and plumbing, which must evolve alongside spatial modifications.

Technical installations in the project are carefully integrated to balance the needs of housing and office spaces. The architects consolidated technical voids near the central core, aligning them with intermediate columns to ensure efficient spatial distribution[14]. Oversizing technical surfaces, especially in basements, is emphasized to future-proof the building's infrastructure, though this may reduce usable areas, such as parking. Similarly, the structural grid enhances flexibility through a configuration of 5.4-meter column intervals and a 0.9-meter partition grid, supporting diverse uses[15]. However, limitations emerge in housing contexts, where living room dimensions could be more generous, reflecting a compromise in user experience to achieve greater reversibility.

The project incorporates volumetric adaptability as a core design feature, enabling both horizontal and vertical modifications or extensions to address future urban needs. This flexibility allows for the creation of cohesive neighborhoods composed of interconnected buildings that share structural consistency while maintaining unique volumetric forms. Vertical extensions, for example, provide the opportunity to expand specific sections of the building, potentially creating mid-level rooftops or terraces that enhance functionality and accessibility[16]. This approach also allows the project to adapt to site-specific regulations, urban planning constraints, and anticipated changes in density or land use, offering a scalable solution at both the building and neighborhood levels.

However, volumetric adaptability introduces technical and economic challenges that must be addressed during the initial design phase. Vertical extensions require structural over-dimensioning to support additional floors, increasing upfront costs and material usage. However, a study by BAMB indicates that over-dimensioning foundations—often the most critical component of such flexibility—represents only less than 2%

12   Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 73.
13   Ibid., 61.
14   Ibid., 61.
15   Ibid., 55.
16   Ibid., 73.

of initial construction costs, making it a relatively modest investment for long-term adaptability[17]. Despite this, several dependencies can complicate future modifications. Roof structures must be designed to be reversible or easily dismantled; otherwise, even minor extensions may necessitate extensive redesign and reconstruction, leading to increased material use and costs estimated at 5%[18]. However, other dependencies, not considered in the study, might require further questioning. The general structure might also require costly over-dimensioning. Similarly, circulation systems and technical systems also require consideration. While volumetric adaptability offers significant potential for responding to urban growth and evolving land-use needs, its successful implementation hinges on strategic planning and investment during the design phase to ensure structural, technical, and logistical feasibility while balancing additional costs and material requirements.

The success of such features depends heavily on the context in which they are applied. The trade-offs associated with floor height, centralized cores, and volumetric adaptability underscore the need for strategic planning and careful evaluation of the anticipated benefits against environmental and financial costs. While the project demonstrates the potential for reversibility to align with long-term sustainability goals, it also highlights the risks of over-investment if future adaptability is not realized.

3.3 Broader considerations

Beyond the specifics of the Black Swan project, the broader concept of spatial reversibility raises significant questions about its applicability.

3.3.1 Stakeholders

Key considerations include the alignment of spatial reversibility with stakeholder priorities, which is essential for its successful implementation. The involvement of local authorities as primary stakeholders is particularly significant in shaping the feasibility and relevance of such projects. Local authorities focus on broader societal and economic interests tied to a building's construction, lifecycle, and its role within the urban fabric. This perspective enables public entities to advocate for spatial reversibility, even when initial costs may seem prohibitive. By championing these principles, local authorities help establish a framework for development that prioritizes and supports the implementation of spatially reversible design[19].

The degree to which adaptability is prioritized varies considerably among different types of developers, shaped by their intentions for the building and their financial objectives. Developers who occupy the buildings they construct are more inclined to prioritize adaptability, viewing their structures as long-term investments. For these owner-occupiers, reversible design features align closely with organizational growth and operational efficiency, allowing buildings to evolve alongside the needs of the business[20]. This strategic approach ensures that adaptable features directly benefit the developers, mitigating the risks associated with inflexible buildings while enhancing

functionality over time. Conversely, developers who build for sale typically prioritize short-term market appeal over long-term adaptability. These profit-driven entities often focus on minimizing initial costs to maximize immediate returns, with little incentive to incorporate features that do not directly contribute to the building's resale value[21]. This reluctance reflects current market dynamics, where adaptable features frequently fail to command a premium, despite their potential long-term advantages for occupants. As a result, adaptability remains underutilized by developers focused solely on short-term profitability.

Rental property developers occupy a middle ground, with a distinct opportunity to benefit from adaptable design principles. For these developers, flexibility and reversibility can facilitate quick internal reconfigurations to accommodate new tenants, optimizing rental income and occupancy rates. The ability to adjust layouts and functionalities with minimal disruption aligns with their financial objectives, making adaptability a pragmatic investment.

To mainstream reversibility in the construction industry, mechanisms such as enhanced market awareness and financial incentives are essential. By bridging the gap between initial costs and long-term benefits, these initiatives can encourage even profit-driven developers to adopt adaptable design principles. Aligning financial rewards with the inclusion of adaptability features can shift industry practices toward a more sustainable and resilient built environment, ensuring that buildings are better equipped to meet future challenges[22].

3.3.2 Excessive change

Reversibility, by facilitating adaptability within buildings, introduces the risk of excessive modifications, which can escalate environmental impacts. While spatial reversibility enhances user satisfaction and allows spaces to evolve with changing needs, it also amplifies the environmental footprint associated with material extraction, manufacturing, transportation, and installation. The inherent challenge of reversibility lies in striking a balance between enabling «necessary» changes and avoiding excessive modifications. To address this, we now consider the components that require modifications to enable the spatial reversibility of the Black Swan project. Given the project's key features, it is mainly the infill that is disturbed during functional changes. Partition walls become central to this question, as they contribute 40% of the overall impacts for non-load-bearing elements[23].

17   K. Wang et al., «Why Invest in a Reversible Building Design?» *IOP Conference Series: Earth and Environmental Science 225* (2019):1-8, 8.
18   Ibid., 8.
19   Anne Démians, «Black Swans - Strasbourg (2013–2019),» https://www.annedemians.com/projets/black-swans---strasbourg-2013-2019.
20   Kirsten Arge, «Adaptable Office Buildings: theory and practice» *Emerald* 23, (2005): 125.

21   Kirsten Arge, «Adaptable Office Buildings: theory and practice» *Emerald* 23, (2005): 125.
22   Ibid., 124–127.
23   Ricardo Mateus et al., «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies,» *Building and Environment* 67 (2013): 148.

Reversible partitions, for instance, could offer significant benefits, such as allowing a growing family to create additional rooms within the same housing unit. However, the convenience of frequent reconfigurations risks amplifying material use and waste over time. In contrast, a family living in a rigid space might choose to move to a larger unit as their needs evolve, avoiding changes to the original space.

This tension highlights the need to assess the impact of reversibility. While adaptable buildings minimize structural demolition and optimize functionality, without careful management, they risk undermining their environmental benefits through operational inefficiencies and excessive changes. The convenience of frequent modifications must not outweigh the ecological advantages of reduced material use, emphasizing the importance of thoughtful planning and strategic implementation in reversible design[24].
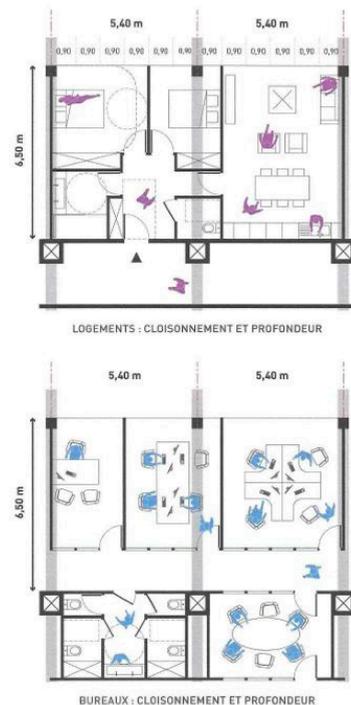

Fig.5

24   Bob Geldermans, Martin Tenpierik, and Peter Luscuere, «Circular and Flexible Infill Concepts: Integration of the Residential User Perspective,» *Sustainability* 11, no. 1 (2019): 1-19, 14.

4. Technical reversibility

One approach to mitigating the environmental and material risks associated with spatial reversibility lies in the development of technical reversibility of the infill, particularly partition walls. Technical reversibility, as defined in ISO 14021:2016, «enables the product to be taken apart at the end of its useful life in such a way that it allows components and parts to be reused, recycled, recovered for energy or, in some other way, diverted from the waste stream»[25]. By prioritizing the design and implementation of technically reversible infill systems, spatial reversibility can be implemented without compromising long-term ecological and material performance.

Achieving technical reversibility involves careful consideration of material composition, connection methods, and the alignment of component service lives[26]. By prioritizing reversible connections and materials that remain separable, it becomes easier to recover the inherent value of these components at the end of their life cycle. For instance, a wooden floor glued to its support can create significant complications when the time comes to replace it. Separating these floorboards from their underlying layers not only diminishes the quality of the materials but can also be very time-consuming. Given the financial pressures that dominate the construction sector, coupled with the fact that labor costs frequently surpass material costs, spending extensive hours disassembling components is rarely viable. The same issue arises if the floorboards are nailed to the support. It is easy to envision the additional time spent prying the boards apart, followed by the tedious task of removing nails from the materials.

This chapter will explore the application of technical reversibility to infill components, with a particular focus on partition walls. Additionally, we will examine other critical elements to understand how reversible design influences material flows, environmental impacts, and operational efficiency. By analyzing these aspects, we aim to provide a comprehensive understanding of the opportunities and challenges associated with implementing technical reversibility in construction.

4.1 Targeted strategy

In buildings designed for reversibility, the ability to reconfigure interior spaces is crucial for adapting to changing uses over time. While the structural framework provides the foundation, the infill—the non-structural elements that define and equip interior spaces (e.g., partition walls, finishes, and fixtures)—plays a pivotal role in ensuring seamless and sustainable modifications[27].

Partition walls enable flexibility by allowing spaces to be converted from one use to another (inter-use change), such as transforming housing into office space. They also support adaptability within a single use (intra-use change), for instance, modifying the layout. Partition walls in housing units are more similar to those in hotel rooms and student housing than to partitions in office spaces. In rural residential buildings designed for spatial reversibility, functional changes may only involve intra-housing adjustments.

25   Luís Bragança et al., eds., *Circular Economy Design and Management in the Built Environment: A Critical Review of the State of the Art, Springer Tracts in Civil Engineering* (Cham: Springer Nature, 2025), 274.
26   David Cheshire, *Building Revolutions: Applying the Circular Economy to the Built Environment* (RIBA Publishing, 2016), 66-68.
27   Bob Geldermans, Martin Tenpierik, and Peter Luscuere, «Circular and Flexible Infill Concepts: Integration of the Residential User Perspective,» *Sustainability* 11, no. 1 (2019): 1-19, 6.

For example, reconfiguring internal partitions to accommodate the changing needs of a growing family might involve adding walls. However, achieving this flexibility may require oversized units, which are inherently inefficient. Greater potential lies in designing buildings with variable unit sizes to adapt to evolving typologies. Flexible partitions between units could provide significant value by enabling apartments to be combined or subdivided with minimal effort.

It is also critical to consider that altering unit dimensions affects more than just partition walls. Interconnected elements such as kitchens, bathrooms, and electrical systems must also be designed with reversibility in mind.

Partition wall requirements and design considerations vary significantly depending on their application. In residential settings, partitions prioritize acoustic insulation to maintain privacy, whether between rooms in the same unit or between separate units. These partitions are predominantly opaque. In contrast, office partitions serve different purposes. While some office partitions, such as those used for meeting rooms or private offices, share similarities with residential partitions, the broader design trend in offices leans toward transparency and openness. Glazed partitions are frequently used to create a sense of collaboration and openness while still delineating workspaces.

Partitions can be sub-classified into two main categories: dry and wet partitions. Dry partitions are used in areas not exposed to humidity, such as living rooms and bedrooms, and are simpler in design. Wet partitions, on the other hand, are designed for humid spaces like kitchens and bathrooms. These require moisture-resistant materials and additional components to ensure durability. Constructing all partitions to meet the rigorous standards of wet applications would be both impractical and uneconomical, making it essential to differentiate between these two types to optimize functionality and cost-efficiency.

These considerations highlight the importance of strategic planning in technical reversibility, ensuring that the flexibility of adaptable design does not compromise long-term sustainability.

4.2 Partition wall systems: composition, installation, and lifecycle considerations

To develop new products that enhance future reusability, one must confront multiple intersecting factors. These innovations cannot afford to overlook the inertia embedded within the construction sector—a sector often resistant to change[28]. For such products to achieve adoption on a meaningful scale, they must not only meet the performance benchmarks set by traditional alternatives while minimizing their environmental footprint but also offer financial competitiveness. This includes not just the cost of the product itself but also the expenses tied to its installation[29].

Here, the classical partition wall is revisited, with an examination of its specific components that hinder technical reversibility. This analysis seeks to explore how these components could evolve, identify opportunities for integrating more sustainable materials, and investigate how their technical reversibility could be improved.

4.2.1 Classical partition wall composition

Partition walls typically consist of three primary components: the structural framework, the insulation, and the panels. The structure is primarily made of galvanized steel profiles, while the insulation between these profiles is often composed of rock wool. The finishing panels are made of gypsum boards, often doubled and of varying thicknesses (typically 1.25 cm) depending on the required properties. The panels are later plastered to achieve the desired smoothness and subsequently painted. These partitions are inexpensive, quick to assemble, lightweight, and provide a uniform finish.

Other minor components also influence the partition's quality. Rubber bands are placed under the steel profiles where they come into contact with the floor, ceiling, or walls to mitigate sound transmission. Additional components include screws to connect the gypsum panels to the steel profiles and tape used to smooth the joints between panels.

4.2.2 Installation process and material considerations for partition wall structures

The installation of partition wall structures typically begins with the placement of horizontal galvanized steel profiles, which are cut to length and positioned on rubber strips to provide acoustic decoupling. These profiles are often mechanically anchored to the underlying structure. Vertical profiles, also cut to the required dimensions, are then fitted between the horizontal profiles to form the partition frame. The connection between these profiles is often achieved using a crimping tool, which locks the profiles together by creating a small indentation in the overlapping metals[30]. This method is favored for its time efficiency, noise-free operation, and simplicity, as it eliminates the need for additional fasteners like screws or rivets. However, crimping permanently deforms the profiles, making the connection challenging to reverse. Although separating crimped profiles is technically possible, the process is labor-intensive and risks compromising the materials' integrity, rendering it unsuitable for designs emphasizing reversibility and reuse.

Steel remains the industry standard for partition structures due to its durability, thin profile, and structural integrity. However, considering the significant environmental impact of steel production, it is worth exploring alternative materials with lower embodied carbon that also offer potential for reversibility and reuse. For partition systems prioritizing reversibility, the selection of materials and their connection methods must carefully balance environmental impact, practicality, and the ability to enable disassembly and reuse.

For instance, the BAMB project explores alternatives such as wood (Saint-Gobain prototypes) and cardboard (Wall-linQ), primarily to reduce the embodied carbon of partition wall components[31]. Although Saint-Gobain prototypes refer to a preassembled and insulated wood frame system[32], this discussion focuses primarily on the use of wood studs in the partition's structure[33].

28   Johannes A.W.H. Van Oorschot, Elma Durmisevic, and Johannes I.M. Halman, «Implementation of Innovation: The Inertia of Implementing the Open Building Concept in Practice,» in *Management and Innovation for a Sustainable Built Environment*, Twente University, Netherlands, 2011, 1-16.
29   Ibid., 6.

30   Rigips SA, *Directives de mise en œuvre: Partie 2 - Sous-Constructions*, 83. https://www.rigips.ch/fr/Mise-en-oeuvre/Directives-de-mise-en-oeuvre/Sous-constructions.
31   European Commission, *D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects*, Horizon 2020 research and innovation programme, 21.
32   Ibid., 21.
33   Wang, K., S. De Regel, W. Debacker, J. Michiels, and J. Vanderheyden. «Why Invest in a Reversible Building Design?» *IOP Conference Series: Earth and Environmental Science* 225 (2019), 2,5.

The use of wooden studs as partition structures is common and can generally be considered reversible due to its mechanical connections[34]. Wood, as a renewable resource, can lower environmental impacts under certain conditions, depending on how it is produced. However, it is prone to pests, swelling, warping, and shrinking, especially when exposed to varying temperatures and humidity, which can reduce its structural reliability over time. Furthermore, wooden studs require full cross-sections to match the strength of U profiles made of steel, increasing material use and limiting space for insulation, which can negatively impact the partition's acoustic performance. Additionally, wood is often transformed to enhance its properties, such as through finger jointing or cross-laminating. While these processes improve strength and expand use cases, they also increase energy demands during production and introduce synthetic adhesives that complicate end-of-life recycling. Higher labor and customization costs further complicate its implementation.

Cardboard offers a low-cost, recyclable option derived from waste products, and its suitability largely depends on the intended use case. While it demonstrates adequate durability for applications with low rates of change[35]—such as partitions expected to remain in place for extended periods—it is less suitable for scenarios requiring frequent disassembly or reconfiguration[36]. Repetitive handling can significantly degrade its structural integrity, even if it performs well in static, long-term applications. Additionally, cardboard is sensitive to moisture, which can compromise its stability and longevity, making it best suited for carefully controlled environments with minimal exposure to physical stress or environmental fluctuations. Cardboard profiles might not detract significantly from the acoustic performance of the partition, as they could potentially be packed with insulation, but they still face challenges in meeting the durability demands of frequently changing partition walls.

Both wood and cardboard can be treated to enhance their resistance to fire, humidity, and pests, but such treatments often involve synthetic chemicals and additional production processes, which increase the materials' embodied carbon and cost. These treatments also complicate end-of-life considerations, further limiting the environmental benefits of these alternatives. Ultimately, while wood and cardboard offer opportunities to reduce the environmental footprint of partition walls, their limitations might hinder their potential to support reversibility and reuse.

4.2.3 Installation process and material considerations for partition wall insulation

Once the steel structure of the classical partition wall is assembled and any necessary technical installations are in place, insulation can be installed. Typically, one side of the profiles is paneled before the insulation is inserted, ensuring easier placement and alignment of the material. Globally, rock wool appears to be the most common choice for insulation[37]. It offers excellent thermal and acoustic properties and is fire-resistant,

making it an ideal candidate for slim partitions where performance is paramount. However, rock wool's production process requires immense amounts of heat, leading to a significant environmental footprint. It is the most prominent CO2 emitter of all the constituent parts of classical partition walls[38].

While rock wool remains a widely used and efficient solution, it should be substituted with more environmentally friendly materials. However, explored alternative insulations often require greater thicknesses to match rock wool's performance. Increasing the thickness of the partition to accommodate alternative insulations has cascading effects: more insulation material is required, the profiles must be larger, and the wall's additional thickness reduces usable surface area within the building, diminishing their appeal[39]. The installation method for partition wall insulation generally ensures reversibility. Insulation is sandwiched between the panels and vertical profiles, allowing for easy removal and substitution with more sustainable materials when they become competitively available. Unlike spray foam insulation or expanding liquids, which are irreversible and environmentally detrimental, solid insulation materials like rock wool are preferred, as they can be easily cut to standard sizes. The reversibility of solid insulation materials makes them suitable for reuse, although in practice, rock wool is rarely reused due to its low financial value compared to other partition components[40]. However, its reuse potential, combined with the possibility of substituting it with better materials in the future, aligns with sustainable construction principles and underscores the importance of avoiding irreversible insulation methods.

Despite its environmental drawbacks, rock wool currently represents the best compromise between performance and cost, even though its carbon footprint leaves much to be desired. Its excellent acoustic, thermal, and fire-resistant properties make it a competitive choice for partition walls.

4.2.4 Installation process and material considerations for partition wall panels

Once insulation is installed within the partition wall structure, the panels are positioned and fixed to the underlying steel framework, typically using screws. Gypsum boards are the most commonly used panels for lightweight partitions[41]. This popularity is due to their lightweight nature, ease of handling, and straightforward installation. Gypsum boards are easily cut to fit around obstacles, and specialized alternatives have been developed for various applications, including fire-resistant, hydrophobic, and acoustic panels. However, gypsum boards also have limitations. Their fragility makes them prone to damage, and their vulnerability to moisture necessitates additional treatments for wet environments.

34   Wang, K., S. De Regel, W. Debacker, J. Michiels, and J. Vanderheyden. «Why Invest in a Reversible Building Design?» *IOP Conference Series: Earth and Environmental Science* 225 (2019): 1-8, 7.
35   European Commission, *D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects*, Horizon 2020 research and innovation programme, 21.
36   Ibid., 21.
37   Numerous documents take rock wool as the 'classical' insulation for comparison such as «LCA Analysis of Three Types of Interior Partition Walls Used in Buildings» in *Proceedings* 2 / «Comparative LCA between Traditional and New Constructive Elements Used as Partition Walls» conference paper presented at CILCA-WALL / «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies» in *Building and Environment* 67.

38   Emmanuel M. Atienza and Jason Maximino C. Ongpeng, «Environmental Impact and Cost Comparison of Different Partition Walls,» *Chemical Engineering Transactions* 94 (2022): 691-696, 694 fig.3.
39   Dileep Kumar et al., «Comparative Analysis of Building Insulation Material Properties and Performance,» *Renewable and Sustainable Energy Reviews* 131 (2020): 5-7.
40   Emmanuel M. Atienza and Jason Maximino C. Ongpeng, «Environmental Impact and Cost Comparison of Different Partition Walls,» *Chemical Engineering Transactions* 94 (2022): 691-696, 694 fig.4.
41   Numerous documents take gypsum boards as the 'classical' panels for lightweight partitions for comparison such as «LCA Analysis of Three Types of Interior Partition Walls Used in Buildings» in *Proceedings* 2 / «Comparative LCA between Traditional and New Constructive Elements Used as Partition Walls» conference paper presented at CILCA-WALL / «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies» in *Building and Environment* 67

From an environmental perspective, gypsum board production is energy-intensive due to the calcination process, which requires vast amounts of heat[42]. While recycling is technically possible, a significant proportion of gypsum boards still end up in landfills at the end of their lifecycle[43]. For specialized variants like fire-resistant or moisture-resistant panels, recyclability is even more limited, with many of these products being entirely landfilled[44]

The traditional mounting system for gypsum panels—screwing them into the steel frame—complicates their reuse. Screw holes reduce the integrity of the panels. While the edges of panels could theoretically be sawn off, when two layers of panels are used, the screws for the second layer penetrate the first toward the center, further limiting their reuse potential. Additionally, finishing techniques such as plastering over screws and seams obscure connections, making disassembly labor-intensive and reducing the viability of reuse.

These issues highlight the need to reconsider both the material and its mounting system to enhance reversibility and environmental performance. Alternative materials and connection methods must address these challenges to support sustainable and reversible design.

Reversible mounting systems, such as the omega profiles proposed in BAMB's P3 Saint-Gobain partition, could reduce damage to panels by avoiding screw hole damage, thereby enhancing their reuse potential[45]. However, these systems may compromise acoustic properties when implemented in single-layer plasterboard partitions due to the seams created between panels. In cases where two panel layers are required, the omega profile would need to be screwed directly into the underlying panels, mitigating its efficiency. Additionally, the mounting system complicates the installation process, as two adjacent panels must be held in place while the profile is fixed to the structure. Furthermore, the aesthetic quality of the joints between panels is affected, failing to achieve the uniform smooth finish possible when panels are screwed directly to the frame.

Exploring alternative materials could offer significant environmental benefits. For instance, bio-based panels, such as those made from mycelium or hemp, have low embodied carbon and are biodegradable. However, they often lack durability and sufficient market data. A study highlights that replacing plasterboard with bio-composite boards reduces carbon emissions by over 50%, human health impacts by 35%, ecosystem impacts by 50%, and resource depletion by 40%[46]. However, the study also notes that bio-composite panels significantly decrease airborne sound insulation due to their lower volumetric mass and reduced thickness (5 mm compared to the 15 mm thickness of plasterboards)[47].

Wood-based panels present another alternative. Plywood panels offer refined aesthetic

qualities that may not require additional finishes, though they are often expensive. Oriented strand boards (OSB) are among the more cost-effective options, but they lack the visual appeal of plywood and often require finishing. Medium-density fiberboard (MDF) panels have a smooth surface and a more polished appearance at a relatively low cost, but they are prone to swelling in humid conditions due to poor moisture resistance. Wood-based panels generally have a higher volumetric mass than alternatives such as gypsum boards. This increased mass complicates transportation, requiring higher logistical costs, and installation of heavier panels can necessitate additional labor. It also increases the number of screws required to secure the panels to the structure. Furthermore, wood-based panels often undergo extensive processing to enhance performance and versatility. For instance, veneers—thin sheets of wood peeled or sliced from logs—are used to create engineered wood products like plywood. Similarly, particleboard and fiberboard are made by compressing wood fibers or particles with synthetic resins, which may emit volatile organic compounds and complicate end-of-life recycling. These processes, while optimizing resource use and improving strength and durability, significantly reduce the environmental benefits of raw wood due to added components, increased energy demands during production, and limited recyclability.

