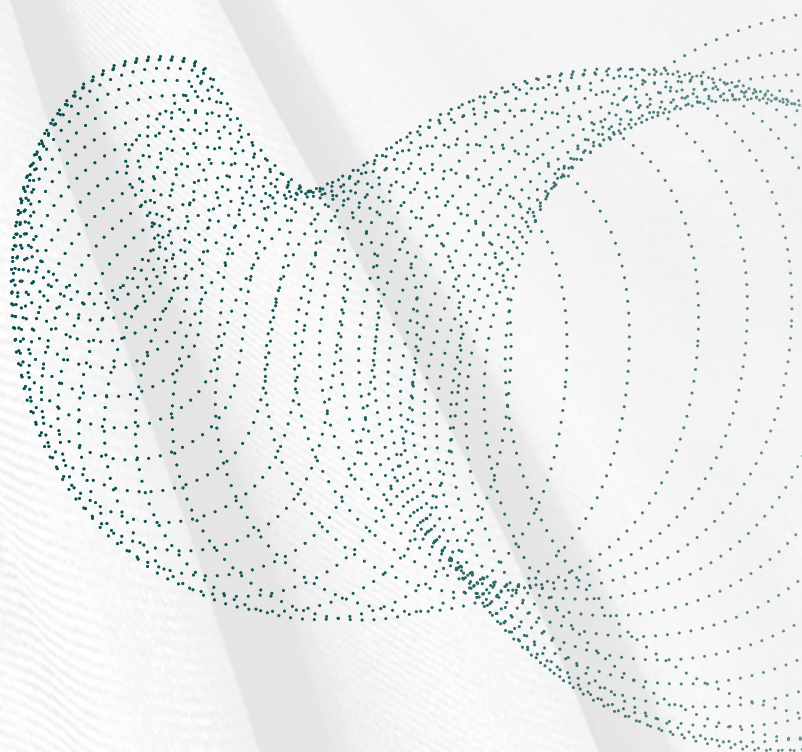




Automated take-back systems for suppliers and manufacturers: an efficient path towards a circular built environment

Scoping and implementation of automated take-back systems based on a digital platform for a wide array of construction products and materials.

February 2024

This white paper is part of the Circular Buildings Coalition's 'Blueprint Projects' initiative, which aims to support organisations that transform the built environment by addressing a key leverage point for change. The views, information, and opinions expressed in this publication are solely those of the author(s) and do not necessarily represent those of the CBC and its co-initiators. The author(s) is solely responsible for the content and accuracy of the information presented herein

The Circular Buildings Coalition (CBC) is a collaboration that convenes industry leaders who aim to accelerate the deployment of circular solutions as a way of securing a global built environment operating within planetary boundaries while ensuring a just transition. The CBC is an initiative of Metabolic, WorldGBC, WBCSD, EMF, Circle Economy and Arup. The CBC is funded by Laudes Foundation.

For more visit: circularbuildingscoalition.org

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About the Circular Buildings Coalition

The Circular Buildings Coalition (CBC) is an initiative formed to accelerate the transition towards a circular economy in the built environment in Europe. Its consortium and funders are Metabolic, Circle Economy, Arup, the World Green Building Council (WGBC), the World Business Council for Sustainable Development (WBCSD) and the Ellen MacArthur Foundation, and it is supported by the Laudes Foundation. The CBC brings together stakeholders from the built environment to overcome barriers and embrace sustainable practices.

About supply

Supply (ZupplySite ApS), a Denmark-based startup, was founded in 2022 with the primary objective of supporting companies in the built environment in their transition to circular economy business models. The company relies on a digital solution that creates digital twins for buildings and their resources, leveraging artificial intelligence (AI) to automate related circular resource flows.

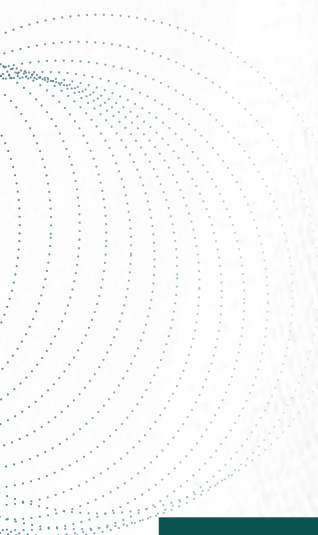
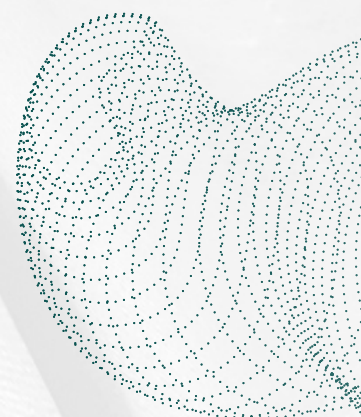




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Executive Summary

This white paper explores the feasibility, scoping and implementation of take-back systems for original manufacturers and suppliers of construction products and materials enabled by supply's digital automation platform.

The primary objective of this white paper is to describe how supply's take-back framework can unlock new circular resource flows for secondary materials, facilitate the connection and execution between supply (building owners) and demand (original manufacturers and suppliers) and as a result increase volumes, predictability and transparency in these processes.

Based on the fact that, if 'business-as-usual' continues, the construction sector in the EU27+UK is expected to exceed the carbon budget that it has been set in order to limit global warming to 1.5°C by 2026, the shift towards new circular business models has become crucial.¹

In partnership with the Circular Buildings Coalition (CBC), supply aims to be at the forefront of this transition.

"DENMARK'S ECONOMY IS ONLY 4% CIRCULAR"

Despite being at the forefront of sustainable development, only 4% of all consumed materials make it back to the economy, being the construction sector one of the most significant contributors for this circularity gap.²

The construction industry's current impact on global waste means there is an acute need to move away from traditional linear models. However, despite various initiatives promoting circularity, the sector's transition has been slower than necessary. Notably, the Circularity Gap Report highlights that Denmark, despite being at the forefront of sustainable development, has only achieved 4% circularity in its economy, with its construction sector being the most significant contributor to this lag. The sector has the highest material and carbon footprints in the country, underscoring the urgency for more effective circular practices.²

"supply digital platform leverages on digital twins and artificial intelligence (AI) to streamline circular resource flows in the building value chain. It emerges as a solid digital solution driving sustainability, efficiency and innovation."

Supply's solution addresses this gap by integrating digital-twin technology and artificial intelligence (AI), providing a comprehensive approach that can unlock new circular resource flows and streamline their implementation in the building supply chain. This not only contributes to waste reduction, but also ensures a higher-rated R strategy (reuse, refurbish, upcycle) for products and materials, while retaining higher values than achieved in standard waste-handling and recycling practices.

Drawing insights from real-world cases for our validation study, including collaborations with industry leaders such as Rockfon, Tarkett and Ikano Bolig, supply's platform for take-back systems has been scoped and designed to result in increased environmental, operational and economic benefits.