4.3 Interconnections

In addition to questions related to the material properties of a partition's constituent parts and their connections, the interconnected nature of partition walls with other building elements—such as floors, ceilings, and technical installations—presents additional challenges that must be addressed to fully realize the potential of reversible systems.

4.3.1 Interconnection with floors and ceilings

The way partition walls interface with floors and ceilings significantly impacts their reversibility and the reusability of surrounding components. Historically, partitions were often installed directly onto the structural slab before the screed was poured, encasing the base profile within the screed. It rendered them largely irretrievable without significant damage to both the floor finishings and the partition itself.

Contemporary practices, by contrast, typically involve mechanically fixing partitions either directly to the structural slab before the floor finishing is applied or on top of the finished flooring. The primary consideration for the former strategy is that removing the partition will leave a section of missing flooring. The latter strategy preserves the finished flooring but can leave visible imperfections, such as discoloration or holes from the connection of the partition's structural profiles. These traces, while repairable, introduce additional costs and labor. For instance, restoring the aesthetic quality of a wooden floor may require sanding, refinishing, or even partial replacement, depending on the extent of the damage. Some users and architects may view these traces as markers of the space's evolution, adding character to the building, while others may prefer to eliminate them entirely for a polished, uniform appearance.

False floors offer an alternative solution by providing a buffer layer between the subfloor and the finished surface, enabling partitions to be installed and removed without impacting the visible flooring. However, false floors are not without drawbacks. Their higher cost, reduced usable ceiling height, and significant material requirements often make them unsuitable, particularly in residential spaces. Additionally, their larger environmental footprint compared to conventional flooring materials must be considered,

42   Yovanna Elena Valencia-Barba et al., «Life Cycle Assessment of Interior Partition Walls: Comparison between Functionality Requirements and Best Environmental Performance,» *Journal of Building Engineering* 44 (2021), 7.
43   The International EPD System, «Gyproc® Normal – Standard Plasterboard, System Registration number: S-P:00388.» Version 4, 2013, 8.
https://api.environdec.com/api/v1/EPDLibrary/Files/3cec4f68-263e-4b33-0365-08dc38ee8ac8/Data
44   The International EPD System, « Gyproc Moisture Resistant 12.5 mm, System Registration Number: S-P-00507.» Version 3, 2013, 8.
https://api.environdec.com/api/v1/EPDLibrary/Files/4314032e-dc99-4f63-9363-08dc3c72202b/Data
45   European Commission, *D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects*, Horizon 2020 research and innovation programme, 28, fig.21.
46   Alberto Quintana-Gallardo et al., «Life-Cycle Assessment and Acoustic Simulation of Drywall Building Partitions with Bio-Based Materials,» *Polymers* 12, no. 9 (2020), 12.
47   Ibid., 13.

even though they are generally easier to refurbish and reuse[48]. Similar considerations apply to ceilings. In offices, where false ceilings are common to conceal technical installations, the sequence of partition installation relative to the ceiling plays a critical role. Partitions installed before the false ceiling extend to the slab above, potentially requiring extensive modifications to the ceiling during reconfiguration. Conversely, partitions installed after the false ceiling are less disruptive but may leave behind minor damage, such as screw holes in the ceiling panels or its structural grid.

4.3.2 Interconnection with electrical installations

Partition walls often house electrical and, occasionally, sanitary installations, adding another layer of complexity to their reversibility. Electrical outlets embedded in partitions require careful planning to ensure accessibility and adaptability. For example, prototypes like the P2 Saint-Gobain partition, as highlighted in the D13 Prototyping + Feedback Report, incorporate a «technical plinth» that routes cables while keeping them accessible for future modifications[49].
Other minor interdependencies may involve the need for reinforcements in partition walls to support elements such as wall-mounted TVs, grab bars in accessible bathrooms, or other fixtures. These additions often require extra bracing or stronger structural profiles, further complicating the partition's reversibility.

4.4. Reversible partition systems - JUUNOO

The adoption of specialized products can be significantly hindered when they diverge too far from common alternatives. For instance, a product requiring entirely new installation methods or a specialized workforce may encounter greater resistance, as the associated training, time, and costs deter developers and contractors. Conversely, products that retain similar properties and installation methods to existing systems are likely to face fewer barriers, as they align more closely with established practices. Reversible partition systems present a promising pathway to overcome these obstacles, fostering dynamic and sustainable advancements in construction practices.
A reversible partition system shifts the focus from the environmental impacts of individual components to the system's overall capacity for reuse and reversibility. These systems enable rapid interchangeability and reuse of components, thereby maximizing the service lives of current materials. Furthermore, as new, better-performing, or more sustainable materials become available, reversible systems provide a framework for their seamless integration without requiring an overhaul of the entire structure.
The Juunoo partition system serves as a case study to highlight the challenges in achieving reversibility within conventional partition design. Combining modularity, flexibility, and reusability, the Juunoo system provides an opportunity to explore alternatives that can help redefine partition systems. The system offers significant benefits by enabling a workflow that is not only similar to but often faster than traditional lightweight partition installations[50]. It achieves this by introducing innovative modifications to the two primary components of partitions: the structure and the panels. While these
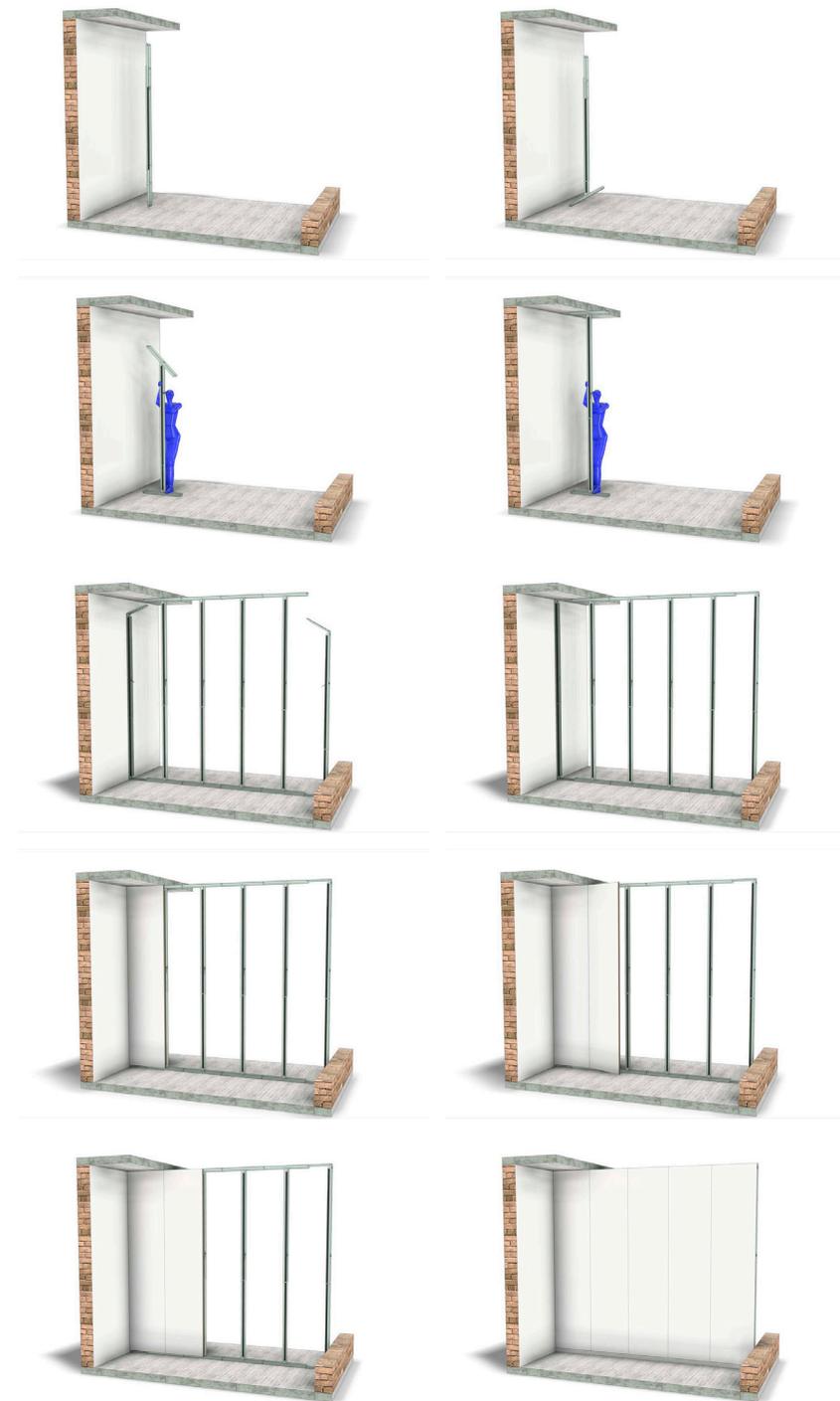

Fig.6-16

48   David Cheshire, *Building Revolutions: Applying the Circular Economy to the Built Environment* (RIBA Publishing, 2016), 94.
49   European Commission, *D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects*, Horizon 2020 research and innovation programme, 28 fig.21.
50   JUUNOO, *JUUNOO The Wall That Pays Off*, 6.

elements retain the familiarity of classical designs, they are enhanced to facilitate reuse and ensure straightforward assembly.

The Juunoo system is engineered to accommodate a wide range of partition wall configurations. It seamlessly adapts to unique shapes, such as partitions under pitched roofs [51]. The system also supports the streamlined incorporation of features like doors[52] and windows[53], with options for fully glazed sections[54]. This adaptability extends to its installation, which can be executed on finished floors, directly on subfloors[55], under false ceilings, or even extending up to structural elements[56]. These design features make the Juunoo system a versatile and efficient solution for a variety of architectural needs.

4.4.1 Structure: modular profiles for versatile configurations

The Juunoo system's structure features three primary types of profiles: a central «I» profile, a «C» profile for end connections, and a horizontal «D» profile designed for openings such as doors and windows[57]. These profiles are telescopic, allowing them to adapt to varying ceiling heights while optimizing transportation dimensions. Installation is facilitated by a «quickspan» lever that temporarily secures each profile, enabling hands-free assembly of subsequent components[58]. Initially, the profiles were constructed with at least 40% recycled materials, reflecting the system's commitment to sustainability[59]. In later iterations, the recycled content has been increased to 98%[60].

The profiles can generally be secured using a single screw per profile or a high-adhesive, reusable Velcro system that minimizes damage to underlying surfaces[61]. The Velcro connections incorporate a masking tape underlayer to prevent adhesive residue and tear-out during removal[62], a notable improvement over earlier applications of this technology[63]. These features enhance the profiles' reversibility and reuse potential, allowing them to be easily repositioned or replaced without significant damage to the surrounding structure.

Additionally, the profiles include pre-cut openings for routing cables and technical installations, eliminating the need for post-installation alterations and preserving the integrity of the components[64].

4.4.2 Panels: click-on technology

Juunoo panels integrate «click-on» technology through a tongue-and-groove joint that simplifies assembly and enhances reversibility[65]. For lighter loads (less than 25 kg per panel), the panels can be fixed using only their Velcro-like tape, further streamlining the installation process. This method leaves the panels intact, facilitating reuse and reducing waste. However, screws are required for greater loads[66] or when fire resistance properties are necessary[67]. The Juunoo tape, designed to withstand up to 30 cycles of reuse without performance degradation, exemplifies the system's focus on sustainability[68]. For cases requiring screws, self-drilling screws are recommended, as they enable the structure to be reused up to ten times before requiring maintenance to preserve functionality[69].

While the tongue-and-groove joints facilitate efficient assembly, they create a linear disassembly process, which can complicate partial panel replacements. In practice, punctual replacements may require the disassembly of adjacent panels. Although this process may not be particularly time-intensive, it could necessitate refinishing a broader surface than the damaged panel, increasing labor and material demands. Leveraging the option to use flat-edged panels, as described in the technical data, could improve the system's disassembly process while maintaining ease of assembly.

The existing array of Juunoo panels is designed to reduce embodied carbon. Standard «click panels» are made from 85% recycled wood[70]. The system also accommodates a variety of panel options with different finishes and acoustic properties, ensuring versatility across applications[71]. The documentation specifies alternative panel types and their implementation, including normal drywall panels, OSB panels, particleboards, and plywood panels, along with detailed measures required for their installation[72]. This adaptability allows users to customize the system to meet specific requirements without compromising reversibility or ease of installation.

By emphasizing adaptability and reuse, the Juunoo system reduces environmental impacts, extends component life cycles, and accommodates the integration of better-performing materials over time. With a design simplicity that minimizes the need for specialized tools or equipment during assembly, the system also reduces labor costs. According to the company, «the installation process is 7 times faster than traditional partitions»[73]. While these time savings may depend on installers becoming familiar with the system's minor intricacies, the potential for faster workflows makes Juunoo a compelling choice.

However, this facilitated interchangeability introduces a nuanced set of challenges. The ability to easily replace and reuse components could inadvertently encourage more frequent changes than necessary, driven by aesthetic preferences or evolving design trends rather than genuine functional needs[74]. This risk might be amplified by initiatives such as Juunoo's buy-back program, which incentivizes users to return components

51   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 35.
52   Ibid., 19.
53   Ibid., 28.
54   Ibid., 89.
55   Ibid., 20.
56   Ibid., 31.
57   Ibid., 6-7.
58   Ibid., 15.
59   Ibid., 12.
60   Rigips SA, *JUUNOO: Réutilisable, rapide et écologique, Rigips SA, 2024*, 2. https://www.rigips.ch/domains/rigips_ch/appBuilder/file.cfc?method=get&lang=fr&id=33896
61   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 20-21.
62   Ibid., 21.
63   Célia Küpfer and Corentin Fivet, *Déconstruction Sélective: Construction Réversible: Recueil pour Diminuer les Déchets et Favoriser le Réemploi dans la Construction* (Structural Xploration Lab, EPFL, Lausanne/ Fribourg: Smart Living Lab, 2021), 132-133.
64   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 37.

65   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 43.
66   Ibid., 40.
67   Ibid., 41.
68   JUUNOO, *JUUNOO The Wall That Pays Off*, 5.
69   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 5.
70   JUUNOO, *JUUNOO The Wall That Pays Off*, 4.
71   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 8.
72   Ibid., 45-51.
73   JUUNOO, *JUUNOO The Wall That Pays Off*, 5.
74   Bob Geldermans, Martin Tenpierik, and Peter Luscuere, «Circular and Flexible Infill Concepts: Integration of the Residential User Perspective,» *Sustainability* 11, no. 1 (2019): 1-19, 8-9.

earlier to maximize resale value, as the buy-back price appears to diminish over time[75].
At the same time, this initiative provides a structured approach to component end-of-life management, as manufacturers can optimize recycling processes and refurbishing methods to ensure minimal waste. Components returned to the company are more likely to undergo efficient and environmentally conscious processing compared to ad hoc disposal by users. This aligns with the principles of the circular economy, where products are kept in use for as long as possible and their materials reintegrated into production cycles.

Nonetheless, the environmental benefits of such programs are moderated by potential increases in transportation emissions. Many specialized production sites for reversible partitions are located far from the point of use, and as material flows between production facilities and use sites increase, so do the associated emissions. Balancing the advantages of optimized recycling and refurbishment with the environmental costs of transportation and the risk of overuse will require careful management. Clear guidelines on optimal replacement intervals, localizing production to reduce transport emissions, and encouraging thoughtful use of reversibility features could mitigate these concerns, ensuring that the full sustainability potential of reversible partitions is realized without unnecessary trade-offs.

For instance, the potential for overuse due to easy disassembly, the interplay between component reuse and material degradation, and the comparative environmental costs of producing highly specialized versus standard materials must all be weighed. While these aspects highlight the system's potential, they also emphasize the need for robust methodologies to fully understand its sustainability performance relative to classical partitions. Quantifying the benefits of the Juunoo reversible partition system compared to traditional partitions requires a more nuanced and comprehensive approach.

While the system clearly offers advantages in modularity, reusability, and adaptability, accurately measuring its environmental impact demands detailed considerations of both its direct and indirect effects. Factors such as the embodied carbon of its components, transportation emissions, durability under multiple reuse cycles, and end-of-life recovery rates must all be meticulously evaluated. These considerations set the stage for the following chapter, which delves into the intricacies of quantifying environmental impacts through EPDs and LCAs, exploring the strengths and limitations of these tools.

---

75   JUUNOO, *JUUNOO Buyback Guarantee*, 5.
https://juunoo.com/wp-content/uploads/2024/10/2024-08-30-BuyBack-Policy-ENG.pdf

5. Quantifying reversibility

In this chapter, we will begin by examining the various life cycle stages included in Environmental Product Declarations (EPDs) and endeavor to identify the potential complexities involved in quantifying their environmental impacts. Furthermore, we will critically analyze limitations that impede the comparability of similar EPDs, illustrating these challenges through a comparative analysis of a conventional partition and the JUUNOO partition.

Subsequently, the concept of reversibility in these quantifications will be investigated, particularly in the context of Life Cycle Assessment (LCA) and the associated frameworks for accountability.

5.1 EPD

Quantifying the environmental impacts of reversibility first requires considering Environmental Product Declarations (EPDs). These product declarations, often created by producers, aim to enable comparisons between products, allowing potential users to make informed choices based on their respective properties. EPDs are divided into five main stages for construction elements: the product stage, the construction stage, the use stage, and the end-of-life stage. Often, a final stage, module D, is included to account for benefits and loads beyond the system boundary[76].

The product stage is divided into three modules: raw material supply (A1), transport to the manufacturer (A2), and manufacturing (A3). These modules examine, respectively, the extraction and transformation of raw materials, the transportation of these raw materials and their packaging to the manufacturing site, and the manufacturing of the product and packaging, as well as the waste produced at this stage[77].

The construction stage is divided into two modules: transport to the building site (A4) and installation in the building (A5). These modules consider, respectively, the transport from the production site to the building site, the installation of the product at the building site, and the waste produced during its installation[78].

The use stage is divided into seven modules: use (B1), maintenance (B2), repair (B3), replacement (B4), refurbishment (B5), operational energy use (B6), and operational water use (B7). The use stage is not always accounted for in EPDs[79].

The end-of-life stage is divided into four modules: deconstruction/demolition (C1), transport of waste to processing (C2), waste processing for reuse, recycling, or energy recovery (C3), and waste disposal (C4). The D module considers the potential for reuse, recycling, or energy recovery of materials once they have been dismantled.[80].

While these stages provide a global and structured framework, EPDs sometimes rely on assumptions to address gaps in data. These assumptions can compromise precision and comparability, presenting significant challenges in evaluating the environmental impacts of a given product. While comparing orders of magnitude between different products is relatively straightforward, it becomes considerably more complex when the products in question are similar. The variables and averages used for each EPD exhibit an unknown rate of variation, which can potentially influence conclusions in one direction or another.

5.1.1 Production stage

Regarding the production stage, EPDs often rely on averaged data for raw material extraction, transportation, and the energy mixes used in production processes across multiple manufacturing sites[81]. While this approach simplifies the assessment, it introduces significant limitations. For instance, energy sources can vary widely between production locations, with some facilities relying heavily on renewable energy while others depend on fossil fuels. Averaging these differences may dilute the specific environmental impacts associated with individual production sites, resulting in outcomes that do not accurately reflect a product's true footprint within specific geographical contexts.

Regarding the construction stage, transportation distances (A4) are often averaged or assumed, failing to account for specific scenarios. For example, in the Rigips metal profile EPD, the average distance from the production site in Germany to the building site is assumed to be 100 km. While the vehicle and fuel type are defined, these variables may not correspond to all situations within a European scope[82]. The impact associated with installation (A5) may also vary slightly, particularly for products that require substantial energy during the installation process[83].

5.1.2 Use stage

The use phase is often excluded from the EPDs of construction materials[84]. However, the use phase impacts associated with maintenance and repairs may not always yield identical values for different products. In scenarios where two products are subjected to identical conditions, damages or external influences, such as mishandling or user behavior, would affect both products similarly. In such cases, the comparability of their environmental impacts remains intact. Nevertheless, the degree of impact may differ in situations involving reversible products. For example, if one product is designed to allow localized repairs (reversible) while the other is not, the use phase becomes highly relevant. A reversible product may enable targeted interventions, reducing material and energy use compared to replacing an entire component.

76   Luís Bragança et al., eds., *Circular Economy Design and Management in the Built Environment: A Critical Review of the State of the Art*, Springer Tracts in Civil Engineering (Cham: Springer Nature, 2025), 132-133.
77   Ibid., 132-135.
78   Ibid.
79   Ibid.
80   Ibid.

81   The International EPD System, «Knauf LLC, Gyproc Moisture Resistant 12.5 mm, System Registration Number: S-P-00507.» 2024, 4. https://api.environdec.com/api/v1/EPDLibrary/Files/5fc62cf7-7e33-4f0c-8f9b-08dcbb5f36b2/Data
82   The International EPD System, «Rigips Metal Profiles, System Registration Number: EPD-IES-0015700 .» Version 1, 2024, 2,6,7. https://api.environdec.com/api/v1/EPDLibrary/Files/cb03ef40-225f-4620-b775-08dca749c5b7/Data
83   Giovanni Brambilla et al., «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings,» *Resources, Conservation & Recycling* 141 (2019): 133, 137.
84   The International EPD System, «Rigips RB 12.5 mm - Standard Plasterboard, System Registration Number: S-P-00786.» Version 2, 2015, 6. https://api.environdec.com/api/v1/EPDLibrary/Files/22410351-637b-4ff5-aa2c-c60c30183b61/Data

Another key consideration in EPDs is the reference service life (RSL) of the product under consideration[85]. The RSL plays a crucial role in distributing a product's environmental impact over its entire lifecycle. For example, consider two identical cars: one with an actual service life of 100,000 km and the other with a service life of 200,000 km. The car with the shorter lifespan effectively doubles the environmental impact per kilometer compared to the longer-lasting one. This underscores the importance of accurate RSL estimations in lifecycle assessments.

This distribution effect highlights how variations in service life can significantly influence the perceived sustainability of a product. At first glance, it might seem that extending the RSL of a component inherently reduces its relative environmental impact. However, this assumption warrants careful scrutiny. For instance, increasing the thickness of a gypsum panel from 1.25 cm to 1.5 cm may suggest enhanced durability, potentially extending its service life. Yet such modifications do not guarantee a longer lifespan, as the end-of-life for these products may also be dictated by external factors, such as changing spatial requirements, renovations, or aesthetic preferences, rather than physical failure. Moreover, increasing panel thickness introduces trade-offs, including higher embodied carbon, greater material consumption, and elevated transportation impacts due to increased volume. Practical service life data only becomes available at the end of a product's lifecycle, at which point this information is no longer actionable. This limitation complicates efforts to design and optimize products for the most effective lifecycle strategies.

5.1.3 End of life stage

In EPDs, the end-of-life (EoL) phase is critical for evaluating the environmental impacts associated with the disposal, recycling, or repurposing of materials and components after use. However, this phase is often oversimplified. For example, demolition or deconstruction rates, recycling efficiency, landfill rates, and transportation distances are typically generalized, failing to account for variations in actual processes that depend on context-specific values[86].

5.1.4 Module D

Speculative assumptions about future recycling rates, energy mixes, and material recovery efficiency undermine the accuracy of Module D calculations, often making them overly optimistic. Furthermore, an excessive focus on Module D can create misaligned incentives by undervaluing improvements in earlier life cycle stages, such as production (A1–A3) or use (B1–B5), which deliver faster and more tangible environmental benefits[87]. The urgency of addressing climate change exacerbates this issue, as global warming is a time-sensitive crisis where emissions today carry greater weight than those in the future due to their cumulative impact[88].

5.2 JUUNOO

5.2.1 Description of the elements of comparison

We now aim to compare the environmental impacts of the Juunoo system with those of a classical partition by analyzing their respective EPDs. This section provides a detailed examination of the elements used for comparison. The analysis involves identifying and defining the key attributes, variables, and criteria that form the basis for evaluation. Each element is critically assessed to ensure its relevance, reliability, and significance within the context of the study.

EPDs commonly use a declared unit as a standardized baseline for comparison, such as 1 m^2 of a partition wall panel. This approach provides a consistent framework for evaluating and comparing the environmental impacts of different products. However, significant challenges arise when making direct comparisons, particularly when the products being evaluated differ in material composition or functional properties. Different materials may require varying thicknesses to achieve equivalent properties, such as acoustic insulation or load-bearing capacity. A thinner material may meet the baseline criteria in one context but fall short in another, while a thicker product may exceed the necessary requirements, leading to overdesign and higher embodied impacts. To address the limitations of relying solely on a declared unit, functional equivalence can be introduced as a complementary consideration. This ensures that comparisons reflect the actual requirements of specific applications or contexts. In theory, this approach enhances the accuracy and reliability of environmental assessments by aligning the products' environmental impacts with their functional performance.

To compare partitions with similar properties, we will analyze the Juunoo BaseClick partition against a single-layer plasterboard partition (Comparison 1) and the Juunoo SilentClick partition against a double-layer plasterboard partition (Comparison 2). This approach is based on their comparable acoustic properties[89].

Comparison 1

The Juunoo BaseClick partition is 100 mm thick, consisting of I75t/C75t profiles clad with 10 mm BaseClick panels. The insulation layer is made of 50 mm glass wool (33 kg/m^3). The partition's calculated acoustic performance is 43 (-4; -10) dB.
The single-layer plasterboard partition is also 100 mm thick, composed of U and C wall profiles (75 mm) clad with 12.5 mm plasterboard. The insulation layer is made of 50 mm glass wool. The partition's estimated acoustic performance is 43 (-3; -9) dB.

Comparison 2

The Juunoo SilentClick partition is 136 mm thick, comprising I75t/C75t profiles clad with 28 mm SilentClick panels. The insulation layer is made of 50 mm glass wool (33 kg/m^3). The partition's calculated acoustic performance is 54 (-5; -10) dB.
The double-layer plasterboard partition is 125 mm thick, composed of U and C wall profiles (75 mm) clad with two 12.5 mm plasterboards on each side. The insulation layer

85   The International EPD System, «Rigips RB 12.5 mm - Standard Plasterboard, System Registration Number: S-P-00786.» Version 2, 2015, 4. https://api.environdec.com/api/v1/EPDLibrary/Files/22410351-637b-4ff5-aa2c-c60c30183b61/Data
86   Ibid., 8.
87   Carine Lausselet et al., «Methods to Account for Design for Disassembly: Status of the Building Sector,» *Buildings* 13, no. 1012 (2023), 8.
88   Ibid, 9.

89   JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 115.

is made of 50 mm glass wool. The partition's estimated acoustic performance is 49 (-2; -9) dB.

These compositions are defined in the respective EPDs of the products as well as in their technical data[90]. However, the EPDs consider the partition as a whole, and detailed quantifications of its constituent parts are unavailable. The Juunoo EPDs account for the average materials required to build 1 m², but the specific details of these calculations are also not provided.

Several limitations related to the product EPDs used in the calculations for the classical partition must be noted. Firstly, the intention was to use Rigips products, as Rigips is the Swiss supplier of the Juunoo system and also supplies components for the classical partition. However, some of the product EPDs were either unavailable or did not include the same impact categories as the Juunoo system's EPD. This discrepancy arises because the EPDs for Rigips products were not developed using the same standards as the EN 15804+A2 standard employed in the Juunoo system's EPD. To address this, similar products from other producers were used.

The selected products pertain to a European geographical scope, but some limitations were encountered. For instance, the insulation used in the Juunoo system is considered to have a volumetric mass of 33 kg/m³, yet the only rock wool insulation meeting the specified requirements has a volumetric mass of 40 kg/m³.

5.2.2 Calculation details for 1 m2 of classical partition

The declared units in the EPDs of the classical partition wall are 1 m², 1 kg, 1 kg, and 1 m² for plasterboards, metal profiles, screws, and insulation, respectively. Based on the calculated material requirements, the values of these EPDs are combined to represent the «complete» partition. However, they must be multiplied by a factor to account for the exact materials required for 1 m² of partition, ensuring that our comparison considers identical declared units. The calculations for these factors will be detailed below. To define the average material requirements for the «classical partition wall,» we will use the «Rigips Material Requirement Calculator»[91].

　　- According to the calculator, the single cladding partition (one plasterboard layer) requires 2 m² of plasterboard, 0.8 lm of UW profiles, 1.8 lm of CW profiles, 1 m² of insulation, and 24 × 25 mm screws.

　　- According to the calculator, the double cladding partition (two plasterboard layers) requires 4 m² of plasterboard, 0.8 lm of UW profiles, 1.8 lm of CW profiles, 1 m² of insulation, 8 × 25 mm screws, and 24 × 35 mm screws.

The required factors for the single-layer partition are as follows:

　　- Panels: 2 m² of plasterboard are required versus 1 m² declared in the considered EPD (factor: 2).

　　- Structure profile: 2.6 lm of profiles are required, with a weight of approximately 0.8 kg/lm (according to the Rigips® C-Wall Profile product specifications), for a total of 2.08 kg of profile required per 1 m² of partition versus the 1 kg declared in the considered EPD (factor: 2.08).

　　- Screws: 24 pieces of 25 mm screws are required, with a weight of 1.4 kg/1,000 pieces, meaning each screw weighs 0.0014 kg. This totals 0.0336 kg of screws required per 1 m² of partition versus the 1 kg declared in the considered EPD (factor: 0.0336).

　　- Insulation: 1 m² of 50 mm thick rock wool insulation is required, while the considered EPD presents 1 m² of 34 mm thick rock wool insulation (factor: 1.47).

The required factors for the double-layer partition are as follows:

　　- Plasterboards: 4 m² of plasterboard are required versus 1 m² declared in the considered EPD (factor: 4).

　　- Structure profile: 2.6 lm of profiles are required, with a weight of approximately 0.8 kg/lm (according to the Rigips® C-Wall Profile product specifications), for a total of 2.08 kg of profile required per 1 m² of partition versus the 1 kg declared in the considered EPD (factor: 2.08).

　　- Screws: 8 pieces of 25 mm screws and 24 pieces of 35 mm screws are required. The 25 mm screws weigh 1.4 kg/1,000 pieces (0.0014 kg per screw), and the 35 mm screws weigh 1.8 kg/1,000 pieces (0.0018 kg per screw). This results in a total of 0.0742 kg of screws required per 1 m² of partition versus the 1 kg declared in the considered EPD (factor: 0.0742).

　　- Insulation: 1 m² of 50 mm thick rock wool insulation is required, while the considered EPD presents 1 m² of 34 mm thick rock wool insulation (factor: 1.47).

5.2.3 Analysis

The objective of this comparison is to explore the complexities involved in evaluating and comparing two elements from the perspective of a non-expert. The limited availability of detailed information regarding the Juunoo system may hinder a concrete comparison of the constituent parts of the considered partitions. However, a significant amount of information can still be inferred from calculations related to the product as a whole. This analysis will focus on comparing the single-layer partition and the BaseClick partition, as they exhibit the most similar acoustic properties.

When initially comparing the calculated values for the single-layer L1 classical partition (Fig.17) with the BaseClick partition (Fig.18), as well as for the double-layer classical partition (Fig.19) with the SilentClick partition (Fig.20), it appears that the classical partition walls have lower global warming potential (GWP) impacts than the Juunoo system. For instance, for L1 versus BaseClick (Fig.21), the total GWP is 1.8 times

90　　　JUUNOO, «For Professionals,» https://juunoo.com/professionals.
91　　　Rigips, «Cloison Montants Simples ou Doubles,» https://www.rigips.ch/fr/Construction-a-sec-pour-bricoleurs/calculer-les-besoins-en-materiel/Cloison_montants_simples_ou_doubles.

greater for the Juunoo partition (2.46E+01 vs. 1.36E+01). However, almost all other environmental impacts are greater for L1 than for BaseClick.

The higher total GWP impact of the BaseClick partition can be better understood by examining the total GWP impact per life cycle stage. Comparing the total GWP values of the L1 partition (Fig.17) with those of the BaseClick partition (Fig.18) is more effectively synthesized in the figure 22 (Fig.22).

Product Stage (A1–A3)

The product stage (A1–A3 modules) is almost identical for both partitions, indicating that the production of both involves similar impacts (Fig. 23). For the classical L1 partition, the structure has the greatest impact, followed by the panels, and finally the insulation. It is reasonable to assume (despite the lack of accessible details) that a similar distribution applies to the BaseClick partition, albeit with differences in allocation. The BaseClick profiles, being more complex and requiring additional production steps, likely contribute a higher impact compared to standard partition profiles. However, this is likely offset by the panels, which are made of recycled wood and do not require the energy-intensive production processes involved in producing gypsum. The insulation likely accounts for similar values in both partitions.

Assembly Stage (A4–A5)

The A4 module (transportation to the site) is similar for both cases but slightly lower for the BaseClick partition, depending on the averaged values considered in its EPD. However, these specific values are not provided in the BaseClick partition's EPD. Given that insulation and panels primarily contribute to the transportation impacts in the classical L1 partition, and considering their size and weight relative to the equivalent components in the BaseClick partition, it is plausible that the slightly lower values for the BaseClick partition result from the profiles' reduced transportation size.

The A5 module (assembly impacts) is significantly lower for the BaseClick partition. This reduction is likely due to the system's design, which aims to streamline assembly. For example, the profiles are delivered with pre-applied tape, the panels are pre-cut to size, and, most notably, the Juunoo profiles do not need to be cut to length on-site, resulting in significantly less waste during this stage.

Use Stage (B Modules)

The B modules of the use stage are not considered for either partition.

L1: 1m²	unit	A1-3	A4	A5	B1–B7	C1	C2	C3	C4	D	A-D
ENVIRONMENTAL IMPACTS:											
GWP GHG	[kg CO2 eq.]	1.39E+01	2.70E-01	1.35E+00		2.65E-02					1.35E+01
GWP FOSSIL	[kg CO2 eq.]	1.39E+01	2.67E-01	1.23E+00		3.67E-02					1.26E+01
GWP BIOGENIC	[kg CO2 eq.]	-1.59E-01	-1.75E-03	2.53E-01		5.77E-05					6.70E-01
GWP LULUC	[kg CO2 eq.]	2.94E-02	3.51E-05	8.36E-04		9.68E-05					3.44E-02
GWP TOT	[kg CO2 eq.]	**1.07E+01**	**2.68E-01**	**1.46E+00**		**3.68E-02**					**1.36E+01**
ODP	[kg CFC-11]	3.11E-07	2.82E-14	6.68E-09		1.68E-14					3.19E-07
AP	[Mole of H+]	2.22E-01	4.25E-04	1.04E-02		4.10E-05					2.28E-01
EP freshwater	[kg P eq.]	3.96E-03	9.71E-07	1.78E-04		4.21E-08					4.14E-03
EP marine	[kg N eq.]	2.03E-02	1.56E-04	1.07E-03		1.51E-05					2.06E-02
EP terrestrial	[Mole of N]	7.59E-01	1.84E-03	3.76E-02		1.70E-04					7.88E-01
POCP	[kg NMVOC]	6.13E-02	3.86E-04	3.50E-03		1.99E-04					6.19E-02
ADP ele.	[kg Sb eq.]	4.56E-04	1.74E-08	3.20E-05							4.88E-04
ADP foss.	[MJ]	2.19E+02	3.66E+00	1.74E+01							2.25E+02
Water deprivation pot	[m³ world]	4.93E+00	3.13E-02	2.99E-01							5.22E+00
RESSOURCE USE:											
RENEWABLE ENERGY TOT	[MJ]	1.76E+01	2.59E-01	2.67E+00		5.50E-03					2.38E+01
NON RENEWABLE ENERGY TOT	[MJ]	2.19E+02	3.66E+00	1.74E+01		1.32E-01					2.23E+02
SECONDARY MAT.	[kg]	4.74E-01	0.00E+00	1.75E-02		0.00E+00					5.19E-01
RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00					0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00					0.00E+00
USE OF FRESH WATER	[m3]	1.21E-01	2.67E-04	8.89E-03		2.79E-05					1.29E-01
WASTE CATEGORIES:											
HAZARDOUS WASTE	[kg]	2.81E-03	1.26E-11	1.40E+00		4.86E-11					2.95E-03
NON HAZAR WAST	[kg]	1.37E+01	5.39E-04	1.90E+00		9.01E-05					3.24E+01
RADIOACTIVE WASTE	[kg]	5.46E-03	5.61E-06	4.41E-04		5.13E-06					6.28E-03
OUTPUT FLOWS:											
COMPONENTS FOR REUSE	[kg]	0.00E+00	0.00E+00	0.00E+00		0.00E+00					1.55E-02
MATERIALS FOR RECY.	[kg]	3.55E-01	1.46E-01	1.55E-02		0.00E+00					2.51E+00
MATERIALS FOR ENERGY RECO.	[kg]	0.00E+00	0.00E+00	0.00E+00		0.00E+00					0.00E+00
EXPORTED ENERGY ELEC.	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00					1.11E-01
EXPORTED ENERGY THERM	[MJ]	0.00E+00	1.11E-01	1.43E-01		0.00E+00					1.43E-01

Fig.17

L2: 1m2

JUUNICO BaseClick: 1m2

ENVIRONMENTAL IMPACTS:

		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D → Infered	A-D
ENVIRONMENTAL IMPACTS:																	
GWP GHG	[kg CO2 eq.]	1,86E+01	4,13E-01	2,07E+00	0	0	0	0	0	0	0	4,41E-02	2,60E-01	5,03E-03	1,46E+00	3,00E+00	1,98E+01
GWP FOSSIL	[kg CO2 eq.]	1,84E+01	4,08E-01	1,92E+00	0	0	0	0	0	0	0	5,42E-02	2,46E-01	3,45E-02	4,06E-01	2,94E+00	1,86E+01
GWP BIOGENIC	[kg CO2 eq.]	-2,15E-01	-3,79E-03	2,94E-01	0	0	0	0	0	0	0	8,28E-05	-3,54E-03	3,48E-02	1,08E+00	4,74E-03	1,19E+00
GWP LULUC	[kg CO2 eq.]	5,13E-02	4,79E-03	1,25E-03	0	0	0	0	0	0	0	9,75E-05	1,31E-04	9,25E-04	1,22E-03		5,96E-02
GWP TOT	**[kg CO2 eq.]**	**1,83E+01**	**4,08E-01**	**2,22E+00**	0	0	0	0	0	0	0	**5,44E-02**	**2,45E-01**	**6,94E-02**	**1,48E+00**	**-2,94E+00**	**1,98E+01**
ODP	[kg CFC-11 eq.]	4,44E-07	4,05E-14	8,68E-09	0	0	0	0	0	0	0	3,44E-14	2,16E-14	8,48E-14	7,46E-13	8,75E-12	4,54E-07
AP	[Mole of H+ eq.]	2,79E-01	6,65E-04	1,25E-02	0	0	0	0	0	0	0	5,31E-05	3,63E-04	2,40E-04	3,38E-03	-6,71E-03	2,88E-01
EP freshwater	[kg P eq.]	4,36E-03	1,47E-05	1,79E-04	0	0	0	0	0	0	0	4,49E-08	9,00E-07	7,76E-08	2,47E-06	-1,86E-07	4,54E-03
EP marine	[kg N eq.]	2,86E-02	2,46E-04	1,48E-03	0	0	0	0	0	0	0	1,99E-05	1,35E-04	6,71E-05	9,48E-04	-1,61E-03	2,99E-02
EP terrestrial	[Mole of N eq.]	8,47E-01	2,88E-03	4,20E-02	0	0	0	0	0	0	0	2,24E-04	3,19E-03	7,39E-04	1,04E-02	-1,74E-02	8,88E-01
POCP	[kg NMVOC eq.]	8,66E-02	6,10E-04	5,00E-03	0	0	0	0	0	0	0	5,61E-05	1,99E-04	1,99E-04	3,10E-03	-5,38E-03	9,05E-02
ADP ele.	[kg Sb eq.]	4,80E-04	2,64E-08	4,02E-05	0	0	0	0	0	0	0	1,27E-09	1,60E-08	6,80E-09	1,43E-08	-3,05E-08	5,20E-04
ADP foss.	[MJ]	2,97E+02	5,57E+00	2,73E-01	0	0	0	0	0	0	0	8,57E-01	3,55E+00	4,96E-01	4,55E+00	-2,20E+01	3,17E+02
Water deprivation pot	[m³ world equiv.]	6,13E+00	4,73E-03	4,04E-01	0	0	0	0	0	0	0	2,07E-03	2,84E-03	4,28E-03	4,43E-02	-4,26E-02	6,55E+00
RESSOURCE USE:																	
RENEWABLE ENERGY TOT	[MJ]	2,30E-01	3,92E-01	4,84E+00	0	0	0	0	0	0	0	1,14E-02	2,47E-01	9,26E-03	9,92E-01	2,74E+00	3,23E+00
NON RENEWABLE ENERGY TOT	[MJ]	2,97E+02	5,58E+00	2,74E+00	0	0	0	0	0	0	0	7,17E-01	3,50E+00	9,98E-02	6,38E+00	-2,39E+01	3,17E+02
SECONDARY MAT.	[kg]	4,82E-01	0,00E+00	1,75E-02	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	6,00E-02	1,05E+00	5,60E-01
RENEWABLE SEC. FUELS	[MJ]	0,00E+00	0	0	0	0	0	0	0	0	0	0,00E+00	0	0	0	0	0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0,00E+00	0	0	0	0	0	0	0	0	0	0,00E+00	0	0	0	0	0,00E+00
USE OF FRESH WATER	[m3]	1,50E-01	4,13E-04	1,30E-02	0	0	0	0	0	0	0	5,64E-05	2,73E-04	2,85E-05	1,55E-03	-2,17E-03	1,64E-01
WASTE CATEGORIES:																	
HAZARDOUS WASTE	[kg]	2,81E-03	1,97E-11	1,40E-04	0	0	0	0	0	0	0	9,72E-11	1,29E-11	-2,58E-13	4,74E-10	-1,30E-10	2,95E-03
NON HAZAR WAST	[kg]	1,39E+01	8,14E-04	3,07E+00	0	0	0	0	0	0	0	1,56E-04	5,07E-04	2,62E-05	3,15E-01	-3,69E-02	4,84E+01
RADIOACTIVE WASTE	[kg]	5,81E-03	8,07E-06	6,25E-04	0	0	0	0	0	0	0	1,11E-05	4,62E-06	1,34E-06	7,40E-05	3,37E-04	6,87E-03
OUTPUT FLOWS:																	
COMPONENTS FOR REUSE	[kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,01E-01
MATERIALS FOR RECY.	[kg]	3,00E-02	0	0	0	0	0	0	0	0	0	0	2,01E-01	4,00E-03	3,60E-02	3,13E-02	3,40E-02
MATERIALS FOR ENERGY RECO.	[kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-5,58E-01	0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8,99E-04	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0,00E+00

Fig.18

			C1	C2	C3	C4	D	A-D
OUTPUT FLOWS:								
COMPONENTS FOR REUSE	[kg]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,55E-02
MATERIALS FOR RECY.	[kg]	6,67E-01	0,00E+00	2,05E+00	0,00E+00	0,00E+00	0,00E+00	2,94E+00
MATERIALS FOR ENERGY RECO.	[kg]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,58E+00
EXPORTED ENERGY ELEC	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	4,42E-02

Fig.19

Fig.20

JUUNOO SilentClick: 1m2
L1: 1m2

ENVIRONMENTAL IMPACTS:		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP GHG	[kg CO2 eq.]	1,35E-01	3,76E-03	5,22E-02	0	0	0	0	0	0	0	3,01E-04	3,68E-01	3,12E-01	0,00E+00	0,00E+00 --> inferred	4,93E-01
GWP FOSSIL	[kg CO2 eq.]	1,28E+01	3,79E-01	4,72E-02	0	0	0	0	0	0	0	2,96E-04	3,67E-01	1,48E-03	0,00E+00	0,00E+00	6,95E-01
GWP BIOGENIC	[kg CO2 eq.]	6,70E-01	1,35E-04	4,94E-03	0	0	0	0	0	0	0	4,36E-06	1,65E-04	3,13E-01	0,00E+00	-4,91E-02	5,61E-02
GWP LULUC	[kg CO2 eq.]	6,62E-02	1,55E-04	5,92E-05	0	0	0	0	0	0	0	7,05E-07	1,48E-04	8,57E-07	0,00E+00	-6,40E-02	2,56E-03
GWP TOT	**[kg CO2 eq.]**	**1,72E+01**	**3,76E-01**	**5,22E-02**	0	0	0	0	0	0	0	**3,01E-04**	**3,68E-01**	**3,13E-01**	**0,00E+00**	**0,00E+00**	**4,93E-01**
ODP	[kg CFC-11 eq.]	3,19E-07	8,39E-08	7,17E-09	0	0	0	0	0	0	0	6,17E-11	8,30E-08	1,07E-10	0,00E+00	-5,48E-06	3,34E-07
AP	[Mole of H+]	2,28E-01	4,43E-03	1,71E-04	0	0	0	0	0	0	0	7,36E-07	4,34E-03	4,24E-06	0,00E+00	-3,28E-01	6,09E-02
EP freshwater	[kg P eq.]	2,83E-03	3,01E-05	1,60E-06	0	0	0	0	0	0	0	8,91E-09	2,63E-06	2,46E-08	0,00E+00	-2,87E-05	-3,27E-05
EP marine	[kg N eq.]	5,91E-02	1,16E-03	4,42E-05	0	0	0	0	0	0	0	1,92E-07	1,13E-03	1,17E-06	0,00E+00	-5,75E-02	3,93E-03
EP terrestrial	[Mole of N]	1,15E+00	1,28E-02	4,71E-04	0	0	0	0	0	0	0	1,86E-06	1,25E-02	1,28E-05	0,00E+00	-9,16E-01	2,60E-01
POCP	[kg NMVOC]	2,25E-01	3,56E-03	1,55E-04	0	0	0	0	0	0	0	4,75E-07	3,48E-03	4,15E-06	0,00E+00	-2,28E-01	4,19E-03
ADP ele.	[kg Sb eq.]	9,33E-03	5,45E-06	6,70E-07	0	0	0	0	0	0	0	3,44E-09	5,32E-06	1,81E-08	0,00E+00	-8,86E-04	8,46E-03
ADP foss.	[MJ]	7,88E+02	5,56E+00	1,08E+00	0	0	0	0	0	0	0	1,18E-02	5,44E+00	1,45E-02	0,00E+00	-7,69E+02	3,11E+01
Water deprivation pot	[m³ world]	4,76E+01	2,04E+00	1,48E-02	0	0	0	0	0	0	0	1,21E-04	1,82E-02	3,11E-04	0,00E+00	-4,70E-01	6,54E+01

RESSOURCE USE:		A1-3	A4	A5								C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	6,08E+02	5,63E-02	8,25E-02	0	0	0	0	0	0	0	1,31E-03	6,11E-02	7,15E-04	0,00E+00	-6,05E+02	3,26E+00
NON RENEWABLE ENERGY TOT	[MJ]	2,16E+03	5,96E+00	-5,43E-01	0	0	0	0	0	0	0	1,18E-02	5,44E+00	-1,37E+03	0,00E+00	6,03E+02	1,40E+03
SECONDARY MAT.	[kg]	3,71E+00	0,00E+00	7,89E-04	0	0	0	0	0	0	0	0,00E+00	5,44E+00	0,00E+00	0,00E+00	-2,13E+00	1,58E+00
RENEWABLE SEC. FUELS	[MJ]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
USE OF FRESH WATER	[m3]	0,315	1,02E-03	3,43E-04	0	0	0	0	0	0	0	2,90E-06	9,89E-04	4,35E-06	0,00E+00	-2,71E-01	-2,69E-01

WASTE CATEGORIES:		A1-3	A4	A5								C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	4,25E+00	6,47E-03	5,02E-03	0	0	0	0	0	0	0	1,28E-05	5,53E-03	0,00E+00	0,00E+00	-4,89E+00	-6,23E-01
NON HAZAR WASTE	[kg]	1,01E+02	4,88E-01	8,78E-02	0	0	0	0	0	0	0	3,68E-04	4,68E-01	0,00E+00	0,00E+00	-1,02E+02	4,42E-02
RADIOACTIVE WASTE	[kg]	2,28E-03	3,78E-05	7,64E-06	0	0	0	0	0	0	0	1,04E-07	3,75E-05	0,00E+00	0,00E+00	-2,12E-03	2,43E-04

OUTPUT FLOWS:		A1-3	A4	A5								C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,05E-01
MATERIALS FOR RECY.	[kg]	3,00E-02	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,40E-02
MATERIALS FOR ENERGY RECO.	[kg]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0,00E+00	0,00E+00	0,00E+00	0	0	0	0	0	0	0	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Fig.21

Juunoo baseclick: 1m2

ENVIRONMENTAL IMPACTS:		A-D
GWP GHG	[kg CO2 eq.]	2,46E+01
GWP FOSSIL	[kg CO2 eq.]	1,49E-01
GWP BIOGENIC	[kg CO2 eq.]	-4,17E-02
GWP LULUC	[kg CO2 eq.]	2,38E-03
GWP TOT	**[kg CO2 eq.]**	**2,46E+01**
ODP	[kg CFC-11 eq.]	2,24E-07
AP	[Mole of H+ eq.]	5,47E-02
EP freshwater	[kg P eq.]	-3,61E-05
EP marine	[kg N eq.]	2,46E-03
EP terrestrial	[Mole of N eq.]	2,45E-01
POCP	[kg NMVOC eq.]	8,45E-03
ADP ele.	[kg Sb eq.]	2,35E-01
ADP foss.	[MJ]	6,31E-01
Water deprivation pot	[m³ world equiv.]	