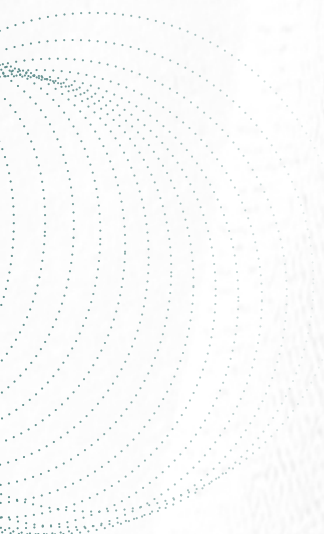


From an easy way of connecting the supply of existing resources from building owners with original manufacturers and suppliers, efficient tracking and automation of circular flows to substantial reductions in time and operational costs, the platform positions itself as a scalable enabler of efficiency, a better R strategy and higher circularity ratios for resources. The digital representation of products and materials enables transparent life-cycle tracking, fostering transparency and improved data sharing among users.

However, challenges to implementing take-back systems persist, such as initial investment risks, industry fragmentation, logistic barriers and consumer preferences. Supply's vision is clear – to overcome present barriers and set a standard framework for implementation of automated take-back systems among building owners with manufacturers and suppliers in the European market. This will be achieved by offering a digital solution that has a quick implementation process with a fast return on investment (ROI). Supply also aims to establish itself as a facilitator for the increased adoption of take-back systems throughout the value chain.

With existing partnerships and early interest from manufacturers, the platform anticipates rapid adoption and wide diffusion, driven by the positive network effect it can create. It aims to engage four major manufacturers within its first year of implementation (2024). Additionally, as part of the diffusion plan for the digital platform, supply aims to publicly share the lessons learned during the process, highlighting implementation guidelines, success factors and benchmarks. This transparency will enable other stakeholders to adopt take-back systems across other product lines or geographical locations.

As the built environment embraces circularity, supply emerges as a solid digital solution, driving sustainability, efficiency and innovation. This white paper navigates the opportunities and challenges, envisioning a future where supply's digital automation platform has changed the landscape of circular practices with take-back systems for the built environment across Europe.





Introduction

THE CONSTRUCTION SECTOR NEEDS TO ACCELERATE THE CHANGE TO CIRCULAR MODELS

The construction and building industry is gradually adopting more sustainable and circular practices and business models, yet this transformation is occurring at a slower pace than our urgent sustainability needs demand. While incremental change is the conventional approach in the industry, radical change is necessary to guarantee that humanity can remain within the planetary boundaries, as highlighted in research conducted by the Stockholm Resilience Center, particularly in the context of climate change and CO² concentration. The study reveals that the threshold for a safe operating space has already been surpassed, with the construction sector emerging as a primary contributor to this concerning trend.^{2,3}

Despite numerous initiatives and efforts aimed at moving away from the traditional 'take-make-dispose' model and embracing circularity, the built environment sector continues to be a significant contributor to the global waste problem. In the EU, for instance, construction and demolition activities still account for a substantial 25-30% of all waste generated.⁴

OTHER RECENTLY ADOPTED SOLUTIONS HAVE LIMITED IMPACT COMPARED TO TAKE-BACK SYSTEMS

While various solutions have been tested within the building and construction industry to establish a more comprehensive circular value chain, the majority of these solutions focus on circular resource flows of secondary materials, without involving the original manufacturers or suppliers in the process, a notable difference from the practices adopted by other industries.

For example, industries like electronics, packaging, retail and fashion have employed higher R strategies in the value chain by involving the original manufacturers or suppliers through take-back systems. These are systems and business models where suppliers and manufacturers reclaim their products or materials at the end of their current usage or at end-of-life. The objectives of these take-back systems are to reduce environmental impact, find new business opportunities, increase operations efficiency, reduce virgin material consumption and lower costs.

'The construction sector requires a **radical change to stay within planetary boundaries**'

Despite the numerous initiatives and efforts aimed at moving away from traditional "take-make-dispose" models, in the EU the construction and demolition still account for

25%-30%
of all waste generated.

"Circular solutions adopted in the construction sector differ from other industries like electronics, packaging retail or fashion where **original manufacturers and suppliers are involved**"

Take back systems: systems and business models where suppliers and manufacturers reclaim their products or materials and bring them back to value chain to reduce environmental impact, virgin resources consumption and costs.



ADOPTION OF TAKE-BACK SYSTEMS IN THE CONSTRUCTION SECTOR HAS BEEN SLOW

Despite the observed operational, financial and environmental benefits in other industries, the adoption of take-back systems within building and construction has been limited, primarily due to the lack of incentives for both sides of the value chain – the resource owners (mainly developers and building owners) and the original manufacturers and suppliers.

Additionally, a major challenge limiting the adoption of take-back systems at scale is the fragmentation of efforts within the industry. Most initiatives tend to be isolated, led by a few key players, and lacking integration and efficiency across the entire value chain. For instance, as revealed in our desk study and interview process, government agencies or building owners and developers often attempt to identify products and materials within existing buildings or new constructions that could be repurposed or find a second life in secondary markets or with other users. While these efforts have shown promise, they also often present additional challenges, because they tend to exclude the original manufacturers or suppliers of these products and materials.

INVOLVING ORIGINAL MANUFACTURERS AND SUPPLIERS WITH TAKE-BACK SYSTEMS OFFERS HIGHER BENEFITS FOR THE VALUE CHAIN

It can be concluded, based on the study we conducted, that establishing take-back systems can result in greater benefits, as original manufacturers and suppliers are better positioned in terms of data on their own products and materials – particularly data about guarantees, testing and design – as well as instructions for handling and logistical, commercial and environmental aspects. Similar benefits have been observed in other industries and described in the below sections.

However, another outcome of the study was that due to the high initial investment of resources required, take-back systems face additional difficulties when trying to scale across different products/materials or locations.

Adopting circular business models currently have a slow adoption due to:



Lack of incentives for stakeholders.



Effort fragmentation between different players in the value chain with lack of integration and data sharing.



Isolated initiatives do rarely include original manufacturers or suppliers.

Advantages of integrating manufacturers and suppliers in the circular value chain through take-back systems:



Knowledge about testing and guarantee procedures.



Capability for resource handling and logistics.

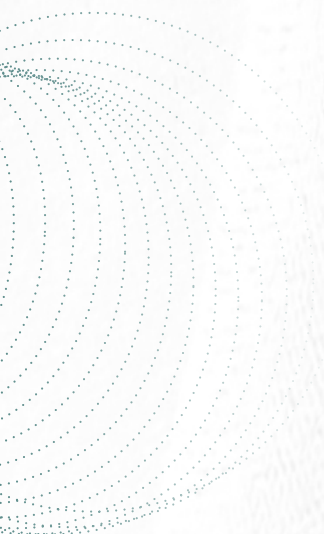


Data and considerations on their own products and materials.



This white paper will outline the scoping, development and implementation process and prove the business case at scale of a take-back system enabled by zupply's digital automation platform. It will also cover the benefits (operational, environmental and financial) and associated risks and challenges. The white paper will describe in detail two specific product and material take-back cases that could be automated with zupply's platform. These cases are ceiling panels for acoustic insulation and modular roofing and flooring elements made mainly from wood. The platform has also been evaluated for other construction products and materials such as lighting fixtures, windows, façade elements and metal load-bearing beams, which will be touched upon, too.

While this white paper initially focuses on the scoping and implementation of specific product or material cases for the purpose of validating zupply's platform, its broader objective is to outline the requirements, benefits and business case of developing and implementing take-back flows at scale with digital tools across diverse product and material lines and in different geographical locations.





Background

Supply is a Danish startup that provides a software automation platform designed to support companies in the built environment in their transition towards adopting circular business models and practices. Further details can be found at <https://supply.site>, and the platform can be accessed at <https://app.supply.site>.

The platform's primary value proposition is to streamline circularity efforts across various industry players by automating manual processes and workflows that traditionally demand significant resources and limit the business case of circularity and scalability. Supply's core technology involves creating digital twins (virtual representations of buildings and their resources that provide data and collaboration capabilities beyond standard material passports) and automating circularity workflows using AI.

Supply's platform has been developed in modules to accommodate different user cases and circular workflows (including resource mapping, external exchange and resale of resources, internal project resource management, reporting data and analytics). One of the current use cases focuses on automating workflows to map all available resources within existing buildings and recommend optimal circular options (repurpose, upcycle, reuse or recycle) for these resources' second life. During the real-world implementation of this software module with customers, it became apparent that the available circular options were sometimes limited due to a lack of available supplier/manufacturer data and uncertainty about how to dismantle, handle, test and process the resources efficiently.

This situation became particularly evident during the early planning stages of the circular flows and resource mapping process for a project in Denmark's Høje Taastrup municipality: the conversion of a group of decommissioned buildings with an approximate built area of 22,000 m², previously the site of the old town hall, into housing units.

The project is led by developer Ikano Boling (<https://www.ikanobolig.dk>), with Lendager architects (<https://lendager.com>) serving as experts in working with circular economy practices, and supply acting as the provider of the software platform to automate workflows from initial mapping up to achieving circularity.

The project is part of the EU's CityLoops initiative and has as its primary objective to showcase how building projects can minimise waste by reusing existing resources, mainly internally – within the project or building portfolio – but also externally. The current circularity benchmark for the project is set at 70% of the resources in the existing buildings becoming circular. It has been recognised that to achieve this goal, it is crucial to develop additional circular options for resource flows such as supplier/manufacturer take-backs, considering the current limitations of internal reuse or external resale in marketplaces.

"To achieve the highest level of circularity for our building's existing resources, we must explore innovative resource flows beyond internal reuse or external resale. Engaging suppliers and manufacturers through take-back programmes for their resources could present a sustainable and valuable business opportunity."

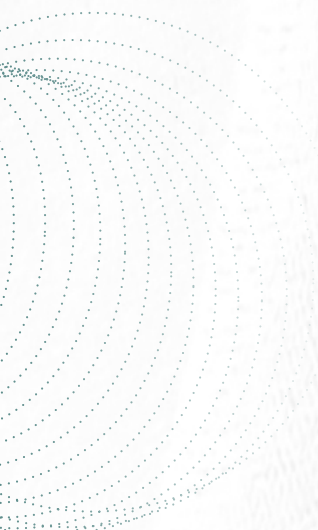
- Lone Lindgård Laursen, sustainability manager,





Having identified this disconnection between existing resource flows and their original suppliers and manufacturers in the circular value chain, supply formulated the hypothesis that the original suppliers and manufacturers, as the stakeholders with the highest potential for circularity and return on investment, are most effective in preventing resource waste through take-back initiatives and reintegrating these resources into the value chain.

This led supply to undertake a validation study and implementation process to scope and evaluate whether a digital tool for automating take-back systems could efficiently address this challenge at different scales.





Validation study

SCOPING, IMPLEMENTING AND EVALUATING BENEFITS AND CHALLENGES OF A DIGITAL SOLUTION TO ESTABLISH AND SCALE TAKE-BACK SYSTEMS

Methodology

Desk study

based on current needs, efforts and available solutions for take-back systems.

Interviews

with circular experts to validate our desk study and define guidelines and requirements for digital solution.

Design sprint

with two selected manufacturers to define scope and technical and process requirements.

Development

of minimum viable product for digital solution for feedback and early functionality tests.

The validation process started with a desk study focused on current needs, efforts and solutions related to take-back systems. This study examined companies within the built environment working on circular economy business models or with established take-back systems. It also considered companies outside the built environment that provide solutions to facilitate the transition of circular business models, with the primary focus on take-back systems. The desk study's main findings and key learnings are described under 'Results' below.

After completing the desk study, a series of interviews were conducted with circular economy experts, both from within and outside the built environment. The interviews aimed to further validate the current efforts, solutions and lessons learned related to take-back systems. These interviews were the basis for determining the requirements of implementing take-back systems for building resources based on digital solutions and ensuring their viability and their potential to increase circularity within the industry. Additionally, the interviews contributed to profiling some of the companies that will be best suited to establish or scale a take-back system within the industry. Interviews also helped identify the potential challenges, risks and opportunities to be considered when implementing take-back systems using digital solutions. Lessons learned and key implementation requirements for the digital solutions obtained from the interviews can be found under 'Results' below.

Subsequently, two specific cases were selected to scope a take-back system based on a digital solution and to explore the related benefits, risks and challenges of implementing it. Design sprints were conducted with the two companies involved, and the business and environmental case was defined. The operational benefits of implementing the take-back system using the supply automation platform as the technology provider were also examined. The design sprint process and its outcomes are detailed below under 'Results'.

Finally, the digital solution created in the design sprints was developed into a minimum viable product (MVP) and feedback sessions were conducted with the two selected companies. The MVP was built on the current technology offering of supply's platform, modified specifically to work as a take-back solution. This tailored MVP has been used for feedback purposes and further implementation within other use cases. A detailed description of the digital solution is provided in section 'Solution overview', while the feedback and related challenges, risks and opportunities are described below under 'Results'.



Results

KEY PRACTICES AND TRENDS IN ESTABLISHING CIRCULAR RESOURCE FLOWS IN THE BUILT ENVIRONMENT

Circular business models implementation in the built environment maturity level is low	It has been observed that many companies within the built environment are in the process of transitioning to circular economy business models. However, current efforts are often limited to or primarily reflected in sustainability strategies. Notably, there are not many widely adopted or scaled circular programmes; the manufacturer and supplier cases that extend beyond strategy are predominantly coming from large enterprises such as Rockwool, Saint-Gobain, Holcim and Tarkett.
Circular resource flows mainly focus on recycling (a low R strategy); not many cases focus on upcycling or reuse	Current circular flows identified by manufacturers and suppliers predominantly focus on lower R strategies such as recycling, rather than repurposing, upcycling or reuse. Notable examples for this include Rockwool's Rockcycle, Knauf Insulation's RESulation, Velux's take-back of their windows and skylights primarily for recycling of materials, and Holcim's ECOPact concrete recycling setup.
Startups and small manufacturers are leading the way in circular efforts	A significant portion of the identified circular flows and take-back initiatives originates from small manufacturers. This suggests that larger companies face higher barriers when transitioning to circular business models due to higher investment requirements and bigger logistics and production changes. Smaller manufacturers and startups, on the other hand, are well-positioned to establish more comprehensive circular setups as a key value proposition. Some examples include A:gain, a Danish manufacturer of building materials focusing on reclaimed waste, NeoLitik, a French company specialising in concrete products crafted from 100% recycled materials, and Mater, a Danish furniture design company with a circular closed loop and take-back system and a focus on manufacturing with reclaimed materials.