RESSOURCE USE:		A-D
RENEWABLE ENERGY TOT	[MJ]	3,13E+00
NON RENEWABLE ENERGY TO	[MJ]	4,82E+02
SECONDARY MAT.	[kg]	1,58E+00
RENEWABLE SEC. FUELS	[MJ]	0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0,00E+00
USE OF FRESH WATER	[m3]	4,42E-02

WASTE CATEGORIES:		A-D
HAZARDOUS WASTE	[kg]	-6,30E-01
NON HAZAR WAST	[kg]	-9,28E-01
RADIOACTIVE WASTE	[kg]	1,99E-04

OUTPUT FLOWS:		A-D
COMPONENTS FOR REUSE	[kg]	2,01E+01
MATERIALS FOR RECY.	[kg]	3,40E-02
MATERIALS FOR ENERGY RECY	[kg]	0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0,00E+00

Fig.22

A1-A3 — L1: 1m2

ENVIRONMENTAL IMPACTS:		A1-A3
GWP GHG	[kg CO2	1,39E+01
GWP FOSSIL	[kg CO2 eq.]	1,38E+01
GWP BIOGENIC	[kg CO2 eq.]	-1,59E-01
GWP LULUC	[kg CO2 eq.]	2,94E-02
GWP TOT	**[kg CO2 eq.]**	**1,37E+01**
ODP	[kg CFC-	3,11E-07
AP	[Mole of	2,22E-01
EP freshwater	[kg P eq.]	3,96E-03
EP marine	[kg N eq.]	2,03E-02
EP terrestrial	[Mole of N	7,59E-01
POCP	[kg	6,13E-02
ADP ele.	[kg Sb eq.]	4,56E-04
ADP foss.	[MJ]	2,19E+02
Water deprivation pot	[m³ world	4,93E+00
RESSOURCE USE:		
RENEWABLE ENERGY TOT	[MJ]	1,76E+01
NON RENEWABLE ENERGY TOT	[MJ]	2,19E+02
SECONDARY MAT.	[kg]	4,74E-01
RENEWABLE SEC. FUELS	[MJ]	0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0,00E+00
USE OF FRESH WATER	[m3]	1,21E-01
WASTE CATEGORIES:		
HAZARDOUS WASTE	[kg]	2,81E-03
NON HAZAR WAST	[kg]	1,37E+01
RADIOACTIVE WASTE	[kg]	5,46E-03
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	[kg]	0,00E+00
MATERIALS FOR RECY.	[kg]	3,55E-01
MATERIALS FOR ENERGY RECO,	[kg]	0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0,00E+00

L1: 1m2	A1-3	A4	A5	C1	C2	C3	C4	D	A1-D	(A1-D)-C3
insulation	2,29E+00	1,11E-01	2,47E-01	1,03E-02	0,00E+00	6,44E-02	-5,16E-02	1,03E-02	2,68E+00	1,35E+01
screws	1,27E-02	2,61E-05	4,84E-04	1,53E-03	1,69E-05	0,00E+00	0,00E+00	-6,40E-03	6,97E-03	
structure	6,84E+00	1,71E-02	5,05E-01	9,24E-03	6,22E-03	5,01E-03	1,56E-03	-2,77E+00	4,62E+00	
panels	4,46E+00	1,40E-01	7,28E-01	1,58E-02	1,19E-01	0,00E+00	7,66E-01	-3,26E-02	6,20E+00	
	1,36E+01	2,68E-01	1,48E+00	3,69E-02	1,26E-01	6,94E-02	7,16E-01	-2,80E+00	1,35E+01	

		A1-3	A4	A5	C1	C2	C3	C4	A1-D	(A1-D)-C3	A1-C4
L1:1m2-per imp. cat.	GWP TOT	1,37E+01	2,68E-01	3,68E-02	1,26E-01	6,94E-02	7,16E-01	-2,84E+00	1,36E+01	1,35E+01	1,64E+01
Juunoo basiclick-per imp. cat.	GWP TOT	1,38E+01	1,53E-01	3,01E-04	1,46E-01	6,94E-02	1,04E+01	0,00E+00	2,46E+01	1,42E-01	2,46E+01
partition 2 layer. per impact cat.	GWP TOT	1,83E+01	4,08E-01	2,22E+00	2,45E-01	1,48E+00	6,94E-02	-2,94E+00	1,98E+01	1,98E+01	2,28E+01
Juunoo silentclick	GWP TOT	1,72E+01	3,76E-01	5,22E-02	3,01E-04	3,68E-01	3,13E+01	0,00E+00	4,93E+01	1,80E+01	4,93E+01

Fig.23

A1-A3 — Juunoo baseclick: 1m2

ENVIRONMENTAL IMPACTS:		A1-A3
GWP GHG	[kg CO2	1,38E+01
GWP FOSSIL	[kg CO2 eq.]	2,41E+01
GWP BIOGENIC	[kg CO2 eq.]	-1,04E+01
GWP LULUC	[kg CO2 eq.]	3,12E-02
GWP TOT	**[kg CO2 eq.]**	**1,38E+01**
ODP	[kg CFC-	2,47E-06
AP	[Mole of	2,10E-01
EP freshwater	[kg P eq.]	1,36E-03
EP marine	[kg N eq.]	2,99E-02
EP terrestrial	[Mole of N	6,69E-01
POCP	[kg	1,09E-01
ADP ele.	[kg Sb eq.]	8,90E-03
ADP foss.	[MJ]	3,73E+02
Water deprivation pot	[m³ world	2,01E+01
RESSOURCE USE:		
RENEWABLE ENERGY TOT	[MJ]	2,13E+02
NON RENEWABLE ENERGY TOT	[MJ]	8,31E+02
SECONDARY MAT.	[kg]	3,71E+00
RENEWABLE SEC. FUELS	[MJ]	0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0,00E+00
USE OF FRESH WATER	[m3]	1,94E-01
WASTE CATEGORIES:		
HAZARDOUS WASTE	[kg]	2,96E+00
NON HAZAR WAST	[kg]	5,44E+01
RADIOACTIVE WASTE	[kg]	1,06E-03
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	[kg]	0,00E+00
MATERIALS FOR RECY.	[kg]	3,00E-02
MATERIALS FOR ENERGY RECO,	[kg]	0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0,00E+00
EXPORTED ENERGY THERM	[MJ]	0,00E+00

End-of-Life Stage (C Modules)

- C1 Module: The classical L1 partition dominates the C1 module, which is expected given the streamlined assembly and disassembly process of the Juunoo system, resulting in lower energy requirements.

- C2 Module: The impacts in the C2 module are nearly identical for both partitions, though this depends on the transportation distances specified in the respective EPDs.

- C3 Module: The C3 module impact is significantly higher for the BaseClick partition. This discrepancy can be explained by several factors. First, the BaseClick partition's EPD considers the entire partition, and with the buyback program in place, all waste processing is accounted for. Additionally, Juunoo recycles much of the material in-house, reusing it directly in the production of new components, and also refurbishes potentially damaged parts. These factors likely contribute to the higher impacts reported for this module, as detailed in the reversible partition chapter.

For the L1 classical partition, the plasterboards do not account for any impacts in the C3 module. According to the Knauf gypsum board EPD: "C3 - Waste Processing: It is assumed that no waste processing is needed at the end-of-product life cycle."[92]. However, the Rigips EPD for a similar product quantifies the impact at 2.64E-01 [kg CO2 eq.], as a portion of the material is recycled[93].

- C4 Module: The L1 classical partition includes minor impacts in the C4 module. Conversely, the BaseClick partition does not account for any impacts in this module. As stated in the Juunoo BaseClick EPD: "In general, no (end-of-life) waste is ever produced when using JUUNOO systems except for the acrylic tape — re-using scenario is considered."[94].

Module D

The D module is considered for the L1 classical partition, but in the BaseClick partition, these benefits are valued at zero.
The previous discussion focused solely on total GWP. A comparison of other impact categories can be found in figure 24 (Fig.24). The partition option with the greatest impacts, per impact category and module, is summarized in figure 25 (Fig.25). This table highlights which partition has the greatest impact for each category and module, illustrating the specific modules and impact categories where the BaseClick partition has worse impacts than the L1 classical partition.
The table shows that, as a whole (considering the total values), the BaseClick partition

has a worse impact in 3 out of 14 environmental impact categories. However, it shows higher impacts in 9 out of those categories when considering Module A1–A3, 13 in Module A4, and so on. The greater total impact of the L1 classical partition appears to stem primarily from the A5, C1, C4, and D modules (note: the D module is inverted, meaning a higher value corresponds to lesser impacts). Meanwhile, the BaseClick partition exhibits higher impacts in the A1–A3, A4, C2, and C3 modules.
The table also reveals that in the resource use category, the BaseClick partition dominates the A1–A4 modules. In the waste categories, although the BaseClick partition dominates the A1–C3 modules, the waste from the L1 classical partition in Module C4, combined with the greater D module values for the BaseClick partition, counterbalances this advantage. Consequently, the L1 classical partition has a lower total impact for this category.
In the output flows category, waste creation during the installation phase dominates for the L1 classical partition, while components for reuse are significantly higher for the BaseClick partition.

Further comparative figures, as well as the individual EPD values for the contituant parts of the L1 and L2 classical partitions can be found in the appendices.

---

92   The International EPD System, «Gyproc® Normal – Standard Plasterboard, System Registration Number: S-P:00388.» Version 4, 2024, 8.
https://api.environdec.com/api/v1/EPDLibrary/Files/3cec4f68-263e-4b33-0365-08dc38ee8ac8/Data
93   Ibid.
94   EPD Hub, «Environmental product declaration in accordance with EN 15804+A2 & ISO 14025 / ISO 21930 Juunoo BaseClick.» 2022, 5.
https://26550443.fs1.hubspotusercontent-eu1.net/hubfs/26550443/Professionals%20Website/Testing%20and%20Certs/EPD_JUUNOO_BaseClick.pdf

Fig.24

Fig.25

5.3 Life Cycle Assessment (LCA)

Certain limitations previously identified can be adapted to specifically address the challenges inherent in reuse scenarios. Reuse is often promoted as a sustainable alternative to producing new components, as it can avoid the environmental impacts associated with raw material extraction and manufacturing. However, the actual benefits of reuse are highly contingent on the specific conditions of each case. When considering the uncertain future reuse of elements, the challenges of making precise assumptions grow exponentially, as a product's lifecycle extends into multiple interconnected life cycles.

5.3.1 Tracking and evolving impacts

A significant challenge in reusing construction components is accurately tracking the original production impacts (A1–A3) across multiple lifecycles. Many reusable products lack detailed records that accompany the component throughout its lifecycles, leading to uncertainty about how emissions from the original production were allocated in prior use cycles and how they should be distributed in subsequent ones. This highlights the need for continuity of information to provide a reliable basis for impact allocation across lifecycles.

5.3.2 Disassembly, transport, and storage

The construction phase for reused elements presents unique challenges not typically encountered in conventional construction. A key issue is the geographic location of specialized production and distribution facilities for reused materials. These facilities are often located farther from construction sites compared to mainstream alternatives, partly due to urban land pressures that force reuse-focused enterprises to establish operations outside city centers[95]. This increased distance can significantly amplify transportation-related impacts, potentially diminishing the overall environmental benefits of reuse. Furthermore, the disassembly process required for reuse is generally slower and more complex than conventional demolition. For large or heavy components, this process often involves prolonged use of heavy machinery, leading to increased fuel consumption and higher environmental impacts[96]. In addition to environmental considerations, disassembly incurs substantial financial costs, primarily due to higher labor requirements. Workers may need to make multiple trips to construction sites, adding logistical complexity and increasing associated emissions.
Once disassembled, elements typically require sorting, distribution, and storage at various facilities. This process introduces additional environmental impacts related to land use, as well as the construction, maintenance, and operation of storage facilities. These impacts are compounded by the need to manage and store materials until demand for their reuse materializes[97]. If these elements are subsequently reused, their outbound transportation impacts may be further exacerbated by the smaller quantities required to meet fragmented demand.

5.3.3 Mismatches in service life and functionality

Reusing or enabling the reuse of components often requires additional material and time investments, but the return on this investment can quickly diminish if the intended service life is not fully realized. For instance, a component designed to last 50 years may be removed after only 20 years due to renovations or changing needs, thereby undermining its potential environmental benefits. When the service life of a component in a building is prematurely shortened, the environmental investment made in its production and reuse fails to deliver proportional benefits.
This inefficiency underscores the critical importance of aligning the expected service life of construction elements with the anticipated life cycle of the interconnected components they are integrated into[98].

5.3.4 Uncertainty in final outcomes

The end-of-life (EoL) phase becomes increasingly speculative for reused components. As these components move through multiple lifecycles, predicting their ultimate disposal, recycling, or reuse scenarios becomes challenging. The reuse of a component can extend its lifecycle well beyond traditional EoL timeframes, but this creates a temporal gap between the original production impact and its eventual disposal. Predicting EoL impacts decades into the future requires making assumptions that are inherently subject to significant uncertainty[99].
Module D presents significant challenges when applied to reusable components. Its purpose is to credit the environmental benefits of reusing materials, typically by accounting for avoided raw material extraction and production impacts. However, the module is fraught with complexities and potential misuse, particularly when used in single-lifecycle analyses.
One key limitation is the difficulty in comparing present products with their future alternatives. Improvements in recycling efficiencies, increased use of recycled materials, and more climate-efficient production processes are likely to reduce the carbon footprint of new building products in the future. As a result, the potential substitution effect of reusing components in the future may be diminished compared to the components they replace[100]. This uncertainty casts doubt on the environmental savings attributed to reuse today, as avoided impacts in the future may prove less significant than current production impacts. Addressing this requires assessment methods to account for so-called «technology factors,» which are designed to produce more realistic results[101]. Conversely, resource scarcity and the depletion of finite raw materials could increase future environmental and economic costs of extraction. Mining operations may require greater energy and resources to access diminishing ore deposits or to source raw materials from more distant or ecologically sensitive locations. In such scenarios, the benefits of reusing existing components could become significantly more pronounced

95   Michaël Ghoyot, Lionel Devlieger, Lionel Billiet, and André Warnier, *Déconstruction et Réemploi: Comment Faire Circuler les Éléments de Construction* (Lausanne: Presses polytechniques et universitaires romandes, 2018), 193-194.
96   Giovanni Brambilla et al., «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings,» *Resources, Conservation & Recycling* 141 (2019), 138–139.
97   Catherine De Wolf, Endrit Hoxha, and Corentin Fivet, «Comparison of Environmental Assessment Methods When Reusing Building Components: A Case Study,» *Sustainable Cities and Society* 61 (2020) 8.

98   David Cheshire, *Building Revolutions: Applying the Circular Economy to the Built Environment* (RIBA Publishing, 2016), 33.
99   Carine Lausselet et al., «Methods to Account for Design for Disassembly: Status of the Building Sector,» *Buildings* 13, no. 1012 (2023), 8.
100   Ibid.
101   Carine Lausselet et al., «Methods to Account for Design for Disassembly: Status of the Building Sector,» *Buildings* 13, no. 1012 (2023), 8.

by reducing future reliance on virgin resource extraction and mitigating associated environmental degradation.

Another major issue with Module D is the risk of double-counting benefits across lifecycles. If Module D credits the avoided emissions of virgin material production in the first lifecycle, these benefits should not also be claimed in subsequent lifecycles. When a single lifecycle is assessed independently from future lifecycles, it becomes likely that the same reuse benefits will be credited multiple times. Furthermore, these benefits are often subtracted from the initial lifecycle of the reusable product without confirming whether they will actually materialize.

In practice, these principles are frequently disregarded. For instance, in a study comparing reusable and non-reusable slabs, Module D was applied unrealistically to emphasize the superiority of reusable products.

5.4 Module D: a case study

An illustrative example of the limitations of Module D considerations can be found in the case of reusable concrete slabs discussed in *Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings*. The objective of this study is to compare the environmental impacts of a demountable steel-concrete composite floor system with three conventional floor system solutions.

The demountable steel-concrete composite floor system is composed of precast concrete slabs connected to steel beams via High-Strength Friction-Grip Bolts. The study evaluates three conventional floor systems: a composite slab, a precast hollow core slab, and a precast solid slab[102]. The slabs are assumed to be used in two sequential buildings with identical geometry but different locations[103].

Recycling was applied to all conventional slab options, while reuse was exclusively applied to the reusable slab[104].

The authors concluded that the total combined impact across both lifecycles showed that the reusable slab had lower environmental impacts than its non-reusable counterparts[105]. However, this conclusion heavily relies on the assumption that the reuse potential of the slab will materialize. The reusable slab exhibited greater initial production impacts, which could only be justified if reuse occurred as anticipated[106]. If the reuse scenario fails to materialize, the slab's environmental performance would be worse than its alternatives. This introduces a significant risk in relying solely on future reuse benefits without considering realistic probabilities and current production impacts.

If the study values were reconsidered under a scenario where none of the slabs were reused at the end of their lifecycle, the conclusions would differ significantly. To demonstrate this, let us focus solely on the A1–A5 modules, which represent production, transport to the construction site, and construction of the slabs. The modules from C1 onward can be excluded under the assumption that none of the slabs are reused in the second building.

Fig.26

102   Giovanni Brambilla et al., «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings,» Resources, Conservation & Recycling 141 (2019), 134.
103   Ibid., 135.
104   Ibid., 135.
105   Ibid., 141.
106   Ibid., 139.
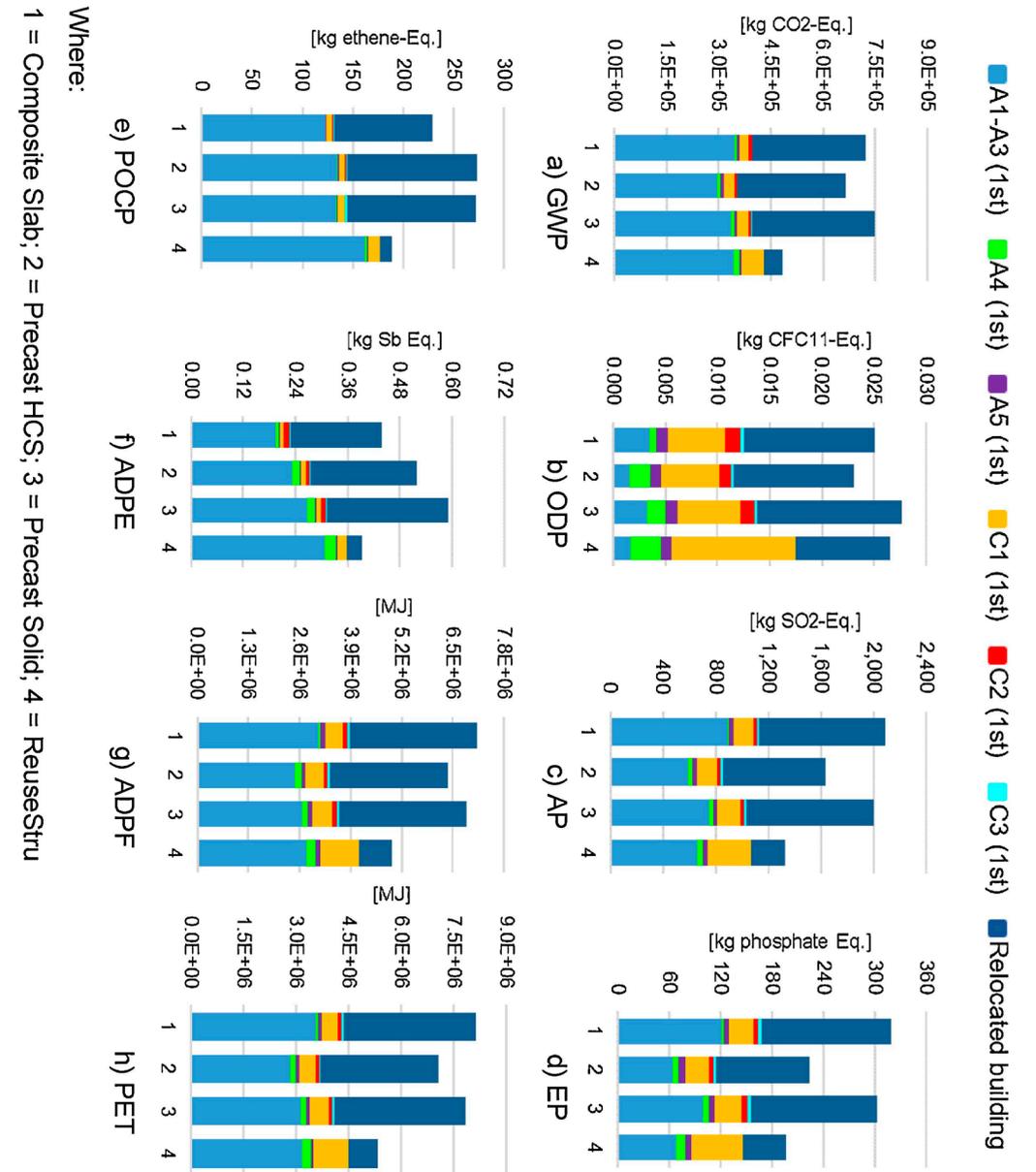
- C1 Module: This module is excluded because it accounts for demolition in conventional slabs, whereas disassembly is considered for the reusable slab[107].

- C2 Module: This module is excluded because it involves transport from the site to a sorting plant or landfill for conventional slabs, while no impact is considered for the reusable slab[108].

- C3 Module: This module is excluded because it considers waste management for conventional slabs, whereas no waste management impact is reported for the reusable slab.

To compare the relative impacts of the slabs in a scenario where no reuse occurs, only the light blue, green, and purple segments are considered in the bar graph. It quickly becomes apparent that the reusable slab, referred to as No. 4 in the graph, has the lowest impacts in none of the considered categories. Instead, the precast hollow core slab, referred to as No. 2, appears to have the lowest overall impact (Fig.26).
This suggests that a potentially better approach would be to modify existing precast hollow-core concrete slabs to increase their reversibility and enable future reuse. By adjusting the slab's connections, the initial production impacts could remain minimal while still facilitating reuse in subsequent lifecycles. This would create a balance between immediate environmental performance and long-term sustainability, reducing reliance on speculative benefits tied to Module D.
This example highlights a critical flaw in the methodology: categorizing existing technologies as non-reusable without exploring feasible modifications and preemptively allocating benefits to reuse scenarios that may never materialize risks presenting a skewed view of environmental performance. A more balanced approach would involve acknowledging incremental improvements to existing technologies while carefully assessing the likelihood and feasibility of reuse. This dynamic is considered in *D13 Prototyping + Feedback Report*, Testing BAMB results through prototyping and Pilot Projects when comparing developmental strategies for creating different types of prototypical pilot products[109].

5.5 Allocation methods

We now shift focus to the tools designed to address the ambiguities of reuse in LCAs, providing structured approaches to distribute environmental impacts across lifecycles. Allocation methods are critical for resolving the question of who benefits from reuse: the party reusing an existing element today or the party facilitating its future reuse. By examining these methods, we aim to better understand how to integrate reuse into lifecycle assessments and promote sustainable construction practices. This chapter will explore the allocation methods used to distribute environmental impacts across multiple lifecycles. By analyzing these methods, we aim to understand how their methodologies can incentivize different behaviors. First, we will describe the various methods and their implications.

The «100:0 allocation method»

The first method is known as the «100:0 allocation method.» It accounts for each impact at the moment it occurs. This means that the production of an element intended for reuse is fully accounted for in the initial lifecycle, while end-of-life impacts are considered and allocated only in the final lifecycle. Because the entire production impact is allocated to the first lifecycle, this method encourages the use of reused elements, as their production impacts can be disregarded in subsequent lifecycles. However, this method provides no incentive for designers to enable future reuse, as the benefits stemming from Module D are credited only to the lifecycle where reuse occurs. Consequently, the first lifecycle does not benefit from downstream reusability. This issue is further exacerbated by the fact that the entire production impact of the component must be fully accounted for in the initial cycle, creating a disincentive to design reusable components in the first place[110].

The «0:100 allocation method»

The opposite of the «100:0 method» is the «0:100 method.» In this approach, the production impacts of a component are accounted for only in its final lifecycle. This method incentivizes designers to prioritize future reuse, as production and end-of-life impacts are excluded from the initial lifecycle and instead allocated to the last lifecycle. Additionally, Module D benefits can be credited to the initial lifecycle, making the first lifecycle particularly advantageous[111].

The «Distributed allocation method»

To find common ground between these two extremes, the «distributed allocation method» divides the impacts of production and end-of-life across all lifecycles of the product. Module D benefits are assigned to the lifecycle in which they occur. This approach incentivizes both upstream reuse and downstream reuse equally.
The underlying principle of this method is that the impact of a product should be proportional to its service life. However, due to the inverse nature of the allocation equation, increasing the number of considered lifecycles reduces the distributed impact for each lifecycle. This characteristic makes the method vulnerable to misuse[112].