Table 1: Summary of key practices and trends in establishing circular resource flows in the built environment



CURRENT DIGITAL SOLUTIONS ENABLING TAKE-BACK SYSTEMS

Offering digital solutions has accelerated the shift to circular economy practices in both the built environment and other industries, including some cases of take-back systems. Noteworthy examples include:

“Digital solutions pave the way towards the circular transition”

Concular (Germany), <https://concular.de>:

This company focuses on facilitating circular economy business models for building materials, working with resource mapping tools and a marketplace/material bank solution. A key aspect is the company's contribution to establishing a reclaiming process, similar to a take-back system, for bricks. These reclaimed bricks are then made available for reuse with involvement of the manufacturer, presenting not only a more sustainable option but also a competitive business case. This case underscores the fact that take-back systems can offer benefits beyond sustainability, extending into a competitive business proposition.

Continued (Denmark), <https://continued.fashion>, and **Lizee (France),** www.lizee.co:

Operating in the fashion industry, these startups have played a crucial role in helping companies adopt buy-back, rental, and product-as-a-service solutions through digital means. These examples demonstrate that working in partnership with large enterprises and assisting them in their circularity transition can significantly mitigate challenges and barriers of entry, and expedite the process by leveraging outsourced digital solutions.

Examples in the packaging and electronics sectors:

Many startups in the packaging and electronics sectors were found working with reclaiming or take-back systems based on digital solutions. The main insight here is that typically the main manufacturers or suppliers have a better understanding of their products and the related design and supply chain, making it convenient for them to set up take-back systems.



LESSONS LEARNED AND KEY REQUIREMENTS TOWARDS ESTABLISHING DIGITAL TOOLS FOR TAKE-BACK SYSTEMS IN THE BUILT ENVIRONMENT

A series of interviews with experts in circular economy, business operations and sustainability from various companies within the built environment, including manufacturers and building owners, aimed to define the requirements for digital tools and gather related lessons learned. Further details of the interviewees can be found in the appendix under 'Sources and references'. Results are described below.

Lessons learned; potential barriers and challenges	Requirements for digital take-back platforms during development and implementation
Manufacturers have difficulty managing data and maintaining transparency and privacy, but have access to more accurate information with verifiable sources, including: • design requirements • installation and dismantling instructions • quality assessment and sorting instructions • environmental data (EPD or established calculations) • cost and pricing structures • guarantees and testing	a. Ensure transparency of data flows based on reliable sources, e.g. provided by the manufacturer (EPD, cost and pricing structures, design specs, dismantling and sorting instructions) b. Provide a centralised data source with established roles for inputting, sharing, modifying and accessing data c. Provide live and dynamic tracking of CO and costs for every circular resource flow – do not generalise data but collect it separately for each resource
Usability and awareness of resource owners at building sites is paramount.	a. Create a web-based tool or an app that can be used with a standard mobile phone or computer b. Make sure that using the tool is an efficient process without requiring users at sites to spend too much time to map and create requests for resources to be taken back c. Pool take-back options from different suppliers and manufacturers in one platform, as it will be difficult to provide access to several platforms or different workflows



Lessons learned; potential barriers and challenges	Requirements for digital take-back platforms during development and implementation
	d. Provide an easy-to-use platform that does not require an extensive onboarding process e. Include instructions for platform usage or handling resources within the platform itself
Financial and environmental incentives need to be clearly defined.	a. Provide a decision-making calculation for every resource's potential take-back. This should consider costs vs potential benefits b. Help manufacturers/suppliers calculate the financial and environmental gains of taking back specific batches of resources
Logistically, the platform should be easily integrated into current tools and processes; related logistical costs should not outweigh the benefits (financially, operationally and environmentally) of taken-back resources.	a. Integrate with the current tech stack for e-commerce and/or logistics b. Consider adaptability with current logistics operations (take-back requests might be treated as a product return in the currently established supply chain)
Sustainability efforts suffer from a fragmentation of efforts between resource owners and manufacturers/suppliers.	a. Provide a platform that enhances collaboration and sharing of data between all parties b. Provide a functionality for easy two-way communication
There are scaling challenges and requirements for other customers, product lines or geographical locations.	a. Use a modular approach when building the digital solution, so it can be easily customised for different product lines or markets. (A modular product approach refers to the software development framework set for scalability, where there is no need to customise workflows for each new user – instead the software can be onboarded without intensive new development resources.)



Lessons learned; potential barriers and challenges	Requirements for digital take-back platforms during development and implementation
There is a lack of standards for testing and guarantees.	a. Include recommendations or guidelines on testing to ensure proper guarantees b. Ensure the platform's module provides as much data as possible related to resources, such as years of usage or type of building
The take-back process needs to be efficient (not time-consuming for users)	a. Minimise time requirements by ensuring the platform automates tasks that are currently carried out manually, resulting in operational benefits Tasks that should be automated include: - easy matching and communication between building owners and manufacturers - site quantification, inspections and testing - manual calculations - communication and data exchange - LCA and cost tracking

Table 2: Lessons learned and potential barriers and challenges, and how digital platforms can overcome these challenges

DETAILED SCOPE AND IMPLEMENTATION OF TWO SPECIFIC TAKE-BACK SYSTEMS

Based on the previously described generic requirements, two main cases were selected for a design sprint involving scoping, designing and developing a take-back system based on a digital solution.

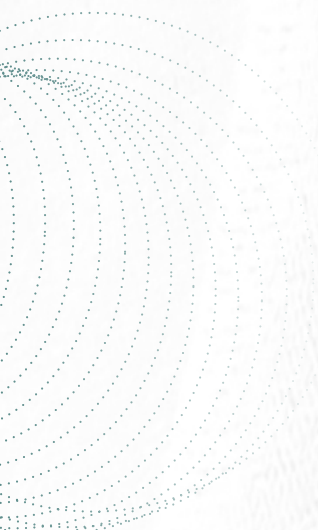
These particular cases were chosen because they were expected to offer valuable lessons learned and promised significant benefits upon implementation. To create a replicable framework that can be applied throughout the value chain, the two selected cases differ significantly in scale, one representing a large enterprise and the other a small-sized manufacturer. This approach allows for a broader range of insights and potential for scalability.

The design sprint approach was chosen as both companies had similar circularity requirements – both needed support with the implementation of take-back systems – but their specific needs for implementation differed, providing the advantage of having an enhanced learning process and greater potential for benefits.



The companies selected for a design sprint were:

- Rockfon (www.rockfon.com), a global manufacturer of acoustic ceiling and wall solutions based on mineral wool. The design sprint focused on designing and scoping a solution that would help them automate and scale their current efforts related to the take-back of ceiling panels from existing buildings for reuse, refurbishing or recycling.
- Rexcon (www.rexcon.dk), a Danish manufacturer of modular building elements – mainly load-bearing wall elements – made largely from wood. The design sprint covered the design and scope of a solution for future product take-backs. Given the small size of the company, Rexcon's goal is to establish a full circular resource flow for its products starting from the moment the products are manufactured or sold. The company's approach is one of proactive waste prevention and its design concept includes ensuring that all products can be reused.





DESIGN SPRINTS: PROCESS AND OUTCOMES

DESIGN SPRINT 1: ROCKFON CASE



Rockfon's Case: take-back of acoustic ceiling panels in existing buildings

Focus product: acoustic ceiling panels

Main purpose of take-back: reuse, recycle and/or refurbish

Sprint participants:

Internal sustainability, circular economy, design and business development representatives and external partners including facility owners/managers and potential new users for the materials after take-back

Digital solution-specific requirements established during the sprint:

- Two-way platform involving both parties (Rockfon and facility owner)
- Automated product identification workflow, including filtering by building type and workflow for assessing resource type and condition
- Location-based approach: every building containing materials to be taken back should be located within a specified distance range of the potential take-back location (to be defined in detail in later stages)
- Dynamic calculation (to take into account life cycle and cost assessment) and tracking of environmental and financial aspects
- Capability for integration with internal logistics and inventory management
- Capability for creating digital inventories of products taken back to be offered to different potential users/partners
- Custom dashboard for data and analytics for reporting and optimisation purposes
- Custom roles and access rights to ensure data transparency and privacy
- Upgrade material passport into a more collaborative and dynamic digital representation of resources



Expected benefits of taking-back materials and of a digital solution:

Business Case:

For each batch of resources that is taken back, a portion is directly reused as new with minimal cleaning measures, another portion is refurbished (details to be defined during implementation), and the remaining portion is recycled. It is estimated that the majority of the ceiling panels that are taken back have many years of use left. Therefore, the majority of panels (around 50% to 75%) are expected to be directly reused or refurbished after cleaning. Damaged or unsuitable ceiling panels will be recycled, reducing overall waste generation in the take-back operation to zero.

The primary proposition is thus to resell used panels that are in an as-new condition, but with much reduced embedded CO₂. In addition, reusing reclaimed parts for new productions is financially attractive, too: the costs for producing ceiling panels with new virgin materials are significantly higher than using reclaimed materials for newly produced panels. In the light of that saving, the expenses of reverse logistics were deemed negligible.

From the outset, building resource owners showed interest in sending back their resources to manufacturers as this represents an opportunity to receive credit at the manufacturers and save on waste handling fees, which typically range from €200 to €400 per tonne of waste.

Environmental benefits:

The following is a scenario analysis of the CO₂ impact of installing newly manufactured ceiling panels on an area of 1000 m² in comparison to the take-back scenario for the same area.

Product type	Standard ceiling panel (avg. 20 mm thickness)
Batch Area	1000 m
Embedded CO₂ when purchasing new panels with standard production	1584 kg CO ₂ eq
Avoided embedded CO₂ when purchasing reused panels after take-back	1667 kg CO ₂ eq
R strategy	50% to 75% of take-back products are expected to be cleaned or refurbished and then reused as new. The remaining is to be recycled to achieve a zero-waste operation.

Table 3: Environmental benefits summary based on Rockfon's EPDs.⁵

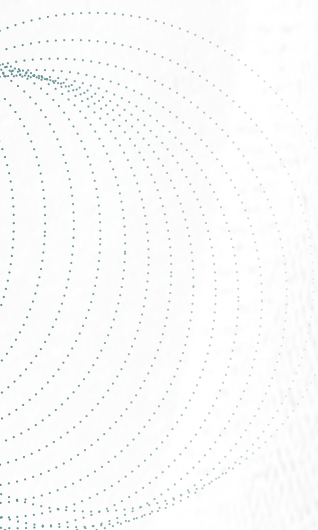


Main operational benefits:

- An estimated 30% reduction in work-hours compared to current take-back efforts, where tasks relating to removing used materials and transporting them to manufacturers/suppliers' premises are carried out manually. This calculation is based on take-back tests that have been conducted without using a digital platform
- - Increased transparency of data due to data-based decision-making in response to take-back requests
- - Quick implementation and scalability to other product lines or markets owing to a modular design approach to software development
- - Automated report generation and data/analytics processing
- - Facility owners and Rockfon can quickly identify and assess the condition and value of materials in take-back requests
- - Simple, secure and transparent collaboration and data sharing between manufacturers and building owners

“We have scoped a solution based on zupply’s technology that will move ahead from localised take-back efforts to a potentially scalable process.”

- Kasper Vibæk, head of sustainability and public affairs,  **Rockfon**.





DESIGN SPRINT 2: REXCON CASE



Rexcon's case: establishing a digital twin and a system for future take-back of products that is effective from the day of production or sale

Focus product: new ReBLOCK products (modular wood-based load-bearing wall elements)

Main purpose of take-back: reuse or refurbish

Sprint participants:

Management,
manufacturing, sales and
design representatives

Digital solution-specific requirements:

- Two-way platform involving both parties (Rexcon and facility or building owners)
- Physical identification (RFID/QR tag) to create a connection between physical and digital representation (digital twin)
- Automated circular maintenance, retrofit or take-back flows with digital representation of every ReBLOCK system
- Location-based approach: every building containing materials to be taken back should be located within a specified distance range of the potential take-back location (to be defined in detail in later stages)
- Dynamic calculation (to accommodate life cycle and cost assessment) and tracking of environmental and financial aspects
- Capability to integrate with internal logistics, inventory management, e-commerce stack and design tools (such as BIM)
- Custom dashboard for data and analytics for reporting and optimisation purposes
- Custom roles and access rights to ensure data transparency and privacy



Expected benefits:

Business Case:

Rexcon's unique value proposition is that every product sold is digitally represented and can be tracked along its life cycle for digital maintenance and retrofitting purposes until it is taken back by the manufacturer. It is calculated that the sales price for ReBLOCK systems can be higher, with lower operational costs for circularity.

Main operational benefits

- Ability to track product flows in the value chain from day one using supply's platform for data tracking
- Support for the unique selling proposition that all products are digitally represented with a connection to a physical QR or RFID tag, enabling collaboration between user and manufacturer
- Increased transparency of data due to data-based decision-making in response to take-back requests
- Quick implementation and scalability to other product lines or markets
- Automated report generation and data/analytics processing
- Ability of facility owners to quickly scan RFID or QR codes, identify their products and create take-back and circular maintenance requests

Environmental benefits

ReBLOCK systems have been designed to maintain their value through their lifetime. In accordance with the EU Waste Framework Directive, there is a focus on preventing waste by ensuring readiness for direct reuse during their extended product life.⁶

Having a digital twin for every ReBLOCK system will ensure proper traceability and transparency throughout their life cycle. The ReBLOCK system has been designed to be circular and produced with sustainable materials. Implementing a digital twin and a take-back system will maximise its environmental benefits. Traceability is crucial: one of the design sprint's conclusions was that any product that is not properly tagged and tracked will eventually become waste.

“Supply's digital-twin technology will enable us to create a digital representation of our products, thereby enhancing our circular product offerings, including take-backs.”

- Jesper Sørensen,
CEO and admin director,

REXCON



IMPLEMENTATION AND DEVELOPMENT OF MVP

Based on the design sprint outcomes, a minimum viable product (MVP) was developed by the supply team for a generic user case including the minimum platform requirements for a working take-back platform. This MVP and its planned future development is described in Section 'Digital solution overview'. It does not currently include integration with an e-commerce or logistics tech stack but it does cover the minimum requirements.

Other features and modules developed and reflected in the MVP were only presented for feedback purposes. They were further tested in feedback sessions with additional products, including manufacturers of lighting fixtures, windows, façade elements and metal load-bearing beams.