The «European Commission Environmental Footprint allocation method»

A slight variation of the distributed allocation method is the «European Commission Environmental Footprint» allocation method. This approach addresses the issue of uncertainty regarding the number of lifecycles considered. It distributes production and end-of-life impacts equally, but only between the initial and final lifecycles. No impacts are allocated to intermediate lifecycles, thereby encouraging the reuse of components between cycles. Module D benefits are equally divided between adjacent lifecycles, allowing all lifecycles to benefit from both downstream and upstream reuse[113].

107   Giovanni Brambilla et al., «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings,» Resources, Conservation & Recycling 141 (2019), 135.
108   Ibid., 137.
109   European Commission, D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects, Horizon 2020 research and innovation programme, 58-59.

110   Catherine De Wolf, Endrit Hoxha, and Corentin Fivet, «Comparison of Environmental Assessment Methods When Reusing Building Components: A Case Study,» *Sustainable Cities and Society* 61 (2020), 3.
111   Ibid., 4.
112   Ibid., 4.
113   Ibid., 4.

The «Degressive allocation method»

The «Degressive Allocation Method» combines the production and end-of-life impact allocation strategy of the distributed allocation method with the Module D allocation strategy of the European Commission Environmental Footprint method. Similar to other methods, this approach depends on the number of lifecycles considered, which can dilute the impact of a particular lifecycle by distributing it across multiple lifecycles[114].

The «SIA 2032 allocation method»

The «SIA 2032» allocation method allows for the distribution of impacts to be made relative to the product's total or expected service life. Impacts are divided based on the duration of the product's use in a given building lifecycle. This method assumes that products may be used longer than their initially expected lifespan. In such cases, the impacts of the construction and use phases are not considered if the product is reused beyond its expected service life. This method supports both designing with reused products and enabling future reuse but does not account for any Module D benefits[115].

Allocation methods for quantifying impacts across lifecycles offer a promising approach to addressing some of the limitations inherent in single-lifecycle assessments, particularly in the context of reusable components. As demonstrated in the «Results» section of the paper, the findings indicate that the methods yield varying outcomes for different lifecycles. This suggests that the final results depend on the chosen allocation method and the assumptions made regarding the number of lifecycles[116].

Certain methods produce more favorable results when applied to specific allocation strategies in particular lifecycles. Considering that reusable products in a circular economy are likely to flow between different owners across sequential lifecycles, these studies could potentially be tailored to benefit a specific owner during a particular lifecycle[117].

This study does not account for material quality losses, and the shortcomings of neglecting material degradation have already been discussed. To further illustrate how allocation methods might produce differing results in certain scenarios, we will briefly consider two components with different service lives to highlight the impacts these differences can have across allocation methods. For a short-lived component, its Module D benefits will likely occur sooner, reducing uncertainty compared to a longer-lived component. Given the short global warming horizons typically considered, a short-lived component will replace new components more quickly when reused, leading to avoided emissions sooner than a longer-lived component. Similarly, if a technological factor is applied in a way that predicts lower environmental impacts for future production, a short-lived component would benefit because its reuse occurs sooner, amplifying avoided emissions. Conversely, allocation methods such as «distributed,» «degressive,» and «SIA 2032,» which consider either the number of lifecycles or the general service life of a component, might favor longer service life components. This could imply that over-dimensioning components might be advantageous in these allocation methods. However, as previously discussed, this may not align with reality, as over-dimensioning increases the risk of a product's environmental impact being underutilized due to premature obsolescence. For allocation methods that explicitly account for material

degradation, it is reasonable to assume that the initial lifecycles will bear the greatest share of a short-lived component's impacts[118].

Ultimately, these challenges raise fundamental questions about the purpose of LCAs and the stakeholders they are designed to serve. Rather than serving as precise tools for measuring actual environmental impacts, LCAs often function as regulatory mechanisms intended to guide developers and industry stakeholders toward predefined sustainability goals. While this may align with government objectives, it risks oversimplifying complex environmental considerations and limiting the practical utility of LCAs for design optimization or informed decision-making. Addressing these challenges requires refining LCA frameworks to better accommodate uncertainties, integrate historical data, and support more nuanced comparisons between products based on real-world scenarios and performance.

114   Ibid., 4-5.
115   Ibid., 5.
116   Ibid., 7.
117   Ibid., 2.

118   Carine Lausselet et al., «Methods to Account for Design for Disassembly: Status of the Building Sector,» *Buildings* 13, no. 1012 (2023), 7.

5.6 Beyond environmental impacts

Having discussed the limitations and allocation methods used to distribute the benefits and burdens of a product across its lifecycles, it is crucial to introduce an additional layer of complexity in quantifying a construction product's benefits. While environmental impact assessments provide valuable insights and contribute to advancing a more sustainable construction sector, they are rarely sufficient on their own to guide comprehensive decision-making processes. Other key factors, such as the functional equivalence of the product with conventional alternatives and their financial implications, play a significant role in determining the viability and adoption of more sustainable options.

In the following section, a case study will be presented to highlight the challenges and limitations inherent in multi-criteria comparisons of construction products. While this approach emphasizes the importance of integrating environmental, functional, and economic considerations into decision-making frameworks, the case study reveals significant issues with the selection of functional indicators and the weighting methods applied. By examining these limitations, the study underscores the need for more robust and transparent methodologies in multi-criteria decision-making processes.

The paper considered for this case study is entitled *Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies.*

5.6.1 Methodology description

In this study, the authors compare the qualities of different lightweight sandwich membrane partition wall compositions (LSM) with a heavyweight conventional masonry partition wall (HCM) and a reference lightweight plasterboard partition wall (LRP). The reference partitions are detailed in Section 2.1. Three indicators are considered: environmental, functional, and economic. Functionality is assessed based on three requirements: airborne sound insulation, thermal insulation, and «flexibility in use»[119]. However, the way the flexibility parameter is defined appears questionable: «Flexibility (F) is a qualitative parameter that characterizes the capacity of moving the wall within the indoor space. At this level, it was decided to classify the three different building technologies on a scale bounded between 0 (conventional practice) and 1 (best practice). Therefore, the best score (F = 1) was given to the LSM technology, while the HCM received a score of 0. The LRP was assigned an intermediate qualitative level of 0.5.»[120]

The values are then normalized to avoid biases caused by differences in scale or units and to account for their differing natures[121]. The normalization method is further described in Section 3.6. The normalized values are subsequently weighted and aggregated[122].

The weighting method assigns:
- 12% to airborne acoustic insulation,
- 38% to thermal insulation, and
- 50% to flexibility in use.

This approach results in the «less well-defined» indicator (flexibility in use) being weighted more heavily than the other two scientifically defined indicators. The global assessment of each partition considers three parameters: environmental impact, functional performance, and economic performance. These are weighted and combined to produce the global assessment values. Environmental performance represents 40% of the global assessment value, while functional and economic performance each contribute 30%[123].

5.6.2 Variation in flexibility and weighting values for LSM partitions

The sensitivity analysis proposed in the paper focuses solely on the global assessment weighting method[124]. To expand on this, I analyzed the variation in final results for less drastic flexibility values and more equally distributed weighting of the functional indicators.

- Fig. 27 presents the final results calculated in the original study.

- Fig. 28 shows the variation in final results when altering the weighting of the functional indicators by assigning equal distribution among acoustic insulation, flexibility, and thermal insulation.

- Fig. 29 explores the impact of altering the flexibility (F) value for the lightweight sandwich partitions (LSM), with F = 0.75 instead of F = 1.

- Fig. 30 combines both variations, setting the flexibility (F) value of LSM partitions to 0.75 while applying equally weighted functional parameters.

The analysis particularly examines the variation in values for LSM9 and LRP, as these partitions are identified as having the best global assessment values. The global results indicate that LSM9 performs better overall than LRP (LSM9: 0.84, LRP: 0.74). LSM9 outperforms LRP in environmental and functional categories but is more expensive, costing approximately 10 Euro/m² more than the LRP partition.

In the adjusted configurations (Fig. 28, Fig. 29, and Fig. 30), the gap between LSM9 and

119   Ricardo Mateus et al., «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies,» Building and Environment 67 (2013), 152.
120   Ricardo Mateus et al., «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies,» Building and Environment 67 (2013), 153.

121   Ricardo Mateus et al., «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies,» *Building and Environment* 67 (2013), 153.
122   Ibid., 154.
123   Ibid., 154.
124   Ibid., 158.

Fig.27

0		Nda	Ndf	Nde		Global original
F(12/50/38%)	(x100)	0.40%	0.30%	0.30%		
0.5	LSM1	0.5196	0.5798	0.39		0.49878
0.5	LSM2	0.6874	0.53	0.43		0.56296
0.5	LSM3	0.6	0.6068	0.4		0.54204
0.5	LSM4	0.4194	0.546	0.38		0.44556
0.5	LSM5	0.238	0.5992	0		0.27496
0.5	LSM6	0.1076	0.5756	0.34		0.31772
0.5	LSM7	0.2946	0.88	0.38		0.49584
0.5	LSM8	0.6854	0.5916	0.69		0.65864
0.5	LSM9	0.994	0.595	0.86		0.8341
0.5	LSM10	0.7868	0.5376	0.73		0.695
0	HCM	0.521	0.337	1		0.6095
0.25	LRP	0.8148	0.4194	0.96		0.73974

Fig.28

1		Nda	Ndf	Nde		Global
F(33/33/33%)	(x100)	0.40%	0.30%	0.30%		
1	LSM1	0.5196	0.4033293	0.39		0.44583879
1	LSM2	0.6874	0.4166625	0.43		0.52895875
1	LSM3	0.6	0.4566621	0.4		0.49699863
1	LSM4	0.4194	0.4033293	0.38		0.40275879
1	LSM5	0.238	0.4499955	0		0.23019865
1	LSM6	0.1076	0.4566621	0.34		0.28203863
1	LSM7	0.2946	0.66666	0.38		0.431838
1	LSM8	0.6854	0.4433289	0.69		0.61415867
1	LSM9	0.994	0.5033283	0.86		0.80659849
1	LSM10	0.7868	0.4233291	0.73		0.66071873
0	HCM	0.521	0.466662	1		0.6483986
0.5	LRP	0.8148	0.5433279	0.96		0.77691837

Fig.29

2		Nda	Ndf	Nde		Global
F(12/50/38%)	(x100)	0.40%	0.30%	0.30%		
0.75	LSM1	0.5196	0.4548	0.39		0.46128
0.75	LSM2	0.6874	0.405	0.43		0.52546
0.75	LSM3	0.6	0.4818	0.4		0.50454
0.75	LSM4	0.4194	0.421	0.38		0.40806
0.75	LSM5	0.238	0.4742	0		0.23746
0.75	LSM6	0.1076	0.4506	0.34		0.28022
0.75	LSM7	0.2946	0.755	0.38		0.45834
0.75	LSM8	0.6854	0.4666	0.69		0.62114
0.75	LSM9	0.994	0.47	0.86		0.7966
0.75	LSM10	0.7868	0.4126	0.73		0.6575
0	HCM	0.521	0.337	1		0.6095
0.5	LRP	0.8148	0.4194	0.96		0.73974

Fig.30

3		Nda	Ndf	Nde		Global
F(33/33/33%)	(x100)	0.40%	0.30%	0.30%		
0.75	LSM1	0.5196	0.3199968	0.39		0.42083904
0.75	LSM2	0.6874	0.33333	0.43		0.503959
0.75	LSM3	0.6	0.3733296	0.4		0.47199888
0.75	LSM4	0.4194	0.3199968	0.38		0.37775904
0.75	LSM5	0.238	0.366663	0		0.2051989
0.75	LSM6	0.1076	0.3733296	0.34		0.25703888
0.75	LSM7	0.2946	0.5833275	0.38		0.40683825
0.75	LSM8	0.6854	0.3599964	0.69		0.58915892
0.75	LSM9	0.994	0.4199958	0.86		0.78159874
0.75	LSM10	0.7868	0.3399966	0.73		0.63571898
0	HCM	0.521	0.466662	1		0.6483986
0.5	LRP	0.8148	0.5433279	0.96		0.77691837

Fig.31

4		Nda	Ndf	Nde		Global
F(12/50/38%)	(x100)	0.40%	0.30%	0.30%		
1	LSM1	0.5196	0.5798	0.39		0.49878
1	LSM2	0.6874	0.53	0.43		0.56296
1	LSM3	0.6	0.6068	0.4		0.54204
1	LSM4	0.4194	0.546	0.38		0.44556
1	LSM5	0.238	0.5992	0		0.27496
1	LSM6	0.1076	0.5756	0.34		0.31772
1	LSM7	0.2946	0.88	0.38		0.49584
1	LSM8	0.6854	0.5916	0.69		0.65864
1	LSM9	0.994	0.595	0.86		0.8341
1	LSM10	0.7868	0.5376	0.73		0.695
1	HCM	0.521	0.837	1		0.7595
1	LRP	0.8148	0.6694	0.96		0.81474

Fig.32

5		Nda	Ndf	Nde		Global
F(33/33/33%)	(x100)	0.40%	0.30%	0.30%		
1	LSM1	0.5196	0.4033293	0.39		0.44583879
1	LSM2	0.6874	0.4166625	0.43		0.52895875
1	LSM3	0.6	0.4566621	0.4		0.49699863
1	LSM4	0.4194	0.4033293	0.38		0.40275879
1	LSM5	0.238	0.4499955	0		0.23019865
1	LSM6	0.1076	0.4566621	0.34		0.28203863
1	LSM7	0.2946	0.66666	0.38		0.431838
1	LSM8	0.6854	0.4433289	0.69		0.61415867
1	LSM9	0.994	0.5033283	0.86		0.80659849
1	LSM10	0.7868	0.4233291	0.73		0.66071873
1	HCM	0.521	0.799992	1		0.7483976
1	LRP	0.8148	0.7099929	0.96		0.82691787

Fig.33

6		Nda	Ndf	Nde		Global
F(12/50/38%)	(x100)	0.40%	0.30%	0.30%		
1	LSM1	0.5196	0.5798	0.39		0.49878
1	LSM2	0.6874	0.53	0.43		0.56296
1	LSM3	0.6	0.6068	0.4		0.54204
1	LSM4	0.4194	0.546	0.38		0.44556
1	LSM5	0.238	0.5992	0		0.27496
1	LSM6	0.1076	0.5756	0.34		0.31772
1	LSM7	0.2946	0.88	0.38		0.49584
1	LSM8	0.6854	0.5916	0.69		0.65864
1	LSM9	0.994	0.595	0.86		0.8341
1	LSM10	0.7868	0.5376	0.73		0.695
0.5	HCM	0.521	0.587	1		0.6845
0.75	LRP	0.8148	0.5444	0.96		0.77724

Fig.34

7		Nda	Ndf	Nde		Global
F(33/33/33%)	(x100)	0.40%	0.30%	0.30%		
1	LSM1	0.5196	0.4033293	0.39		0.44583879
1	LSM2	0.6874	0.4166625	0.43		0.52895875
1	LSM3	0.6	0.4566621	0.4		0.49699863
1	LSM4	0.4194	0.4033293	0.38		0.40275879
1	LSM5	0.238	0.4499955	0		0.23019865
1	LSM6	0.1076	0.4566621	0.34		0.28203863
1	LSM7	0.2946	0.66666	0.38		0.431838
1	LSM8	0.6854	0.4433289	0.69		0.61415867
1	LSM9	0.994	0.5033283	0.86		0.80659849
1	LSM10	0.7868	0.4233291	0.73		0.66071873
0.5	HCM	0.521	0.633327	1		0.6983981
0.75	LRP	0.8148	0.6266604	0.96		0.80191812

LRP diminishes progressively. Notably, the variation in weighting values appears to have a greater impact on the results than the changes in flexibility values, as evidenced by the comparisons between Fig. 28 and Fig. 29 with Fig. 27.

5.6.3 Variation in flexibility and weighting values for conventional partitions

Building on the conclusions of the «Module D Case Study,» slight modifications to the conventional HCM and LRP partitions can be considered to increase their flexibility. These partitions are typically regarded as having reduced flexibility due to their irreversible nature. However, as previously explored, strategies to enhance the reversibility of conventional partitions offer opportunities to improve their performance. For instance, the HCM partition could be constructed using lime-based mortar instead of cement-based mortar, which would enhance its flexibility. The LRP partition could increase its flexibility by incorporating reversible connections for the plasterboard panels, such as the Velcro tape used in the Juunoo partition. By implementing these changes, the variation in final results for altered flexibility (F) values can be assessed for both the HCM and LRP partitions.

- In (Fig. 31), the flexibility values are taken to be 1 for both LSM partitions as well as the conventional partitions. The weighting values for functionality are considered to be the same as in the initial study (12%/50%/38%).

- In (Fig. 32), the flexibility value is identical to (Fig. 4), but the weighting values are equally distributed for all functional indicators.

However, this might not be entirely realistic, given that the flexibility might not be equal for all partitions. The final figures, (Fig. 33) and (Fig. 34), consider the same functional indicator weights as (Fig. 31) and (Fig. 32), respectively. However, their flexibility values are corrected and considered to be equal to 1 for LSM partitions, 0.5 for the HCM partition, and 0.75 for the LRP partition.

- In (Fig. 31), the LRP global assessment value jumps from 0.739 in the study initially to 0.814 when it is considered fully reversible, but this is still not enough to surpass LSM9.

- (Fig. 32) is the only configuration in which the LRP partition surpasses the global assessment values of the LSM9 partition.

- (Fig. 33) and (Fig. 34) are meant to represent a more realistic approach, and we can see that the difference between the initial global assessment values of 0.84 for LSM9 and 0.74 for LRP is considerably diminished in (Fig. 33) and negligible in (Fig. 34).

The exploration of improvements to conventional partitions, such as increasing their flexibility through design modifications, illustrates the potential for traditional technologies to close the performance gap with innovative alternatives. This suggests that sustainability in construction should not only focus on the adoption of novel technologies but also on the optimization of existing ones.

5.6.4 Financial considerations for the Juunoo system

To estimate the cost differences between the Juunoo system and a conventional partition, we will consider the creation of a 10 lm, 3 m high partition. The Swiss prices for all components of the Juunoo system were not available; only the structure's price could be found. Therefore, we will compare the cost difference exclusively between the structural elements of the two partitions, as replacing even just the structure will enhance the overall reversibility. (All prices are sourced from: https://www.rigips.ch/fr/produits/liste-de-prix, consulted on 11.01.2025).

Classical profiles

The classical partition will require 20 lm of UW75 profiles for the floor and ceiling, as well as 54 ml of CW75 profiles for the vertical studs (disposed every 60 cm along the 10 m span of the partition, 18 pcs of 3m height).
The prices of the classical profiles are 7.60.-/lm for the UW75 profiles and 8.60.-/lm for the CW75 profiles.
The classical partition structure comes out to: ((7.60.- * 20lm)+(8.60.- * 54lm)) = (152.- + 464.40.- = 616.40.- for the 30 m2 partition)

Juunoo profiles

The Juunoo partition would require 2 «C75L» profiles (one at both ends), as well as 16 «I75L»profiles.
The prices of the Juunoo profiles are 54.-/pcs for the C75L profiles and 56.-/pcs for the I75L profiles.
The Juunoo partition structure comes out to: ((54.- * 2pcs)+(56.- * 16pcs)) = (108.- + 896.- = 1004.- for the 30 m2 partition).

It is clear that the Juunoo system's structure is significantly more expensive than the classical partition structure. However, due to the reduced labor time required for installing the Juunoo system, these additional initial costs may be partially offset.
Additionally, the residual value of the profiles could influence the final lifecycle costs.
The Juunoo system's buy-back program guarantees up to 30% of the initial price for the profiles at the end of their lifecycle[125]. This means that at the end of its lifecycle, the Juunoo structure could amount to 702.80.-, excluding shipping and dismantling costs[126]

125   JUUNOO, JUUNOO Buyback Guarantee, 5. https://juunoo.com/wp-content/uploads/2024/10/2024-08-30-BuyBack-Policy-ENG.pdf
126   JUUNOO, JUUNOO Buyback Guarantee, 2. https://juunoo.com/wp-content/uploads/2024/10/2024-08-30-BuyBack-Policy-ENG.pdf

6. Conclusion

Addressing the question of sustainability within the construction industry is an intricate and multifaceted endeavor. In 1987, the United Nations' Brundtland Commission defined sustainability as «meeting the needs of the present without compromising the ability of future generations to meet their own needs». By this definition, the most sustainable approach would arguably be to stop building altogether, instead focusing on repairing, reusing, and maintaining what already exists. Yet, as one looks across cities like Lausanne, the skyline is dotted with cranes, a constant reminder that we are still building. This raises a critical question: if halting construction entirely is not a feasible option, how can reversibility serve as a tool to reduce the carbon footprint of buildings and limit the compromise to future generations' ability to meet their needs? This endeavor is rifed with complexities. As explored in this text, the unquantifiable nature of reversibility is a significant barrier to its broader adoption. Its benefits can only be fully understood once implemented, which inherently involves a leap of faith. It is an endeavor whose benefits may not manifest during the lifetime of those initiating the project. This reality raises a pivotal question for investors or anyone planning to construct a building: Why should they commit to such an approach?

In Switzerland, low housing vacancy rates and high demand for accommodations undermine the financial rationale for reversible construction. Developers see little incentive to prioritize adaptability when current market dynamics ensure that buildings, even those with mismatched functionality, will still find occupants. This leads to a fundamental industry mindset: Why question a system that appears to be working? Who within the building sector would challenge a market that remains profitable? Apartments or offices are being rented, and vacancy rates continue to decline[127]—why disrupt this status quo ?

During my exploration, my intention was to provide tangible, scientific, and economic reasons to prioritize designs rooted in reuse and adaptability. This, I believed, would allow us to advocate for a transformative vision of what buildings could achieve in their lifecycle.

As I navigated this topic, I reflected on how to turn sustainability into a practical and scalable reality within the construction sector. One avenue was imagining government-supported initiatives that leverage legislative and policy tools to incentivize circular practices and promote reversibility in design. Projects that align with circular economy principles—such as reusing materials or designing for disassembly—could receive direct subsidies to offset the initial costs. Grants could be allocated to support research and development in innovative construction methods, encouraging breakthroughs in sustainable design. Carbon pricing on imported materials would internalize the environmental costs of their production and transportation, making less sustainable options less economically attractive. Similarly, imposing higher taxes on materials or practices that harm the environment could discourage their use, shifting the industry's focus toward more sustainable alternatives.

These tools, while practical, still felt insufficient. The rigid structures they often create tend to constrain creativity, bound architects to follow existing paradigms rather than explore new ones. They fail to ignite a broader cultural and emotional shift in how we view our built environment.

In all of this, where are we as architects? In our studies, sustainability is a ubiquitous topic, explored through a multitude of lenses, which is undoubtedly a positive development. It fosters an environment where practitioners are encouraged to reflect critically on contemporary challenges and to question the foundational principles of their craft. However, this academic focus on theory can sometimes come at the expense of technical expertise. This gap often leaves architects feeling less prepared to implement innovative solutions, particularly when collaborating with specialists. Without practical, real-world experience, architects may lack the confidence to advocate for or implement reversible principles effectively. Moreover, they may find themselves overshadowed by developers and contractors, whose priorities often emphasize cost reduction and immediate returns.

The pursuit of quantification in architecture often highlights the inherent difficulty of qualifying certain intangible aspects. This focus on measurable outcomes frequently comes at the expense of exploring qualitative dimensions that define the essence of architectural design. For instance, flexibility within design, particularly through concepts such as open building, could underscore the potential for user-centered approaches. By enabling individuals to customize interior spaces, architecture fosters a sense of ownership and agency, connecting users more deeply to the spaces they inhabit. Ultimately, the attempt to quantify architecture reveals its nature as an art form akin to music or visual arts—one that engages emotions and inspires desire. Architecture's power lies not in its ability to adhere strictly to regulatory frameworks but in its capacity to evoke wonder and foster connections. By shifting away from enforcement-based systems and toward designs that people instinctively yearn to experience, architects can catalyze profound cultural change. While facts and figures are essential for grounding decisions, they lack the ability to inspire on their own. Architecture must transcend these limitations, moving individuals through designs that harmonize emotional resonance with practical goals. Winning hearts will pave the way for overcoming technical hurdles.

Throughout this thesis, it has become evident that reversibility is a strategic tool requiring careful application in targeted situations. To fully grasp the stakes and understand where reversibility can have a positive impact, it demands the collaboration of individuals with diverse expertise. It necessitates not only the seamless transfer of knowledge but also open communication and a collective commitment to finding common ground among stakeholders. Within this intricate web of coordination, the architect's role becomes pivotal. This mediatory function is far from being merely logistical; it is profoundly strategic. The architect's ability to identify shared goals and craft solutions that harmonize practical constraints with aspirational objectives is crucial in weaving the threads of collaboration into meaningful progress.