Valuable outcomes on the MVP feedback sessions from other use cases were:

- **Window manufacturers:** Digital twins and automated take-back can work and automate reverse logistics for windows and skylights. However, there are many products that have already been sold, and traceability of their data is no longer possible. In order to work properly, the digital solution would need to establish an efficient way of mapping existing windows and tagging new ones. The main business case for manufacturers involves retaining the main frame of a window and 'reglazing' – replacing the glass components. This makes take-back an affordable and more sustainable option. Early talks with one manufacturer, Velux, have commenced.
- **Lighting fixtures manufacturers:** Creating a specific digital twin for each lighting fixture (bulbs, lamps etc) is not economical, but linking the fixture to a digital twin for an entire building's lighting system can be valuable, forming the basis of digital maintenance and enabling take-back of complete batches for reuse or recycling. There would need to be a good balance between the amount of data needed and the use of it. The main business case is that this will open up opportunities for more affordable and sustainable components and for establishing a product-as-a-service framework, which is already being tested in similar applications. Early talks with one manufacturer, Fischer Lighting, have commenced.
- **Façade elements:** Creating a digital twin and automated circularity flows is one of the company's current requirements as Arup transitions into product-as-a-service and digitally enabled maintenance models. The first step towards setting up a product-as-a-service model is establishing a proper closed loop via take-backs. The main business case is that the façade typically has the highest levels of embedded carbon in a building, while making its elements circular does not require a significantly costlier process than the rest of the building. Early project talks with one supplier of façade elements, Arup, have commenced.
- **Metal load-bearing beams:** Automating take-back and reuse flows of structural beams is convenient for higher reuse ratios; however, the engagement should be between the resource owner or demolition company and potential other users. Since these products are typically standard-built, it might not be necessary to engage the original manufacturer or supplier. The main business case is that the reuse potential will be a higher R strategy than recycling, representing higher savings for the builder or resource owner.

Digital solution overview

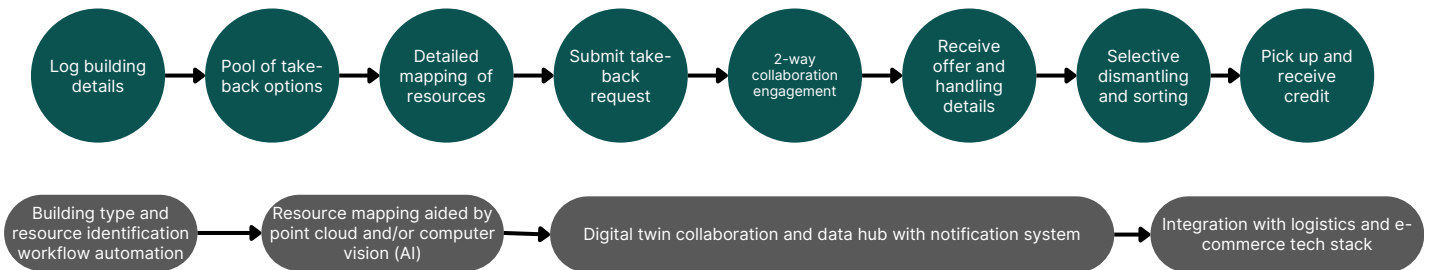
What is the take-back automation module in zupply's digital platform?

The take-back automation module is designed and developed as an MVP to function as a two-way platform.

RESOURCE-OWNER SIDE:

This module helps facility managers or building owners to create a digital twin of their building by mapping the existing resources from buildings that are to be renovated, retrofitted or demolished, and to work with a pool of manufacturer and supplier options towards a potential take-back of resources. This side is based on a modified version of the digital-twin creation and collaboration workflow already developed and tested by zupply. Figure 1 below represents the basic user flow on the resource-owner side:

Building owner or facility manager user flow



Main platform workflows and features for resource owner's side

Figure 1: User flow for resource-owner side

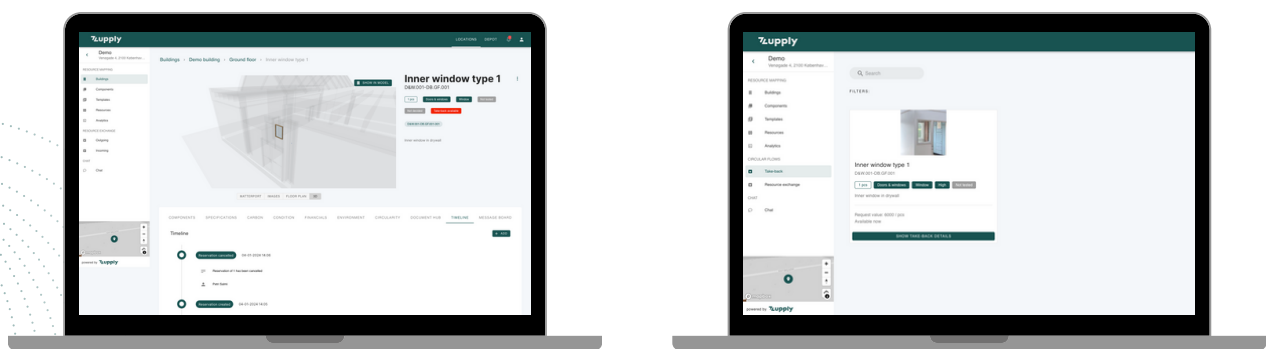


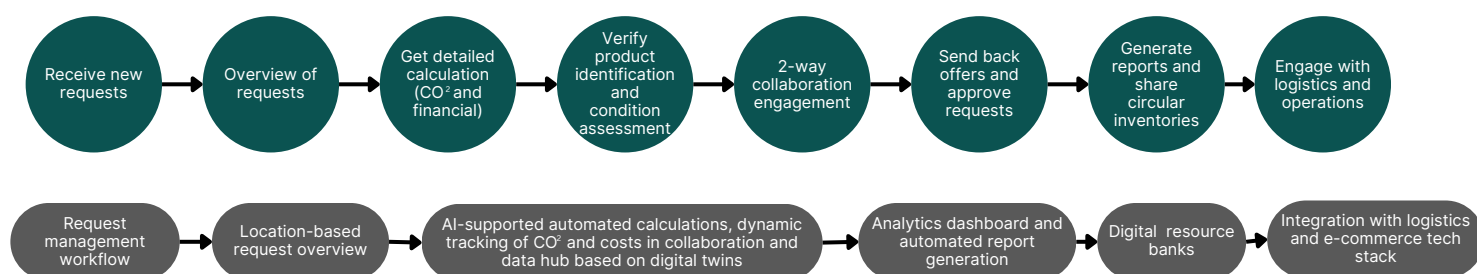
Figure 2: are screen shots of the digital twin of resource to be sent back as per the platform workflow



SUPPLIER-AND-MANUFACTURER SIDE:

This module's core functionality is to be the back office and collaboration/data hub for manufacturers and suppliers to manage take-back flows and evaluate take-back requests. It includes functionalities supporting suppliers and manufacturers to work with resource owners to achieve efficient take-backs and provides financial and environmental data for decision-making and reporting purposes. Specific resource requests are managed with a modified version of supply's platform and a newly developed back-office interface.

Manufacturer take-back user flow



Main platform workflows and features for manufacturers's side

Figure 3: User flow for original manufacturers and suppliers

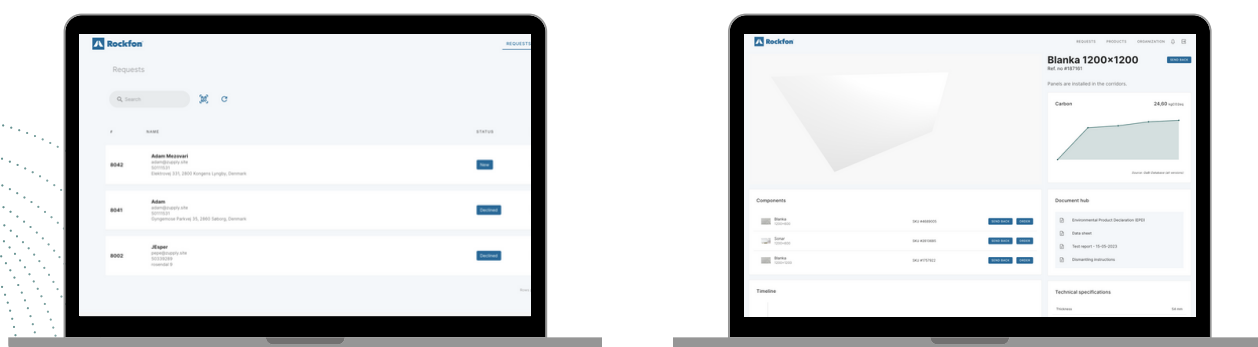


Figure 4: screen shots of the back office to be used by the manufacturer. It has been customized for Rockfon in the picture.

The take-back automation module has been designed as both a stand-alone digital product and as a separate software module for seamless integration with other elements of supply's circular automation platform.

The main value of the platform is that it facilitates the collaboration of suppliers/manufacturers and resource owners, focusing on the efficient reclaiming of products and materials from existing buildings set for demolition, retrofit or renovation, as well as from new construction sites.



At its core, the take-back workflow automation is a location-based, web-based software application. The application creates digital twins for each product or material that act as virtual representations, making it easy to track and manage the products throughout their life cycle and take-back process.

The key aspect of the take-back automation system is setting up tailored workflows for retrieving products and materials efficiently. These automated workflows should streamline the mapping, assessment, quantification and tracking of resources. They should also enhance user collaboration and significantly improve the entire take-back process. The platform's automation capabilities and modular design approach mean it can enable a scalable implementation for different use cases.

Findings: opportunities and barriers

As demonstrated in the two sprint cases and other feedback sessions, implementing a take-back system for building products and materials with supply's digital platform presents financial, environmental and operational opportunities. Firstly, the representation of products in a digital twin facilitates efficient and dynamic tracking throughout their life cycle, enabling monitoring from mapping or initial purchase all the way up to the eventual need for take-back. This transparency and automation ensure a streamlined process for both manufacturers and building owners. Secondly, a digital platform can automate and optimise circular flows, reducing manual tasks and resource consumption. It was estimated that this process could reduce up to 30% of the time currently spent on these tasks. Thirdly, the potential for increased circularity contributes to sustainability goals, offering environmental benefits by minimising waste and reducing the demand for virgin materials. Additionally, a well-designed digital platform allows manufacturers to establish take-back systems that extend the lifespan of their products, increasing customer loyalty and attracting environmentally conscious consumers. This was reflected in the business case findings, where it was shown that the selling proposition could be upgraded to 'lower embedded carbon' or 'circular-first products'. Finally, the data-driven insights provided by digital twins can offer details on each resource flow, enhancing the transparency and circularity of building resources in general.

While there are significant opportunities associated with implementing a take-back system, several barriers must be addressed. One primary challenge is the initial investment required for the development and integration of digital platforms, leading to manufacturer hesitation due to concerns about financial feasibility and incentives. Ensuring collaboration and data-sharing among stakeholders in the building supply chain is essential but can be hindered by existing industry fragmentation and competition. The complexity of managing diverse product lines and materials is another barrier, requiring careful consideration of the varied properties and conditions of different resources for the creation of a comprehensive and scalable take-back system.

Overcoming consumer habits and preferences for new products rather than refurbished or recycled materials may be a hurdle in achieving widespread acceptance of take-back systems. Lastly, logistical, regulatory and legal frameworks and processes must be adapted, with the leadership of original manufacturers, to accommodate the innovative nature of digital take-back systems, ensuring compliance, guarantees and legal and sustainability clarity for all parties involved.



Why automate circular resource take-back flows with supply's digital solution?

Automating circular resource take-back flows with supply's digital solution offers significant advantages. By providing a centralised pool of options for building owners, the platform creates a network effect. When undertaking circular projects, using digital platforms such as supply could significantly increase circular opportunities and scalability. The centralised approach streamlines the process, fostering collaboration and ensuring a more efficient and interconnected circular value chain. Supply's digital solution facilitates the identification of products and materials suitable for take-back, improving the overall visibility and accessibility of circular options within the built environment.

Furthermore, the decision to automate with supply is further encouraged by the platform's proven track record of a quick return on investment when other platform's modules are being implemented by other clients. With low implementation costs and a rapid deployment process, building owners and manufacturers can experience fast and tangible benefits (operational, financial and environmental). The efficiency gains and resource savings achieved through supply's digital solution contribute not only to the bottom line but also to the overall sustainability goals of an organisation. As a result, the digital automation platform presents a compelling business case for the adoption of circular practices within the built environment.

Impact objectives

The goal of this paper is to set a framework for establishing take-back systems based on digital solutions in the European market. Additionally, supply's vision is to establish itself as the go-to platform for implementing these solutions. Supply has already secured customers and partnerships for its current digital product offering in Finland, Denmark, Canada and the UK. By expanding the product offering to include take-backs for manufacturers and suppliers, supply aims to create a network effect, especially by including major companies such as Rockfon, which has a global presence. This strategic alignment allows supply to scale alongside these industry leaders. Anticipating strong engagement within the first year of implementation (2024), supply aims to onboard four different manufacturers, all of whom have expressed interest in the platform.

The cases selected for the design sprint, Rexcon and Rockfon, demonstrate that implementing a take-back system has the potential to result in scalable financial, operational and environmental benefits for all key players involved. In addition to these selected cases, the global flooring manufacturer Tarkett (www.tarkett-group.com) has also provided a letter of intent for implementing take-back with supply, showcasing the positive network effect that a digital platform can create.

This expansion positions supply as a pivotal player in driving the adoption of circular practices within the built environment. The strategic partnerships and early interest from manufacturers emphasise the platform's value proposition, indicating a promising trajectory for supply to become a key enabler of sustainable and circular business models across Europe.



Current status of supply's take-back digital platform

The first version of the take-back automation module has been developed and utilised as a minimum viable product (MVP) for validation with the help of customer interviews and design workshops.

Following the implementation of user feedback, an iterative version has been deployed and tested for basic functionality with actual data in existing buildings, but for limited product types with semi-automatic workflows.

While the initial focus has been on core functionality, integrations with other platforms and systems from the supplier/manufacturer side have been scoped but not yet developed. The main reason for this is that the basic workflow functionality can be achieved independently as a stand-alone. Forthcoming development will prioritise integrations based on specific customer needs.

Letters of intent from Rockfon, Rexcon and Tarkett have been received in connection to a pilot project in the Danish or Finish market for certain product lines. After completion of the pilot project, its potential to scale it to other markets or product lines will be evaluated. A letter of intent of Ikano Bolig in the role of facility owner has also been received.

The back-end technology at the core of the take-back automation module is built upon the existing product offerings within supply's platform. This technology has undergone extensive testing in various workflow automations related to circularity and has been specifically adapted for the purpose of this module.