This pivot demands liberation from rigid systems of control that stifle innovation. Architects must reclaim the freedom to experiment and lead with bold creativity, pushing the boundaries of possibility. Doing so requires rejecting the repetitive strategies of the past and envisioning a future where regulations evolve to support imaginative and sustainable paradigms. Through this position, architects have the opportunity to reclaim agency in the construction process and «champion» reversibility. By leveraging their unique perspective and skills, architects can become advocates for reversibility—not only as a design tool but as an essential strategy for addressing the environmental and societal challenges of the built environment.

127   RTS, «Pénurie de logements en Suisse romande: causes et conséquences expliquées,» *RTS Info*. https://www.rts.ch/info/economie/2025/article/penurie-de-logements-en-suisse-romande-causes-et-consequences-expliquees-28746814.html.

Bibliography

Architectures Anne Démians. «Black Swans - Strasbourg (2013–2019).» https://www.annedemians.com/projets/black-swans---strasbourg-2013-2019.

Arge, Kirsten. «Adaptable Office Buildings: theory and practice» in *Emerald* 23 (2005): 119-127.

Atienza, Emmanuel M., and Jason Maximino C. Ongpeng. «Environmental Impact and Cost Comparison of Different Partition Walls.» *Chemical Engineering Transactions* 94 (2022): 691-696. DOI:10.3303/CET2294115.

Bragança, Luís, Philip Griffiths, Rand Askar, Adriana Salles, Viorel Ungureanu, Katerina Tsikaloudaki, Diana Bajare, Gabriel Zsembinszki, and Meri Cvetkovska, eds. *Circular Economy Design and Management in the Built Environment: A Critical Review of the State of the Art*. Springer Tracts in Civil Engineering. Cham: Springer Nature, 2025. https://doi.org/10.1007/978-3-031-73490-8.

Brambilla, Giovanni, Monica Lavagna, George Vasdravellis, and Carlo Andrea Castiglioni. «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings.» *Resources, Conservation & Recycling* 141 (2019): 133-142. https://doi.org/10.1016/j.resconrec.2018.10.014.

Cheshire, David. *Building Revolutions: Applying the Circular Economy to the Built Environment*. RIBA Publishing, 2016.

De Wolf, Catherine, Endrit Hoxha, and Corentin Fivet. «Comparison of Environmental Assessment Methods When Reusing Building Components: A Case Study.» *Sustainable Cities and Society* 61 (2020): 1-11. https://doi.org/10.1016/j.scs.2020.102322.

European Commission. *D13 Prototyping + Feedback Report, Testing BAMB results through prototyping and Pilot Projects*. Horizon 2020 research and innovation programme. Brussels: European Commission, 2018.

EPD Hub. «Environmental product declaration in accordance with EN 15804+A2 & ISO 14025 / ISO 21930 Juunoo BaseClick.» https://26550443.fs1.hubspotusercontent-eu1.net/hubfs/26550443/Professionals%20Website/Testing%20and%20Certs/EPD_JUUNOO_BaseClick.pdf

Geldermans, Bob, Martin Tenpierik, and Peter Luscuere. «Circular and Flexible Infill Concepts: Integration of the Residential User Perspective.» *Sustainability* 11, no. 1 (2019). https://doi.org/10.3390/su11010261.

Ghoyot, Michaël, Lionel Devlieger, Lionel Billiet, and André Warnier. *Déconstruction et Réemploi: Comment Faire Circuler les Éléments de Construction*. Lausanne: Presses polytechniques et universitaires romandes, 2018.

Gontier, Pascal. *Home: Habitat Ouvert et sur Mesure. Transition Écologique*, directed by Dominique Gauzin-Müller. Museo Éditions, 2018.

Hossain, Md. Uzzal, Dongxing Xuan, S. Thomas Ng, and Ben Amor. «Designing Sustainable Partition Wall Blocks Using Secondary Materials: A Life Cycle Assessment Approach.» *Journal of Building Engineering* 43 (2021): 1-7. DOI:10.1016/j.jobe.2021.103035.

JUUNOO. *JUUNOO Buyback Guarantee*. https://juunoo.com/wp-content/uploads/2024/10/2024-08-30-BuyBack-Policy-ENG.pdf

JUUNOO. *JUUNOO Technical Documentation ENG Metric*. Version 2023-05-23.

JUUNOO. *JUUNOO The Wall That Pays Off. Brochure*_JUUNOO_2022-EN-online.pdf.

Küpfer, Célia, and Corentin Fivet. *Déconstruction Sélective: Construction Réversible: Recueil pour Diminuer les Déchets et Favoriser le Réemploi dans la Construction*. Structural Xploration Lab, EPFL, Lausanne/Fribourg: Smart Living Lab, 2021. DOI: 10.5281/zenodo.4314325.

Kumar, Dileep, Morshed Alam, Patrick X.W. Zou, Jay G. Sanjayan, and Rizwan Ahmed Memon. «Comparative Analysis of Building Insulation Material Properties and Performance.» *Renewable and Sustainable Energy Reviews* 131 (2020). https://doi.org/10.1016/j.rser.2020.110038.

Lausselet, Carine, Oddbjørn Andvik Dahlstrøm, Marit Thyholt, Aida Eghbali, and Patricia Schneider-Marin. «Methods to Account for Design for Disassembly: Status of the Building Sector.» *Buildings* 13, no. 1012 (2023). https://doi.org/10.3390/buildings13041012.

Manewa, Anupa, Christine Pasquire, Alistair Gibb, and Robert Schmidt III. *A Paradigm Shift Towards Whole Life Analysis in Adaptable Buildings*. Loughborough University, UK, 2009.

Mateus, Ricardo, Sara Neiva, Luís Bragança, Paulo Mendonça, and Mónica Macieira. «Sustainability Assessment of an Innovative Lightweight Building Technology for Partition Walls: Comparison with Conventional Technologies.» *Building and Environment* 67 (2013): 147–159. DOI:10.1016/j.buildenv.2013.05.012.

Minunno, Roberto, Timothy O'Grady, Gregory M. Morrison, and Richard L. Gruner. «Exploring Environmental Benefits of Reuse and Recycle Practices: A Circular Economy Case Study of a Modular Building.» *Resources, Conservation & Recycling* 160 (2020): 1-14. https://doi.org/10.1016/j.resconrec.2020.104855.

Quintana-Gallardo, Alberto, Jesús Alba, Romina del Rey, José E. Crespo-Amorós, and Ignacio Guillén-Guillamón. «Life-Cycle Assessment and Acoustic Simulation of Drywall Building Partitions with Bio-Based Materials.» *Polymers* 12, no. 9 (2020). https://doi.org/10.3390/polym12091965.

Rasmussen, F. N., M. Birkved, and H. Birgisdóttir. «Upcycling and Design for Disassembly – LCA of Buildings Employing Circular Design Strategies.» IOP Conference Series: Earth and Environmental Science 225 (2019): 1-8. https://doi.org/10.1088/1755-1315/225/1/012040.

Rigips. «Cloison Montants Simples ou Doubles.» https://www.rigips.ch/fr/Construction-a-sec-pour-bricoleurs/calculer-les-besoins-en-materiel/Cloison_montants_simples_ou_doubles.

Rigips SA. *Directives de mise en œuvre: Partie 2 - Sous-Constructions*. https://www.rigips.ch/fr/Mise-en-oeuvre/Directives-de-mise-en-oeuvre/Sous-constructions.

Rigips SA. *JUUNOO: Réutilisable, rapide et écologique*. Rigips SA, 2024. https://www.rigips.ch/domains/rigips_ch/appBuilder/file.cfc?method=get&lang=fr&id=33896.

Rossi, Barbara E. D., Anne-Françoise Marique, Mauritz Glaumann, and Sigrid Reiter. «Life-cycle Assessment of Residential Buildings in Three Different European Locations, Basic Tool.» *Building and Environment* 51 (2012): 395–401. https://doi.org/10.1016/j.buildenv.2011.11.017.

Rouvillois, Jonathan, eds. *La Réversibilité des Bâtiments pour une Ville Décarbonée*. Paris: Éditions du Moniteur, 2023.

RTS. «Pénurie de logements en Suisse romande: causes et conséquences expliquées.» RTS Info. https://www.rts.ch/info/economie/2025/article/penurie-de-logements-en-suisse-romande-causes-et-consequences-expliquees-28746814.html.

Sánchez, N., N. García, R. Irusta, and A. Moral. «Comparative LCA between Traditional and New Constructive Elements Used as Partition Walls.» Conference paper presented at CILCA-WALL, April 2009. https://www.researchgate.net/publication/266080181.

Taylor, W. B. «The Use of Life Cycle Costing in Acquiring Physical Assets.» *Long Range Planning* 14, no. 6 (1981): 32–43. https://doi.org/10.1016/0024-6301(81)90058-3.

The International EPD System. «Gyproc® Normal – Standard Plasterboard, System Registration number: S-P:00388.» Version 4, 2013. https://api.environdec.com/api/v1/EPDLibrary/Files/3cec4f68-263e-4b33-0365-08dc38ee8ac8/Data.

The International EPD System, «Gyproc Moisture Resistant 12.5 mm, System Registration Number: S-P-00507.» Version 3, 2013. https://api.environdec.com/api/v1/EPDLibrary/Files/4314032e-dc99-4f63-9363-08dc3c72202b/Data

The International EPD System, «Knauf LLC, Gyproc Moisture Resistant 12.5 mm, System Registration Number: S-P-00507.» 2024. https://api.environdec.com/api/v1/EPDLibrary/Files/5fc62cf7-7e33-4f0c-8f9b-08dcbb5f36b2/Data

The International EPD System, «Rigips Metal Profiles, System Registration Number: EPD-IES-0015700 .» Version 1, 2024. https://api.environdec.com/api/v1/EPDLibrary/Files/cb03ef40-225f-4620-b775-08dca749c5b7/Data

The International EPD System, «Rigips RB 12.5 mm - Standard Plasterboard, System Registration Number: S-P-00786.» Version 2, 2015. https://api.environdec.com/api/v1/EPDLibrary/Files/22410351-637b-4ff5-aa2c-c60c30183b61/Data

United Nations. «Sustainability.» United Nations Academic Impact. Accessed December 17, 2024. https://www.un.org/en/academic-impact/sustainability.

Valencia-Barba, Yovanna E., and José M. Gómez-Soberón. «LCA Analysis of Three Types of Interior Partition Walls Used in Buildings.» Proceedings 2, no. 1595 (2018): 1-7. Presented at *Economy, Sustainable Development, and Energy International Conference*, Edinburgh, UK, June 25–27, 2018. DOI:10.3390/proceedings2221595.

Valencia-Barba, Yovanna E., José M. Gómez-Soberón, María Consolación Gómez-Soberón, and María Neftalí Rojas-Valencia. «Life Cycle Assessment of Interior Partition Walls: Comparison between Functionality Requirements and Best Environmental Performance.» *Journal of Building Engineering* 44 (2021). DOI:10.1016/j.jobe.2021.102978.

Van Oorschot, Johannes A.W.H., Elma Durmisevic, and Johannes I.M. Halman. «Implementation of Innovation: The Inertia of Implementing the Open Building Concept in Practice.» In *Management and Innovation for a Sustainable Built Environment*. Twente University, Netherlands, 2011.

Wang, K., S. De Regel, W. Debacker, J. Michiels, and J. Vanderheyden. «Why Invest in a Reversible Building Design?» IOP Conference Series: Earth and Environmental Science 225 (2019): 1-8. https://doi.org/10.1088/1755-1315/225/1/012005.

Wang, K., S. Vanassche, A. Ribeiro, M. Peters, and J. Oseyran. «Business Models for Building Material Circularity: Learnings from Frontrunner Cases.» In Proceedings of the International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste, Delft University of Technology,

Images

Figure 1: Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 52.

Figure 2: Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 54.

Figure 3: Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 68.

Figure 4: Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 73.

Figure 5: Jonathan Rouvillois, eds., *La Réversibilité des Bâtiments pour une Ville Décarbonée* (Paris: Éditions du Moniteur, 2023), 56.

Figures 6-10: JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 14.

Figures 11-16: JUUNOO, *JUUNOO Technical Documentation ENG Metric*, Version 2023-05-23, 4.

Figure 26: Giovanni Brambilla et al., «Environmental Benefits Arising from Demountable Steel-Concrete Composite Floor Systems in Buildings,» Resources, Conservation & Recycling 141 (2019), 139.

Appendices

Plasterboard EPD

S-P-12093
Knauf. plasterboard 12.5mm/m2

ENVIRONMENTAL IMPACTS:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP GHG	[kg CO2 eq.]	2.27E+00	7.11E-02	3.64E-01	0	0	0	0	0	0	7.92E-03	6.07E-02	3.58E-01	-1.63E-02		3.12E+00
GWP FOSSIL	[kg CO2 eq.]	2.25E+00	7.02E-02	3.45E-01	0	0	0	0	0	0	7.91E-03	6.06E-02	1.14E-01	-1.63E-02		2.83E+00
GWP BIOGENIC	[kg CO2 eq.]	-2.65E-02	-1.02E-03	1.92E-02	0	0	0	0	0	0	1.21E-05	-8.88E-04	2.49E-05			2.61E-01
GWP LULUC	[kg CO2 eq.]	1.09E-02	6.38E-04	2.09E-04	0	0	0	0	0	0	2.61E-07	5.56E-04	2.41E-04	-6.78E-06		1.25E-02
GWP TOT	[kg CO2 eq.]	2.23E+00	6.99E-02	3.64E-01	0	0	0	0	0	0	7.92E-03	5.97E-02	3.83E-01	-1.63E-02		3.10E+00
ODP	[kg CFC-11]	6.76E-08	6.12E-15	8.15E-13	0	0	0	0	0	0	3.13E-16	5.25E-15	2.88E-13	-1.63E-02		6.76E-08
AP	[Mole of H+]	7.69E-03	1.20E-04	1.03E-03	0	0	0	0	0	0	4.73E-06	8.15E-05	8.73E-04	-3.71E-05		9.76E-03
EP freshwater	[kg P eq.]	1.98E-04	2.51E-07	6.39E-07	0	0	0	0	0	0	5.08E-10	2.16E-07	6.46E-07	-1.16E-09		2.00E-04
EP marine	[kg N eq.]	1.99E-03	4.47E-05	2.05E-04	0	0	0	0	0	0	2.05E-06	2.93E-05	2.47E-04	-8.90E-06		2.51E-03
EP terrestrial	[Mole of N]	2.06E-02	5.22E-04	2.23E-03	0	0	0	0	0	0	6.05E-06	3.50E-04	2.70E-03	-9.63E-05		2.63E-02
POCP	[kg NMVOC]	5.98E-03	1.12E-04	7.47E-04	0	0	0	0	0	0	8.42E-11	7.10E-05	8.08E-04	-2.97E-05		7.69E-03
ADP ele.	[kg Sb eq.]	1.13E-05	4.48E-09	4.13E-06	0	0	0	0	0	0	1.31E-01	3.90E-09	4.57E-09	-1.71E-10		1.54E-05
ADP foss.	[MJ]	3.84E+01	9.53E-01	4.97E-06	0	0	0	0	0	0	1.31E-01	8.16E-01	1.49E+00	-1.22E-01		4.66E+01
Water deprivation pot	[m³ world]	5.97E-01	7.96E-04	5.19E-02	0	0	0	0	0	0	4.13E-04	6.91E-04	1.20E-02	-2.32E-04		6.63E-01

RESSOURCE USE:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	2.66E+00	6.63E-02	1.08E+00	0	0	0	0	0	0	3.30E-04	5.77E-02	2.31E-01	2.04E-02		4.12E+00
NON RENEWABLE ENERGY TOT	[MJ]	3.84E+01	9.56E-01	4.98E+00	0	0	0	0	0	0	1.31E-01	8.18E-01	1.49E+00	-1.23E-01		4.67E+01
SECONDARY MAT.	[kg]	0	0	0	0	0	0	0	0	0	0	0	0	0		0.00E+00
RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0		0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0		0.00E+00
USE OF FRESH WATER	[m3]	1.45E-02	7.31E-05	2.03E-03	0	0	0	0	0	0	9.90E-06	6.38E-05	3.60E-04	-1.05E-05		1.70E-02

WASTE CATEGORIES:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	3.69E-09	3.52E-12	1.47E-08	0	0	0	0	0	0	2.32E-11	3.03E-12	3.74E-11	-3.04E-13		1.85E-08
NON HAZAR WAST	[kg]	1.14E-01	1.37E-04	5.83E-01	0	0	0	0	0	0	2.89E-05	1.18E-04	7.34E+00	1.76E-03		8.04E+00
RADIOACTIVE WASTE	[kg]	1.63E-04	1.23E-06	8.90E-05	0	0	0	0	0	0	4.27E-08	1.06E-06	1.73E-05	2.18E-06		2.74E-04

OUTPUT FLOWS:	unit	A1-3	A4	A5	B	C	D	A-D
COMPONENTS FOR REUSE	[kg]	0	0	0	0	0		0.00E+00
MATERIALS FOR RECY.	[kg]	1.56E-01	0	0	0	0		9.71E-01
MATERIALS FOR ENERGY RECO.	[kg]	0	0	0	0	0		0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0	4.00E-02	0	0	0		0.00E+00
EXPORTED ENERGY THERM	[MJ]	0	0	0	0	0		0.00E+00

Structure EPD

EPD-IES-001S700
Rigips: Metal profiles/ kg

ENVIRONMENTAL IMPACTS:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP GHG	[kg CO2 eq.]	3.26E+00	8.23E-03	2.17E-01	0	0	0	0	0	0	4.44E-03	2.42E-03	7.51E-04	-1.33E+00		2.17E+00
GWP FOSSIL	[kg CO2 eq.]	3.25E+00	8.13E-03	2.16E-01	0	0	0	0	0	0	4.43E-03	2.39E-03	7.47E-04	-1.33E+00		2.15E+00
GWP BIOGENIC	[kg CO2 eq.]	2.18E-02	1.99E-05	2.62E-02	0	0	0	0	0	0	4.53E-06	7.65E-07	-4.60E-08	2.11E-03		5.01E-02
GWP LULUC	[kg CO2 eq.]	3.21E-03	5.79E-05	1.80E-04	0	0	0	0	0	0	8.45E-08	1.83E-05	2.18E-06	-5.95E-04		3.42E-03
GWP TOT	[kg CO2 eq.]	3.29E+00	8.23E-03	2.43E-01	0	0	0	0	0	0	4.44E-03	2.41E-03	7.49E-04	-1.33E+00		2.22E+00
ODP	[kg CFC-11]	8.43E-08	7.23E-16	4.17E-09	0	0	0	0	0	0	3.41E-16	4.07E-15	2.81E-18	-3.95E-12		8.85E-08
AP	[Mole of H+]	7.53E-02	9.51E-05	3.86E-03	0	0	0	0	0	0	6.99E-06	1.27E-05	5.44E-06	-3.03E-03		7.62E-02
EP freshwater	[kg P eq.]	1.71E-03	3.01E-08	8.48E-05	0	0	0	0	0	0	8.58E-10	1.10E-08	6.27E-09	-9.97E-08		1.79E-03
EP marine	[kg N eq.]	5.27E-03	3.28E-06	2.94E-04	0	0	0	0	0	0	2.42E-06	8.71E-06	1.40E-06	-7.28E-04		4.86E-03
EP terrestrial	[Mole of N]	3.04E-01	3.86E-05	1.54E-02	0	0	0	0	0	0	2.67E-05	9.66E-05	1.54E-05	-7.88E-03		3.12E-01
POCP	[kg NMVOC]	1.57E-02	8.27E-06	8.82E-04	0	0	0	0	0	0	7.31E-06	1.64E-05	4.24E-06	-2.43E-03		1.42E-02
ADP ele.	[kg Sb eq.]	2.08E-04	8.27E-09	1.14E-05	0	0	0	0	0	0	4.49E-11	1.58E-05	6.83E-11	-1.40E-08		2.19E-04
ADP foss.	[MJ]	5.42E+01	1.12E-01	3.23E+00	0	0	0	0	0	0	5.91E-02	1.16E-02	9.95E-06	-9.96E+00		4.77E+01
Water deprivation pot	[m³ world]	1.78E+00	9.52E-05	9.16E-02	0	0	0	0	0	0	1.14E-05	4.73E-04	7.95E-05	-1.92E-02		1.85E+00

RESSOURCE USE:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	4.12E+00	7.95E-03	2.05E-01	0	0	0	0	0	0	2.61E-04	2.90E-03	1.30E-03	1.66E+00		6.00E+00
NON RENEWABLE ENERGY TOT	[MJ]	5.42E+01	1.13E-01	3.23E+00	0	0	0	0	0	0	5.92E-02	4.11E-02	4.80E-02	-1.01E+01		4.76E+01
SECONDARY MAT.	[kg]	1.32E-01	0	6.54E-03	0	0	0	0	0	0	1.21E-05	9.66E-05	9.96E-03			1.39E-01
RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0		0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0		0.00E+00
USE OF FRESH WATER	[m3]	4.15E-02	0	2.21E-03	0	0	0	0	0	0	4.24E-07	1.37E-05	2.51E-06	-8.60E-04		4.29E-02

WASTE CATEGORIES:	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	1.35E-03	4.71E-13	6.71E-05	0	0	0	0	0	0	1.71E-13	1.52E-13	-1.24E-13	1.52E-10	-2.54E-11		1.42E-03
NON HAZAR WAST	[kg]	6.40E+00	1.62E-05	3.19E-01	0	0	0	0	0	0	1.22E-05	5.92E-06	1.26E-06	5.00E-02	-2.00E-02		6.75E+00
RADIOACTIVE WASTE	[kg]	2.09E-03	1.46E-07	1.16E-04	0	0	0	0	0	0	6.84E-08	5.31E-08	6.43E-07	1.13E-07	1.77E-04		2.38E-03

OUTPUT FLOWS:	unit	A1-3	A4	A5	B	C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0.00E+00	0.00E+00	7.45E-03	0	0	0	0	0		7.45E-03
MATERIALS FOR RECY.	[kg]	2.04E-02	0.00E+00	7.45E-03	0	0	0	9.50E-01	0		9.71E-01
MATERIALS FOR ENERGY RECO.	[kg]	0	0	0	0	0	0	0	0		0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0	1.01E-03	0	0	0	0	0	0		0.00E+00
EXPORTED ENERGY THERM	[MJ]	0	0	0	0	0	0	0	0		0.00E+00

Insulation EPD

	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
EPD-IES-0017669																	
ROCKWOOL®: Insulation 34mm(40kg/m3)																	
ENVIRONMENTAL IMPACTS:																	
GWP GHG	[kg CO2 eq.]	3,25E+00	6,69E-03	1,01E-01	0	0	0	0	0	0	0,00E+00	7,04E-03	0,00E+00	2,03E-02	-3,51E-02		1,85E+00
GWP FOSSIL	[kg CO2 eq.]	3,32E+00	6,61E-03	6,11E-02	0	0	0	0	0	0	6,95E-03			4,43E-02	-6,38E-01		1,79E+00
GWP BIOGENIC	[kg CO2 eq.]	-7,54E-02	1,95E-05	1,07E-01	0	0	0	0	0	0	9,64E-02			2,72E-01	-9,73E-01		2,97E-02
GWP LULUC	[kg CO2 eq.]	2,69E-03	6,13E-05	2,95E-05	0	0	0	0	0	0	0			0	0		1,45E-03
GWP TOT	**[kg CO2 eq.]**	**3,25E+00**	**6,69E-03**	**1,68E-01**	0	0	0	0	0	0	0			0	0		**1,83E+00**
ODP	[kg CFC-11]	3,17E-12	8,61E-16	4,28E-13	0	0	0	0	0	0	7,66E-06			6,87E-05	-1,76E-04		1,77E-12
AP	[Mole of H+]	1,00E+00	9,86E-06	8,45E-05	0	0	0	0	0	0							1,14E-02
EP freshwater	[kg P eq.]	3,97E-06	2,42E-08	2,42E-04	0	0	0	0	0	0							8,23E-06
EP marine	[kg N eq.]	1,06E-01	2,42E-05	2,86E-07	0	0	0	0	0	0							1,32E-03
EP terrestrial	[Mole of N]	1,16E+00	9,86E-05	3,26E-05	0	0	0	0	0	0							2,33E-02
POCP	[kg NMVOC]	3,29E-01	8,66E-06	1,15E-04	0	0	0	0	0	0							4,06E-03
ADP ele.	[kg Sb eq.]	2,13E-05	4,36E-10	5,71E-09	0	0	0	0	0	0							4,12E-03
ADP foss.	[MJ]	3,52E+01	9,01E-02	4,51E-01	0	0	0	0	0	0							
Water deprivation pot	[m³ world]	1,38E-01	7,99E-05	1,24E-02	0	0	0	0	0	0	8,52E-05						
RESSOURCE USE:																	
RENEWABLE ENERGY TOT	[MJ]	4,05E+00	7,48E-02	5,44E-02	0	0	0	0	0	0	6,99E-03			4,43E-02	-6,38E-01		1,94E+00
NON RENEWABLE ENERGY TOT	[MJ]	3,53E+01	1,03E+00	4,51E-01	0	0	0	0	0	0	9,64E-02			2,72E-01	-9,73E-01		2,02E+01
SECONDARY MAT.	[kg]	2,03E-01	0	2,62E-03	0	0	0	0	0	0	0			0	0		1,34E-01
RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0			0	0		0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0			0	0		0,00E+00
USE OF FRESH WATER	[m3]	3,99E-02	8,19E-05	1,48E-04	0	0	0	0	0	0	7,66E-06			6,87E-05	-1,76E-04		4,12E-03
WASTE CATEGORIES:																	
HAZARDOUS WASTE	[kg]	3,75E-09	3,19E-12	7,80E-11	0	0	0	0	0	0	2,99E-13			5,93E-12	-4,89E-11		3,79E-09
NON HAZAR WAST	[kg]	1,11E-01	1,57E-04	4,98E-02	0	0	0	0	0	0	1,47E-05			1,36E+00	-3,42E-04		1,52E+00
RADIOACTIVE WASTE	[kg]	5,24E-04	1,93E-06	1,12E-05	0	0	0	0	0	0	1,80E-07			3,10E-06	-3,65E-05		5,04E-04
OUTPUT FLOWS:																	
COMPONENTS FOR REUSE	[kg]	0	0	0	0	0	0	0	0	0	0			0	0		0,00E+00
MATERIALS FOR RECY.	[kg]	0	0	4,38E-02	0	0	0	0	0	0	0			0	0		4,38E-02
MATERIALS FOR ENERGY RECO.	[kg]	0	0	0	0	0	0	0	0	0	0			0	0		0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0	0	7,30E-02	0	0	0	0	0	0	7,66E-06			0	0		7,30E-02
EXPORTED ENERGY THERM	[MJ]	0	0	9,70E-02	0	0	0	0	0	0	0			0	0		9,70E-02