Remaining challenges

Despite the learnings in the feedback sessions and the creation of iterative versions for the MVP, some challenges are still remaining and will need to be mitigated during implementation:

Technical

- Integrations need to be further developed to ensure smooth compatibility with e-commerce and logistics processes.
- The balance between customisation options and scalability for the solution needs to be further evaluated.

Legal

- Testing and guarantees policies and guidelines need to be further defined following consultation with selected manufacturers.

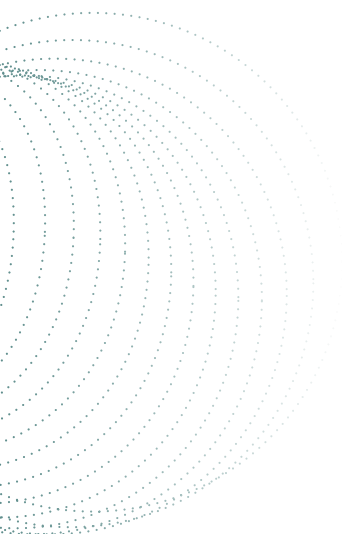
Logistics and Operations

- The potential needs to be evaluated of a local approach for take-back inventories (setting up a material 'buffer') versus a centralised larger inventory, as inventory issues present a major challenge during implementation.
- Specific locations, product and building types that could be good business and sustainability cases need to be defined.



Mitigation Plan

As part of the implementation and onboarding plans agreed with Ikano Bolig, Tarkett, Rexcon and Rockfon, there will be a pilot period during which remaining challenges will be tackled with all involved parties. Most of the mitigation actions were defined in the design sprint and have been reflected in the technology or business model. Further learnings will come from the implementation and pilot period.





Diffusion overview

Supply has been positioned as an innovative solution when undertaking a building project following circular business models. The development of this white paper and experiences gathered in several projects have shown that to achieve the maximum resources being circulated with the highest R strategies, additional circular resource flows should be explored and implemented. Supply's current technology and business proposition means that the option of increasing the product offering to help manufacturers establish take-back systems represents the highest potential for financial, operational and environmental benefits.

THE NETWORK EFFECT AND DIFFUSION HAVE BEEN STARTED TOWARDS A SCALABLE ADOPTION

Based on this, supply will further develop the digital platform MVP to be completely for the three manufacturers that have confirmed their interest with a letter of intent (Rockfon, Rexcon and Tarkett). The third letter of intent, received from Tarkett, was a result of the diffusion and network effect that the platform is already creating.

The platform will be tested by executing the first resource take-back transactions between selected building owners, including Ikano Bolig, and manufacturers. During the preparations for this white paper, the City of Helsinki also became a user of supply, and the platform's building owner side will be tested further with this new partnership.

LESSONS LEARNED AND FRAMEWORK TO BE SHARED OPENLY

All reporting, lessons learned and future guidelines for replicating the process by other adopters or use cases will be made publicly available. Once the framework for establishing take-backs systems based on digital tools has been completed and tested, it will also be made publicly available, along with the environmental and financial benefits expected.

Further on in the process, we aim to provide sufficient information for other stakeholders to adopt take-back workflows in different geographical locations or for different product lines.

Key actors

INTEREST FROM BOTH SIDES OF PLATFORM: BUILDING OWNERS AND MANUFACTURER

Supply has received letters of intent from Rockfon, Rexcon and Tarkett instructing it to proceed with setup and implementation of a pilot test and potentially scaling of the automated take-back system. This was the result from the conducted design sprint and further diffusion as part of the validation process.

In consultation with Rockfon and Rexcon, supply has already pre-selected partners for the building-owner side. Lendager Architects and Ikano Bolig have also committed lending support for developing the product further.

The first take-back match of a product – acoustic panels – has been achieved, with Rockfon as supplier/manufacturer and Ikano Bolig as building owner. A letter of intent from Ikano Bolig has been received, stating the aim to explore the possibility of sending back acoustic panels from existing buildings to Rockfon using supply's platform. Two specific buildings have been selected.



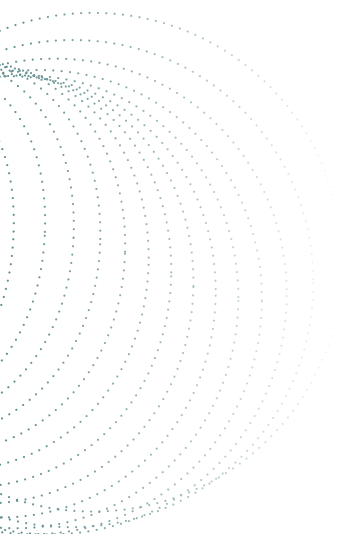
Milestones and timeline

The implementation and pilot phase for the take-back system with the selected manufacturers, Rockfon, Rexcon and Tarkett, will be completed within six months of publication, with the following milestones to be achieved:

- Development design sprints with manufacturers and building owners are completed.
- Digital platform customised for different manufacturer take-back cases (Rockfon, Tarkett and Rexcon) including back office and take-back workflow is fully developed and tested. This is currently at MVP stage but will be developed as a fully functional product. The platform will be designed in a modular approach to enable easy adoption by other manufacturers
- Building owner is fully onboarded and trained in use of the take-back module
- Mapping and quality assessment workflow for existing resources, request management and integration with logistics and e-commerce stack from manufacturer are developed
- User and site testing for the platform are completed
- First transactions of batches are being taken back from developer/building owner by manufacturer with results reported on platform
- Lessons learned and guidelines of development and implementation process have been shared

Call to action

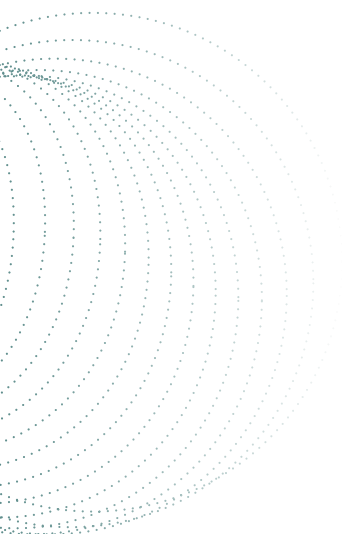
Supply is aiming to onboard four major manufacturers within the next months' implementation phase, so the company is searching for other potential cases along with other building owners willing to test the solution and help develop the framework further.





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Appendix-A

A series of interviews were conducted to gather insights into potential barriers or lessons learned and key implementation requirements for digital tools to establish take-back systems for the built environment. The interviewees included:

- Julia Vol, former sustainability manager at Rockwool and current circular manager at Danfoss
- Kasper Sánchez Vibæk, head of sustainability and public affairs at Rockfon
- The former sustainability manager at a Danish manufacturer of ventilation solutions
- Tegan Spinner, founder of Worthmore, a startup for circularity of electronics based on a digital platform
- Jesper Sørensen, founder of Rexcon, which specialises in modular wood-based elements for walls and flooring
- The founder of a Danish manufacturer of building materials derived from reclaimed waste
- A senior manager and innovation specialist at a global manufacturer of window and skylight systems
- Anders Bang Kiertzner, circular economy director at Lendager Architects
- Lone Lindgård Laursen, sustainability manager at Ikano Bolig
- The technical sustainability manager at Swisspearl
- Janne Lauronen, sales and circularity representative at Tarkett