Insulation EPD

Screw EPD

	unit	A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
EPD-AWU-20230570-CBA1-EN																	
Würth: Stel screws (TN)/ kg																	
ENVIRONMENTAL IMPACTS:																	
GWP GHG	[kg CO2 eq.]	3,25E+00	7,54E-03	1,24E-01	0	0	0	0	0	0	4,26E-02	4,26E-02	4,34E-03	0	-1,64E+00		1,79E+00
GWP FOSSIL	[kg CO2 eq.]	3,32E+00									4,26E-02	4,26E-03		0	-1,65E+00		1,77E+00
GWP BIOGENIC	[kg CO2 eq.]	1,95E-05									2,12E-05	1,27E-05		0	3,04E-03		6,29E-03
GWP LULUC	[kg CO2 eq.]	6,13E-05									3,90E-06	3,98E-05		0	-6,74E-04		2,13E-03
GWP TOT	**[kg CO2 eq.]**	**3,25E+00**									**4,26E-02**	**4,34E-03**	**0**	**0**	**-1,64E+00**		**1,79E+00**
ODP	[kg CFC-11]	4,28E-13									5,59E-16	5,59E-16		0	4,58E-12		8,60E-12
AP	[Mole of H+]	8,45E-05									6,40E-06	6,40E-06		0	-3,68E-03		9,96E-01
EP freshwater	[kg P eq.]	4,49E-08									4,19E-13	1,57E-08		0	-1,57E-07		8,23E-06
EP marine	[kg N eq.]	2,54E-04									1,83E-05	2,34E-06		0	-8,85E-04		1,05E-01
EP terrestrial	[Mole of N]	2,82E-04									2,34E-06	2,76E-05		0	-9,58E-03		1,15E+00
POCP	[kg NMVOC]	6,95E-05									5,62E-06	5,62E-06		0	-2,94E-03		3,26E-01
ADP ele.	[kg Sb eq.]	2,14E-09									2,06E-09	2,85E-10		0	-1,85E-08		2,13E-05
ADP foss.	[MJ]	9,59E-01									9,36E-03	5,85E-02		0	-1,24E+01		2,48E+01
Water deprivation pot	[m³ world]	1,24E-02									3,58E-03	5,19E-05		0	-2,52E-02		1,29E-01
RESSOURCE USE:																	
RENEWABLE ENERGY TOT	[MJ]	4,05E+00	6,56E-03	1,34E-01	0	0	0	0	0	0	1,28E-01	4,26E-03	0	0	1,87E+00		6,19E+00
NON RENEWABLE ENERGY TOT	[MJ]	3,53E+01	9,05E-02	9,59E-01	0	0	0	0	0	0	9,36E-01	5,87E-02	0	0	-1,26E-01		2,47E+01
SECONDARY MAT.	[kg]	2,03E-01	0	0	0	0	0	0	0	0	3,90E-06	0	0	0	8,08E-01		1,01E+00
RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0,00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0,00E+00
USE OF FRESH WATER	[m3]	3,76E-03	7,18E-06	4,23E-04	0	0	0	0	0	0	2,15E-04	4,66E-06	0	0	-1,13E-03		3,28E-03
WASTE CATEGORIES:																	
HAZARDOUS WASTE	[kg]	1,23E-08	2,80E-13	5,50E-11	0	0	0	0	0	0	5,43E-11	1,82E-13	0	0	-5,33E-11		1,24E-08
NON HAZAR WAST	[kg]	3,76E-02	1,38E-05	2,50E-03	0	0	0	0	0	0	2,06E-04	8,95E-06	0	0	-2,43E-02		1,60E-02
RADIOACTIVE WASTE	[kg]	4,98E-04	1,66E-07	1,47E-04	0	0	0	0	0	0	1,46E-04	1,10E-07	0	0	1,80E-04		9,71E-04
OUTPUT FLOWS:																	
COMPONENTS FOR REUSE	[kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0,00E+00
MATERIALS FOR RECY.	[kg]	1,01E-02	0	0	0	0	0	0	0	0	0	1,00E+00	0	0	0		1,01E+00
MATERIALS FOR ENERGY RECO.	[kg]	0	0	1,09E-01	0	0	0	0	0	0	0	0	0	0	0		0,00E+00
EXPORTED ENERGY ELEC	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1,09E-01
EXPORTED ENERGY THERM	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0,00E+00

Screw EPD

L1 composition

L2 composition

L1: 1m2

ENVIRONMENTAL IMPACTS:

		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP-GHG	[kg CO2 eq.]	1.86E+01	4.13E-01	2.07E+00								2.65E-02	1.38E-01	5.03E-03	7.47E-01	-2.91E+00	1.35E+01
GWP FOSSIL	[kg CO2 eq.]	1.84E+01	4.08E+00	1.92E+00								5.42E-02	1.26E-01	3.45E-02	1.78E-01	-2.94E+00	1.86E+01
GWP BIOGENIC	[kg CO2 eq.]	-2.15E-01	-3.79E-03	2.94E-01								8.28E-05	-1.76E-03	3.48E-02	5.40E-01	4.74E-03	6.70E-01
GWP LULUC	[kg CO2 eq.]	5.13E-02	4.79E-03	2.53E-01								9.68E-05	1.17E-03	1.31E-04	4.43E-04	-1.18E-03	3.44E-02
GWP TOT	**[kg CO2 eq.]**	**1.83E+01**	**4.08E-01**	**1.48E+00**								**3.68E-02**	**1.26E-01**	**6.94E-02**	**7.18E-01**	**-2.84E+00**	**1.68E+01**
ODP	[kg CFC-11 eq.]	3.11E-07	2.82E-14	8.68E-09								1.68E-14	1.11E-14	8.48E-14	1.70E-13	8.47E-12	3.19E-07
AP	[Mole of H+ eq.]	2.22E-01	4.25E-04	1.04E-02								4.10E-05	2.06E-04	2.40E-04	1.64E-03	-6.49E-03	2.28E-01
EP freshwater	[kg P eq.]	3.96E-03	9.71E-07	1.78E-04								4.21E-08	4.61E-07	1.17E-06	1.71E-06	-1.77E-07	4.14E-03
EP marine	[kg N eq.]	2.03E-02	1.56E-04	1.07E-03								1.51E-05	7.68E-05	6.71E-05	4.54E-04	-1.56E-03	2.06E-02
EP terrestrial	[Mole of N eq.]	7.59E-01	1.84E-03	3.76E-02								1.70E-04	9.02E-04	7.39E-04	4.97E-03	-1.68E-02	7.88E-01
POCP	[kg NMVOC eq.]	6.13E-02	3.86E-04	3.50E-03								4.20E-05	1.76E-04	1.99E-04	1.48E-03	-5.20E-03	6.19E-02
ADP ele.	[kg Sb eq.]	4.56E-04	1.74E-08	3.20E-05								1.02E-09	8.22E-09	6.80E-09	5.14E-09	-2.94E-08	4.88E-04
ADP foss.	[MJ]	2.19E+02	3.66E+00	1.74E+01								5.76E-01	1.72E+00	1.57E+00	2.12E+01	2.23E+02	
Water deprivation pot	[m³ world equiv.]	4.93E+00	3.13E-03	2.99E-01								1.16E-03	1.46E-03	2.03E-02	-4.11E-02	5.22E+00	

RESSOURCE USE:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	1.76E+01	2.59E-01	2.67E+00		5.50E-03	1.32E-01	5.30E-01	2.62E+00	2.38E-01	
NON RENEWABLE ENERGY TOT	[MJ]	2.19E+02	3.66E+00	1.74E+01		4.17E-01	1.87E+00	9.98E-02	3.40E+00	-2.31E+01	2.23E+02
SECONDARY MAT.	[kg]	4.74E-01	0.00E+00	1.75E-02		0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.71E-02	5.19E-01
RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
USE OF FRESH WATER	[m3]	1.21E-01	2.67E-04	8.89E-03		2.79E-05	1.45E-04	8.22E-04	8.26E-04	-2.11E-03	1.29E-01

WASTE CATEGORIES:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	2.81E-03	1.26E-11	1.40E-04		4.86E-11	6.82E-12	4.00E-10	-1.27E-10	2.95E-03	
NON HAZAR.WAST	[kg]	1.37E-01	5.39E-04	1.90E+00		9.01E-05	2.70E-04	2.62E-05	1.69E+01	-3.94E-02	3.24E+01
RADIOACTIVE WASTE	[kg]	5.46E-03	5.61E-06	4.41E-04		5.13E-06	2.50E-06	1.34E-06	3.94E-05	3.25E-04	6.28E-03

OUTPUT FLOWS:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0.00E+00	0.00E+00	1.55E-02		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-02
MATERIALS FOR RECY.	[kg]	3.55E-01	0.00E+00	1.46E-01		0.00E+00	0.00E+00	2.01E+00	0.00E+00	0.00E+00	2.51E+00
MATERIALS FOR ENERGY RECO.	[kg]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0.00E+00	0.00E+00	1.11E-01		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-01
EXPORTED ENERGY THERM.	[MJ]	0.00E+00	0.00E+00	1.43E-01		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E-01

L1

L2: 1m2

ENVIRONMENTAL IMPACTS:

		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP-GHG	[kg CO2 eq.]	1.96E+01	4.13E-01	2.07E+00								4.41E-02	2.60E-01	5.03E-03	1.46E+00	-3.06E+00	1.99E+01
GWP FOSSIL	[kg CO2 eq.]	1.84E+01	4.08E+00	1.92E+00								5.42E-02	2.46E-01	3.45E-02	4.06E-01	-2.94E+00	1.86E+01
GWP BIOGENIC	[kg CO2 eq.]	-2.15E-01	-3.79E-03	2.94E-01								8.28E-05	-3.54E-03	3.48E-02	1.08E+00	4.74E-03	1.19E+00
GWP LULUC	[kg CO2 eq.]	5.13E-02	4.79E-03	1.25E-03								9.75E-05	2.28E-03	1.31E-04	9.25E-04	-1.22E-03	5.96E-02
GWP TOT	**[kg CO2 eq.]**	**1.83E+01**	**4.08E-01**	**2.22E+00**								**5.44E-02**	**2.45E-01**	**6.94E-02**	**1.48E+00**	**-2.94E+00**	**1.98E+01**
ODP	[kg CFC-11 eq.]	4.46E-07	4.05E-14	8.68E-09								3.44E-14	2.16E-14	8.48E-14	7.46E-13	8.75E-12	4.54E-07
AP	[Mole of H+ eq.]	2.78E-01	6.65E-04	1.25E-02								5.31E-05	3.63E-04	2.40E-04	3.38E-03	-6.71E-03	2.88E-01
EP freshwater	[kg P eq.]	4.35E-03	1.47E-06	1.79E-04								4.49E-08	9.00E-07	6.80E-09	2.47E-06	-1.86E-07	4.54E-03
EP marine	[kg N eq.]	2.86E-02	2.46E-04	1.48E-03								1.99E-05	1.35E-04	6.71E-05	9.48E-04	-1.61E-03	2.99E-02
EP terrestrial	[Mole of N eq.]	8.47E-01	2.88E-03	4.20E-02								2.24E-04	7.39E-04	7.39E-04	1.04E-02	-1.74E-02	8.88E-01
POCP	[kg NMVOC eq.]	8.66E-02	6.10E-04	5.00E-03								5.61E-05	3.16E-04	1.99E-04	3.10E-03	-5.38E-03	9.05E-02
ADP ele.	[kg Sb eq.]	4.80E-04	2.64E-08	4.02E-05								1.27E-09	1.60E-08	6.80E-09	1.43E-08	-3.05E-08	5.20E-04
ADP foss.	[MJ]	2.97E+02	5.57E+00	2.73E+01								8.57E-01	9.00E-01	3.35E+00	4.55E+00	-2.20E-01	3.17E+02
Water deprivation pot	[m³ world equiv.]	6.13E+00	4.73E-03	4.04E-01								2.07E-03	2.84E-03	4.28E-03	4.43E-02	-4.26E-02	6.55E+00

RESSOURCE USE:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	2.30E-01	3.92E-01	4.84E+00		1.14E-02	2.47E-01	9.26E-03	9.92E-02	2.74E+00	3.23E-01
NON RENEWABLE ENERGY TOT	[MJ]	2.97E+02	5.89E+00	2.74E+01		7.17E-01	3.50E+00	9.98E-02	6.38E+00	-2.39E+01	3.17E+02
SECONDARY MAT.	[kg]	4.82E-01	0.00E+00	1.75E-02		0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.00E-02	5.60E-01
RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
USE OF FRESH WATER	[m3]	1.50E-01	4.13E-14	1.30E-02		5.64E-05	2.73E-04	2.85E-05	1.55E-03	-2.17E-03	1.64E-01

WASTE CATEGORIES:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	2.81E-03	1.97E-11	1.40E-04		9.72E-11	1.29E-11	-2.58E-13	4.74E-10	-1.30E-10	2.95E-03
NON HAZAR.WAST	[kg]	1.39E+01	8.14E-04	3.07E+00		1.56E-04	5.07E-04	2.62E-05	3.15E+01	-3.69E-02	4.84E+01
RADIOACTIVE WASTE	[kg]	5.81E-03	8.07E-06	6.25E-04		1.11E-05	4.62E-06	1.34E-06	7.40E-05	3.37E-04	6.87E-03

OUTPUT FLOWS:

		A1-3	A4	A5	...	C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0.00E+00	0.00E+00	1.55E-02		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-02
MATERIALS FOR RECY.	[kg]	6.67E-01	0.00E+00	2.26E-01		0.00E+00	0.00E+00	2.05E+00	0.00E+00	0.00E+00	2.94E+00
MATERIALS FOR ENERGY RECO.	[kg]	0.00E+00	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0.00E+00	0.00E+00	1.15E-01		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-01
EXPORTED ENERGY THERM.	[MJ]	0.00E+00	0.00E+00	1.43E-01		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E-01

L2

Juunoo BaseClick

JUUNOO BaseClick: 1 m2

ENVIRONMENTAL IMPACTS:

		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
GWP-GHG	[kg CO2 eq.]	1.72E-01	3.79E-01	5.22E-02	0	0	0	0	0	0	0	3.01E-04	1.46E-01	1.04E-01	0	0.00E+00	4.93E-01
GWP FOSSIL	[kg CO2 eq.]	4.84E-01	3.79E-01	4.72E-02	0	0	0	0	0	0	0	2.96E-04	1.46E-01	1.48E-03	0	-2.43E+01	6.95E-01
GWP FOSSIL	[kg CO2 eq.]	-3.12E+01	1.35E-04	4.94E-03	0	0	0	0	0	0	0	4.36E-06	6.57E-05	1.04E-01	0	-4.68E-02	5.61E-02
GWP BIOGENIC	[kg CO2 eq.]	6.62E-02	1.55E-04	5.92E-05	0	0	0	0	0	0	0	7.05E-07	5.89E-05	8.57E-07	0	-2.90E-02	2.56E-03
GWP LULUC	[kg CO2 eq.]	1.72E-01	3.79E-01	5.22E-02	0	0	0	0	0	0	0	3.01E-04	1.46E-01	1.04E-01	0	0.00E+00	4.93E-01
GWP TOT	**[kg CO2 eq.]**	**1.72E-01**	**3.79E-03**	**5.22E-02**	0	0	0	0	0	0	0	**3.01E-04**	**1.46E-01**	**1.04E-01**	**0**	**0.00E+00**	**4.93E-01**
ODP	[kg CFC-11]	5.64E-06	8.39E-08	7.17E-09	0	0	0	0	0	0	0	6.17E-11	8.30E-08	1.07E-10	0	0.00E+00	3.34E-07
AP	[Mole of H+]	2.47E-06	4.43E-03	7.17E-09	0	0	0	0	0	0	0	6.17E-11	3.30E-08	0	0	0.00E+00	4.93E-01
AP	[Mole of H+]	2.10E-01	1.81E-03	1.71E-04	0	0	0	0	0	0	0	7.36E-07	1.72E-03	4.24E-06	0	-1.99E-01	5.47E-02
EP freshwater	[kg P eq.]	1.36E-03	1.28E-06	1.60E-06	0	0	0	0	0	0	0	8.91E-09	2.66E-08	2.46E-08	0	-3.61E-05	3.27E-05
EP marine	[kg N eq.]	2.99E-02	4.69E-06	4.42E-05	0	0	0	0	0	0	0	1.52E-07	4.48E-04	1.17E-06	0	-2.84E-02	3.93E-03
EP terrestrial	[Mole of N]	6.69E-01	5.20E-03	4.71E-04	0	0	0	0	0	0	0	1.86E-06	4.97E-03	1.28E-05	0	-4.35E-01	2.65E-01
POCP	[kg NMVOC]	1.09E-01	1.44E-03	1.55E-04	0	0	0	0	0	0	0	4.75E-07	1.38E-03	4.15E-06	0	-1.13E-01	4.19E-03
ADP ele.	[kg Sb eq.]	8.90E-03	2.22E-06	6.70E-07	0	0	0	0	0	0	0	3.44E-09	2.11E-06	1.81E-08	0	-4.57E-04	8.45E-03
ADP foss.	[MJ]	3.73E+02	2.26E+00	1.08E-07	0	0	0	0	0	0	0	1.18E-02	2.16E+00	1.45E-02	0	-3.55E+02	2.35E-01
Water deprivation pot	[m³ world]	2.01E+01	8.30E-03	1.48E-02	0	0	0	0	0	0	0	1.21E-04	7.23E-03	3.11E-04	0	-1.95E-01	6.31E-01

RESSOURCE USE:

		A1-3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	2.13E+02	2.29E-02	8.25E-02	0	0	0	0	0	0	0	1.31E-03	2.43E-02	7.15E-04	0	-2.10E+02	3.13E+00
NON RENEWABLE ENERGY TOT	[MJ]	8.31E+02	2.26E+00	-5.43E-01	0	0	0	0	0	0	0	1.18E-02	2.16E+00	-4.58E-02	0	1.05E+02	4.82E+02
SECONDARY MAT.	[kg]	3.71E+00	0	7.89E-04	0	0	0	0	0	0	0	0	0	0	0	2.13E+00	1.58E+00
RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00E+00
USE OF FRESH WATER	[m3]	0.194	4.13E-04	3.43E-04	0	0	0	0	0	0	0	2.90E-06	3.93E-04	4.35E-06	0	-1.51E-01	4.42E-02

WASTE CATEGORIES:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	2.99E+00	2.63E-03	5.02E-03	0	1.28E-05	2.20E-03	0	0	0	-6.30E-01
NON HAZAR WASTE	[kg]	5.44E+01	1.98E-01	8.78E-02	0	3.68E-04	1.86E-01	0	0	-5.58E+01	-9.28E-01
RADIOACTIVE WASTE	[kg]	1.06E-03	1.54E-05	7.64E-06	0	1.04E-07	1.49E-05	0	0	-8.99E-04	1.99E-04

OUTPUT FLOWS:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0	0	0	0	0	0	0	0	0	2.01E-01
MATERIALS FOR RECY.	[kg]	3.00E-02	0	0	0	0	0	2.01E-01	0	0	3.40E-02
MATERIALS FOR ENERGY RECO.	[kg]	0	0	0	0	0	0	4.00E-03	0	0	0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0	0	0	0	0	0	0	0	0	0.00E+00
EXPORTED ENERGY THERM	[MJ]	0	0	0	0	0	0	0	0	0	0.00E+00

Juunoo SilentClick

JUUNOO SilentClick: 1 m2

ENVIRONMENTAL IMPACTS:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D --> Inferred	A-D
GWP-GHG	[kg CO2 eq.]	1.72E-01	3.79E-01	5.22E-02	0	3.01E-04	1.46E-01	1.04E-01	0	0.00E+00	4.93E-01
GWP FOSSIL	[kg CO2 eq.]	4.84E-01	3.79E-01	4.72E-02	0	2.96E-04	3.67E-01	3.13E-01	0	-2.43E+01	6.95E-01
GWP FOSSIL	[kg CO2 eq.]	-3.12E+01	3.79E-05	4.94E-03	0	4.36E-06	1.65E-04	1.31E-01	0	-4.35E+01	5.61E-02
GWP BIOGENIC	[kg CO2 eq.]	6.62E-02	1.55E-04	5.92E-05	0	7.05E-07	1.48E-04	8.57E-07	0	-4.91E-02	2.56E-03
GWP LULUC	[kg CO2 eq.]	1.72E-01	3.79E-03	5.22E-02	0	3.01E-04	1.46E-01	1.04E-01	0	0.00E+00	4.93E-01
GWP TOT	**[kg CO2 eq.]**	**1.72E-01**	**3.79E-03**	**5.22E-02**	0	**3.01E-04**	**3.68E-01**	**3.13E-01**	**0**	**0.00E+00**	**4.93E-01**
ODP	[kg CFC-11]	5.64E-06	8.39E-08	7.17E-09	0	6.17E-11	8.30E-08	1.07E-10	0	0.00E+00	3.34E-07
AP	[Mole of H+]	2.10E-01	1.81E-03	1.71E-04	0	7.36E-07	4.34E-03	4.24E-06	0	-5.48E-06	6.09E-02
EP freshwater	[kg P eq.]	1.36E-03	1.28E-06	1.60E-06	0	8.91E-09	2.46E-08	2.66E-08	0	-3.28E-01	3.27E-05
EP marine	[kg N eq.]	2.99E-02	4.69E-06	4.42E-05	0	1.52E-07	1.13E-03	1.17E-06	0	-5.75E-02	3.93E-03
EP terrestrial	[Mole of N]	6.69E-01	5.20E-03	4.71E-04	0	1.86E-06	1.25E-02	1.28E-05	0	-9.16E-01	2.65E-01
POCP	[kg NMVOC]	1.09E-01	1.44E-03	1.55E-04	0	4.75E-07	3.48E-03	4.15E-06	0	-2.28E-01	4.19E-03
ADP ele.	[kg Sb eq.]	8.90E-03	2.22E-06	6.70E-07	0	3.44E-09	5.32E-06	1.81E-08	0	-8.86E-04	8.45E-03
ADP foss.	[MJ]	7.88E+02	5.56E+00	1.08E+00	0	1.18E-02	5.44E+00	1.45E-02	0	-7.59E+02	3.11E+01
Water deprivation pot	[m³ world]	4.76E+01	2.04E-02	1.48E-02	0	1.21E-04	1.82E-02	3.11E-04	0	-4.70E+01	6.54E-01

RESSOURCE USE:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D	A-D
RENEWABLE ENERGY TOT	[MJ]	6.08E+02	5.63E-02	8.25E-02	0	1.31E-03	6.11E-02	7.15E-04	0	-6.05E+02	3.20E+00
NON RENEWABLE ENERGY TOT	[MJ]	2.16E+03	5.56E+00	-5.43E-01	0	1.18E-02	5.44E+00	-1.37E-03	0	6.03E+02	1.40E+03
SECONDARY MAT.	[kg]	3.71E+00	0.00E+00	7.89E-04	0	0.00E+00	0.00E+00	0.00E+00	0	-2.13E+00	1.58E+00
RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00
NON RENEWABLE SEC. FUELS	[MJ]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00
USE OF FRESH WATER	[m3]	0.315	1.02E-03	3.43E-04	0	2.90E-06	9.89E-04	4.35E-06	0	-2.71E-01	-2.69E-01

WASTE CATEGORIES:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D	A-D
HAZARDOUS WASTE	[kg]	4.25E+00	6.47E-03	5.02E-03	0	1.28E-05	5.53E-03	0.00E+00	0	-4.89E+00	-6.23E-01
NON HAZAR WASTE	[kg]	1.01E+02	4.88E-01	8.78E-02	0	3.68E-04	4.68E-01	0.00E+00	0	-1.02E+02	4.42E-02
RADIOACTIVE WASTE	[kg]	2.28E-03	3.78E-05	7.64E-06	0	1.04E-07	3.75E-05	0.00E+00	0	-2.12E-03	2.43E-04

OUTPUT FLOWS:

		A1-3	A4	A5	B1-B7	C1	C2	C3	C4	D	A-D
COMPONENTS FOR REUSE	[kg]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	5.05E-01	0.00E+00	0.00E+00	5.05E-01
MATERIALS FOR RECY.	[kg]	3.00E-02	0.00E+00	0.00E+00	0	0.00E+00	4.00E-03	0.00E+00	0.00E+00	0.00E+00	3.40E-02
MATERIALS FOR ENERGY RECO.	[kg]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXPORTED ENERGY ELEC	[MJ]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EXPORTED ENERGY THERM	[MJ]	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

A1-D

	L1: 1m2	Juunoo baseclick: 1m2
ENVIRONMENTAL IMPACTS:		
GWP GHG	1,35E+01 [kg CO2 eq.]	1,64E+01 [kg CO2 eq.]
GWP FOSSIL	1,28E+01 [kg CO2 eq.]	1,57E+01 [kg CO2 eq.]
GWP BIOGENIC	6,70E-01 [kg CO2 eq.]	6,65E-01 [kg CO2 eq.]
GWP LULUC	3,66E-02 [kg CO2 eq.]	3,44E-02 [kg CO2 eq.]
GWP TOT	**1,36E+01 [kg CO2 eq.]**	**1,64E+01 [kg CO2 eq.]**
ODP	3,19E-07 [kg CFC-11 eq.]	3,19E-07 [kg CFC-11 eq.]
AP	2,28E-01 [Mole of H+ eq.]	2,35E-01 [Mole of H+ eq.]
EP freshwater	4,14E-03 [kg P eq.]	4,15E-03 [kg P eq.]
EP marine	2,06E-02 [kg N eq.]	2,22E-02 [kg N eq.]
EP terrestrial	7,88E-01 [Mole of N eq.]	8,05E-01 [Mole of N eq.]
POCP	6,19E-02 [kg NMVOC eq.]	6,71E-02 [kg NMVOC eq.]
ADP ele,	4,88E-04 [kg Sb eq.]	4,88E-04 [kg Sb eq.]
ADP foss,	2,23E+02 [MJ]	2,44E+02 [MJ]
Water deprivation pot	5,22E+00 [m³ world equiv,]	5,26E+00 [m³ world equiv,]
RESSOURCE USE:		
RENEWABLE ENERGY TOT	2,38E+01 [MJ]	3,13E+00 [MJ]
NON RENEWABLE ENERGY TOT	2,23E+02 [MJ]	4,82E+02 [MJ]
SECONDARY MAT,	5,19E-01 [kg]	1,58E+00 [kg]
RENEWABLE SEC, FUELS	0,00E+00 [MJ]	0,00E+00 [MJ]
NON RENEWABLE SEC, FUELS	0,00E+00 [MJ]	0,00E+00 [MJ]
USE OF FRESH WATER	1,29E-01 [m3]	4,42E-02 [m3]
WASTE CATEGORIES:		
HAZARDOUS WASTE	2,95E-03 [kg]	-6,30E-01 [kg]
NON HAZAR WAST	3,24E+01 [kg]	-9,28E-01 [kg]
RADIOACTIVE WASTE	6,28E-03 [kg]	1,99E-04 [kg]
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	1,55E-02 [kg]	2,01E+01 [kg]
MATERIALS FOR RECY,	2,51E+00 [kg]	3,40E-02 [kg]
MATERIALS FOR ENERGY RECO,	0,00E+00 [kg]	0,00E+00 [kg]
EXPORTED ENERGY ELEC	1,11E-01 [MJ]	0,00E+00 [MJ]
EXPORTED ENERGY THERM	1,43E-01 [MJ]	0,00E+00 [MJ]

L1-BaseClick comparison A1-D

A1-C4

	L1: 1m2	Juunoo baseclick: 1m2
ENVIRONMENTAL IMPACTS:		
GWP GHG	2,46E+01 [kg CO2 eq.]	2,46E+01 [kg CO2 eq.]
GWP FOSSIL	1,49E-01 [kg CO2 eq.]	2,44E+01 [kg CO2 eq.]
GWP BIOGENIC	-4,17E-02 [kg CO2 eq.]	5,07E-03 [kg CO2 eq.]
GWP LULUC	2,38E-03 [kg CO2 eq.]	3,14E-02 [kg CO2 eq.]
GWP TOT	**2,46E+01 [kg CO2 eq.]**	**2,46E+01 [kg CO2 eq.]**
ODP	2,24E-07 [kg CFC-11 eq.]	2,54E-06 [kg CFC-11 eq.]
AP	5,47E-02 [Mole of H+ eq.]	2,14E-01 [Mole of H+ eq.]
EP freshwater	-3,61E-05 [kg P eq.]	1,36E-03 [kg P eq.]
EP marine	2,46E-03 [kg N eq.]	3,09E-02 [kg N eq.]
EP terrestrial	2,45E-01 [Mole of N eq.]	6,80E-01 [Mole of N eq.]
POCP	-1,02E-03 [kg NMVOC eq.]	1,12E-01 [kg NMVOC eq.]
ADP ele,	8,45E-03 [kg Sb eq.]	8,91E-03 [kg Sb eq.]
ADP foss,	2,35E+01 [MJ]	3,79E+02 [MJ]
Water deprivation pot	6,31E-01 [m³ world equiv,]	2,01E+01 [m³ world equiv,]
RESSOURCE USE:		
RENEWABLE ENERGY TOT	2,12E+01 [MJ]	2,13E+02 [MJ]
NON RENEWABLE ENERGY TOT	2,46E+02 [MJ]	3,77E+02 [MJ]
SECONDARY MAT,	4,91E-01 [kg]	3,71E+00 [kg]
RENEWABLE SEC, FUELS	0,00E+00 [MJ]	0,00E+00 [MJ]
NON RENEWABLE SEC, FUELS	0,00E+00 [MJ]	0,00E+00 [MJ]
USE OF FRESH WATER	1,31E-01 [m3]	1,95E-01 [m3]
WASTE CATEGORIES:		
HAZARDOUS WASTE		2,97E+00 [kg]
NON HAZAR WAST		5,49E+01 [kg]
RADIOACTIVE WASTE		1,10E-03 [kg]
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	2,01E+01 [kg]	2,01E+01 [kg]
MATERIALS FOR RECY,	3,40E-02 [kg]	3,40E-02 [kg]
MATERIALS FOR ENERGY RECO,	0,00E+00 [kg]	0,00E+00 [kg]
EXPORTED ENERGY ELEC	0,00E+00 [MJ]	0,00E+00 [MJ]
EXPORTED ENERGY THERM	0,00E+00 [MJ]	0,00E+00 [MJ]

L1-BaseClick comparison A1-C4

Page 82 — A1-A5

	L1: 1m2	Juunoo baseclick: 1m2
ENVIRONMENTAL IMPACTS:		
GWP GHG	1.55E-01 [kg CO2	1.40E+01 [kg CO2
GWP FOSSIL	1.53E-01 [kg CO2 eq.]	2.43E+01 [kg CO2 eq.]
GWP BIOGENIC	9.24E-02 [kg CO2 eq.]	-1.04E+01 [kg CO2 eq.]
GWP LULUC	3.37E-02 [kg CO2 eq.]	3.13E-02 [kg CO2 eq.]
GWP TOT	**1.55E+01 [kg CO2 eq.]**	**1.40E+01 [kg CO2 eq.]**
ODP	3.19E-07 [kg CFC-	2.51E-06 [kg CFC-
AP	2.33E-01 [Mole of	2.12E-01 [Mole of
EP freshwater	4.14E-03 [kg P eq.]	1.36E-03 [kg P eq.]
EP marine	2.15E-02 [kg N eq.]	3.04E-02 [kg N eq.]
EP terrestrial	7.98E-01 [Mole of N	6.75E-01 [Mole of N
POCP	6.52E-02 [kg	1.11E-01 [kg
ADP ele,	4.88E-04 [kg Sb eq.]	8.90E-03 [kg Sb eq.]
ADP foss,	2.40E+02 [MJ]	3.76E+02 [MJ]
Water deprivation pot	5.23E+00 [m³ world	2.01E+01 [m³ world
RESSOURCE USE:		
RENEWABLE ENERGY TOT	2.05E-01 [MJ]	2.13E+02 [MJ]
NON RENEWABLE ENERGY TOT	2.40E+02 [MJ]	8.33E+02 [MJ]
SECONDARY MAT,	4.91E-01 [MJ]	3.71E+00 [MJ]
RENEWABLE SEC, FUELS	0.00E+00 [MJ]	0.00E+00 [MJ]
NON RENEWABLE SEC, FUELS	0.00E+00 [MJ]	0.00E+00 [MJ]
USE OF FRESH WATER	1.30E-01 [m3]	1.95E-01 [m3]
WASTE CATEGORIES:		
HAZARDOUS WASTE	2.95E-03 [kg]	2.97E+00 [kg]
NON HAZAR WAST	1.56E-01 [kg]	5.47E+01 [kg]
RADIOACTIVE WASTE	5.91E-03 [kg]	1.08E-03 [kg]
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	1.55E-02 [kg]	0.00E+00 [kg]
MATERIALS FOR RECY,	5.01E-01 [kg]	3.00E-02 [kg]
MATERIALS FOR ENERGY RECO,	0.00E+00 [kg]	0.00E+00 [kg]
EXPORTED ENERGY ELEC	1.11E-01 [MJ]	0.00E+00 [MJ]
EXPORTED ENERGY THERM	1.43E-01 [MJ]	0.00E+00 [MJ]

L1-BaseClick comparison A1-A5

Page 83 — A1-A3

	L1: 1m2	Juunoo baseclick: 1m2
ENVIRONMENTAL IMPACTS:		
GWP GHG	1.39E+01 [kg CO2	1.38E+01 [kg CO2
GWP FOSSIL	1.38E+01 [kg CO2 eq.]	2.41E+01 [kg CO2 eq.]
GWP BIOGENIC	-1.59E-01 [kg CO2 eq.]	-1.04E+01 [kg CO2 eq.]
GWP LULUC	2.94E-02 [kg CO2 eq.]	3.12E-02 [kg CO2 eq.]
GWP TOT	**1.37E+01 [kg CO2 eq.]**	**1.38E+01 [kg CO2 eq.]**
ODP	3.11E-07 [kg CFC-	2.47E-06 [kg CFC-
AP	2.22E-01 [Mole of	2.10E-01 [Mole of
EP freshwater	3.96E-03 [kg P eq.]	1.36E-03 [kg P eq.]
EP marine	2.03E-02 [kg N eq.]	2.99E-02 [kg N eq.]
EP terrestrial	7.59E-01 [Mole of N	6.69E-01 [Mole of N
POCP	6.13E-02 [kg	1.09E-01 [kg
ADP ele,	4.56E-04 [kg Sb eq.]	8.90E-03 [kg Sb eq.]
ADP foss,	2.19E+02 [MJ]	3.73E+02 [MJ]
Water depri2vation pot	4.93E+00 [m³ world	2.01E+01 [m³ world
RESSOURCE USE:		
RENEWABLE ENERGY TOT	1.76E+01 [MJ]	2.13E+02 [MJ]
NON RENEWABLE ENERGY TOT	2.19E+02 [MJ]	8.31E+02 [MJ]
SECONDARY MAT,	4.74E-01 [kg]	3.71E+00 [kg]
RENEWABLE SEC, FUELS	0.00E+00 [MJ]	0.00E+00 [MJ]
NON RENEWABLE SEC, FUELS	0.00E+00 [MJ]	0.00E+00 [MJ]
USE OF FRESH WATER	1.21E-01 [m3]	1.94E-01 [m3]
WASTE CATEGORIES:		
HAZARDOUS WASTE	2.81E-03 [kg]	2.96E+00 [kg]
NON HAZAR WAST	1.37E+01 [kg]	5.44E+01 [kg]
RADIOACTIVE WASTE	5.46E-03 [kg]	1.06E-03 [kg]
OUTPUT FLOWS:		
COMPONENTS FOR REUSE	0.00E+00 [kg]	0.00E+00 [kg]
MATERIALS FOR RECY,	3.55E-01 [kg]	3.00E-02 [kg]
MATERIALS FOR ENERGY RECO,	0.00E+00 [kg]	0.00E+00 [kg]
EXPORTED ENERGY ELEC	0.00E+00 [MJ]	0.00E+00 [MJ]
EXPORTED ENERGY THERM	0.00E+00 [MJ]	0.00E+00 [MJ]

L1-BaseClick comparison A1-A3

A1-D

A1-D	L2: 1m2		Juunoo silentclick: 1m2	
ENVIRONMENTAL IMPACTS:				
GWP GHG	1.98E+01	[kg CO2 eq.]	4.93E+01	[kg CO2 eq.]
GWP FOSSIL	1.86E+01	[kg CO2 eq.]	6.95E+01	[kg CO2 eq.]
GWP BIOGENIC	1.19E+00	[kg CO2 eq.]	5.61E-02	[kg CO2 eq.]
GWP LULUC	5.96E-02	[kg CO2 eq.]	2.56E-03	[kg CO2 eq.]
GWP TOT	**1.98E+01**	**[kg CO2 eq.]**	**4.93E+01**	**[kg CO2 eq.]**
ODP	4.54E-07	[kg CFC-11 eq.]	3.34E-07	[kg CFC-11 eq.]
AP	2.88E-01	[Mole of H+ eq.]	6.09E-02	[Mole of H+ eq.]
EP freshwater	4.54E-03	[kg P eq.]	-3.27E-05	[kg P eq.]
EP marine	2.99E-02	[kg N eq.]	3.93E-03	[kg N eq.]
EP terrestrial	8.88E-01	[Mole of N eq.]	2.60E-01	[Mole of N eq.]
POCP	9.05E-02	[kg NMVOC eq.]	4.19E-03	[kg NMVOC eq.]
ADP ele,	5.20E-04	[kg Sb eq.]	8.46E-03	[kg Sb eq.]
ADP foss,	3.17E+02	[MJ]	3.11E+01	[MJ]
Water deprivation pot	6.55E+00	[m³ world equiv,]	6.54E-01	[m³ world equiv,]
RESSOURCE USE:				
RENEWABLE ENERGY TC	3.23E+01	[MJ]	3.20E+00	[MJ]
NON RENEWABLE ENER	3.17E+02	[MJ]	1.40E+03	[MJ]
SECONDARY MAT,	5.60E-01	[kg]	1.58E+00	[kg]
RENEWABLE SEC, FUEL:	0.00E+00	[MJ]	0.00E+00	[MJ]
NON RENEWABLE SEC,	0.00E+00	[MJ]	0.00E+00	[MJ]
USE OF FRESH WATER	1.64E-01	[m3]	-2.69E-01	[m3]
WASTE CATEGORIES:				
HAZARDOUS WASTE	2.95E-03	[kg]	-6.23E-01	[kg]
NON HAZAR WAST	4.84E+01	[kg]	4.42E-02	[kg]
RADIOACTIVE WASTE	6.87E-03	[kg]	2.43E-04	[kg]
OUTPUT FLOWS:				
COMPONENTS FOR REI	1.55E-02	[kg]	5.05E-01	[kg]
MATERIALS FOR RECY,	2.94E+00	[kg]	3.40E-02	[kg]
MATERIALS FOR ENERG	0.00E+00	[kg]	0.00E+00	[kg]
EXPORTED ENERGY ELE	1.15E-01	[MJ]	0.00E+00	[MJ]
EXPORTED ENERGY THE	1.43E-01	[MJ]	0.00E+00	[MJ]

L2-BaseClick comparison A1-D

A1-C4

A1-C4	L2: 1m2		Juunoo silentclick: 1m2	
ENVIRONMENTAL IMPACTS:				
GWP GHG	2.28E+01	[kg CO2 eq.]	4.93E+01	[kg CO2 eq.]
GWP FOSSIL	2.15E+01	[kg CO2 eq.]	4.92E+01	[kg CO2 eq.]
GWP BIOGENIC	1.19E+00	[kg CO2 eq.]	1.05E-01	[kg CO2 eq.]
GWP LULUC	6.08E-02	[kg CO2 eq.]	6.66E-02	[kg CO2 eq.]
GWP TOT	**2.28E+01**	**[kg CO2 eq.]**	**4.93E+01**	**[kg CO2 eq.]**
ODP	4.54E-07	[kg CFC-]	5.81E-06	[kg CFC-]
AP	2.95E-01	[Mole of]	3.89E-01	[Mole of]
EP freshwater	4.54E-03	[kg P eq.]	2.84E-03	[kg P eq.]
EP marine	3.15E-02	[kg N eq.]	6.14E-02	[kg N eq.]
EP terrestrial	9.05E-01	[Mole of N]	1.18E+00	[Mole of N]
POCP	9.59E-02	[kg	2.32E-01	[kg
ADP ele,	5.20E-04	[kg Sb eq.]	9.34E-03	[kg Sb eq.]
ADP foss,	3.39E+02	[MJ]	8.00E+02	[MJ]
Water deprivation pot	6.59E+00	[m³ world	4.77E+01	[m³ world
RESSOURCE USE:				
RENEWABLE ENERGY TOT	2.95E+01	[MJ]	6.08E+02	[MJ]
NON RENEWABLE ENERGY TOT	3.41E+02	[MJ]	8.00E+02	[MJ]
SECONDARY MAT,	5.00E-01	[kg]	3.71E+00	[kg]
RENEWABLE SEC, FUELS	0.00E+00	[MJ]	0.00E+00	[MJ]
NON RENEWABLE SEC, FUELS	0.00E+00	[MJ]	0.00E+00	[MJ]
USE OF FRESH WATER	1.66E-01	[m3]	2.36E-03	[m3]
WASTE CATEGORIES:				
HAZARDOUS WASTE	2.95E-03	[kg]	4.27E+00	[kg]
NON HAZAR WAST	4.85E+01	[kg]	1.02E+02	[kg]
RADIOACTIVE WASTE	6.53E-03	[kg]	2.36E-03	[kg]
OUTPUT FLOWS:				
COMPONENTS FOR REUSE	1.55E-02	[kg]	5.05E-01	[kg]
MATERIALS FOR RECY,	2.94E+00	[kg]	3.40E-02	[kg]
MATERIALS FOR ENERGY RECO,	0.00E+00	[kg]	0.00E+00	[kg]
EXPORTED ENERGY ELEC	1.15E-01	[MJ]	0.00E+00	[MJ]
EXPORTED ENERGY THERM	1.43E-01	[MJ]	0.00E+00	[MJ]

L2-BaseClick comparison A1-C4

A1-A5

ENVIRONMENTAL IMPACTS:	L2: 1m2		Juunoo silentclick: 1m2	
GWP GHG	2,10E+01	[kg CO2	1,76E+01	[kg CO2
GWP FOSSIL	2,08E+01	[kg CO2 eq,]	4,88E+01	[kg CO2 eq,]
GWP BIOGENIC	7,59E-02	[kg CO2 eq,]	-3,12E+01	[kg CO2 eq,]
GWP LULUC	5,73E-02	[kg CO2 eq,]	6,64E-02	[kg CO2 eq,]
GWP TOT	**2,09E+01**	**[kg CO2 eq,]**	**1,76E+01**	**[kg CO2 eq,]**
ODP	4,54E-07	[kg CFC-	5,73E-06	[kg CFC-
AP	2,91E-01	[Mole of	3,85E-01	[Mole of
EP freshwater	4,54E-03	[kg P eq,]	2,83E-03	[kg P eq,]
EP marine	3,03E-02	[kg N eq,]	6,03E-02	[kg N eq,]
EP terrestrial	8,92E-01	[Mole of N	1,16E+00	[Mole of N
POCP	9,22E-02	[kg	2,29E-01	[kg
ADP ele,	5,20E-04	[kg Sb eq,]	9,34E-03	[kg Sb eq,]
ADP foss,	3,30E+02	[MJ]	7,95E+02	[MJ]
Water deprivation pot	6,54E+00	[m³ world	4,76E+01	[m³ world
RESSOURCE USE:				
RENEWABLE ENERGY TOT	2,83E-01	[MJ]	6,08E+02	[MJ]
NON RENEWABLE ENERGY TOT	3,30E+02	[MJ]	2,17E+03	[MJ]
SECONDARY MAT,	5,00E-01	[kg]	3,71E+00	[kg]
RENEWABLE SEC, FUELS	0,00E+00	[MJ]	0,00E+00	[MJ]
NON RENEWABLE SEC, FUELS	0,00E+00	[MJ]	0,00E+00	[MJ]
USE OF FRESH WATER	1,64E-01	[m3]	1,36E-03	[m3]
OUTPUT FLOWS:				
COMPONENTS FOR REUSE	1,55E-02	[kg]	0,00E+00	[kg]
MATERIALS FOR RECY,	8,94E-01	[kg]	3,00E-02	[kg]
MATERIALS FOR ENERGY RECO,	0,00E+00	[kg]	0,00E+00	[kg]
EXPORTED ENERGY ELEC	1,15E-01	[MJ]	0,00E+00	[MJ]
EXPORTED ENERGY THERM	1,43E-01	[MJ]	0,00E+00	[MJ]
WASTE CATEGORIES:				
HAZARDOUS WASTE	2,95E-03	[kg]	4,26E+00	[kg]
NON HAZAR WAST	1,70E-01	[kg]	1,02E+02	[kg]
RADIOACTIVE WASTE	6,44E-03	[kg]	2,33E-03	[kg]

L2-BaseClick comparison A1-A5

A1-A3

ENVIRONMENTAL IMPACTS:	L2: 1m2		Juunoo silentclick: 1m2	
GWP GHG	1,86E+01	[kg CO2	1,72E+01	[kg CO2
GWP FOSSIL	1,84E+01	[kg CO2 eq,]	4,84E+01	[kg CO2 eq,]
GWP BIOGENIC	-2,15E-01	[kg CO2 eq,]	-3,12E+01	[kg CO2 eq,]
GWP LULUC	5,13E-02	[kg CO2 eq,]	6,62E-02	[kg CO2 eq,]
GWP TOT	**1,83E+01**	**[kg CO2 eq,]**	**1,72E+01**	**[kg CO2 eq,]**
ODP	4,46E-07	[kg CFC-	5,64E-06	[kg CFC-
AP	2,78E-01	[Mole of	3,80E-01	[Mole of
EP freshwater	4,36E-03	[kg P eq,]	2,83E-03	[kg P eq,]
EP marine	2,86E-02	[kg N eq,]	5,91E-02	[kg N eq,]
EP terrestrial	8,47E-01	[Mole of N	1,15E+00	[Mole of N
POCP	8,66E-02	[kg	2,25E-01	[kg
ADP ele,	4,80E-04	[kg Sb eq,]	9,33E-03	[kg Sb eq,]
ADP foss,	2,97E+02	[MJ]	7,88E+02	[MJ]
Water deprivation pot	6,13E+00	[m³ world	4,76E+01	[m³ world
RESSOURCE USE:				
RENEWABLE ENERGY TOT	2,30E+01	[MJ]	6,08E+02	[MJ]
NON RENEWABLE ENERGY TOT	2,97E+02	[MJ]	2,16E+03	[MJ]
SECONDARY MAT,	4,82E-01	[kg]	3,71E+00	[kg]
RENEWABLE SEC, FUELS	0,00E+00	[MJ]	0,00E+00	[MJ]
NON RENEWABLE SEC, FUELS	0,00E+00	[MJ]	0,00E+00	[MJ]
USE OF FRESH WATER	1,50E-01	[m3]	0,315	[m3]
WASTE CATEGORIES:				
HAZARDOUS WASTE	2,81E-03	[kg]	4,25E+00	[kg]
NON HAZAR WAST	1,39E+01	[kg]	1,01E+02	[kg]
RADIOACTIVE WASTE	5,81E-03	[kg]	2,28E-03	[kg]
OUTPUT FLOWS:				
COMPONENTS FOR REUSE	0,00E+00	[kg]	0,00E+00	[kg]
MATERIALS FOR RECY,	6,67E-01	[kg]	3,00E-02	[kg]
MATERIALS FOR ENERGY RECO,	0,00E+00	[kg]	0,00E+00	[kg]
EXPORTED ENERGY ELEC	0,00E+00	[MJ]	0,00E+00	[MJ]
EXPORTED ENERGY THERM	0,00E+00	[MJ]	0,00E+00	[MJ]

L2-BaseClick comparison A1-A3