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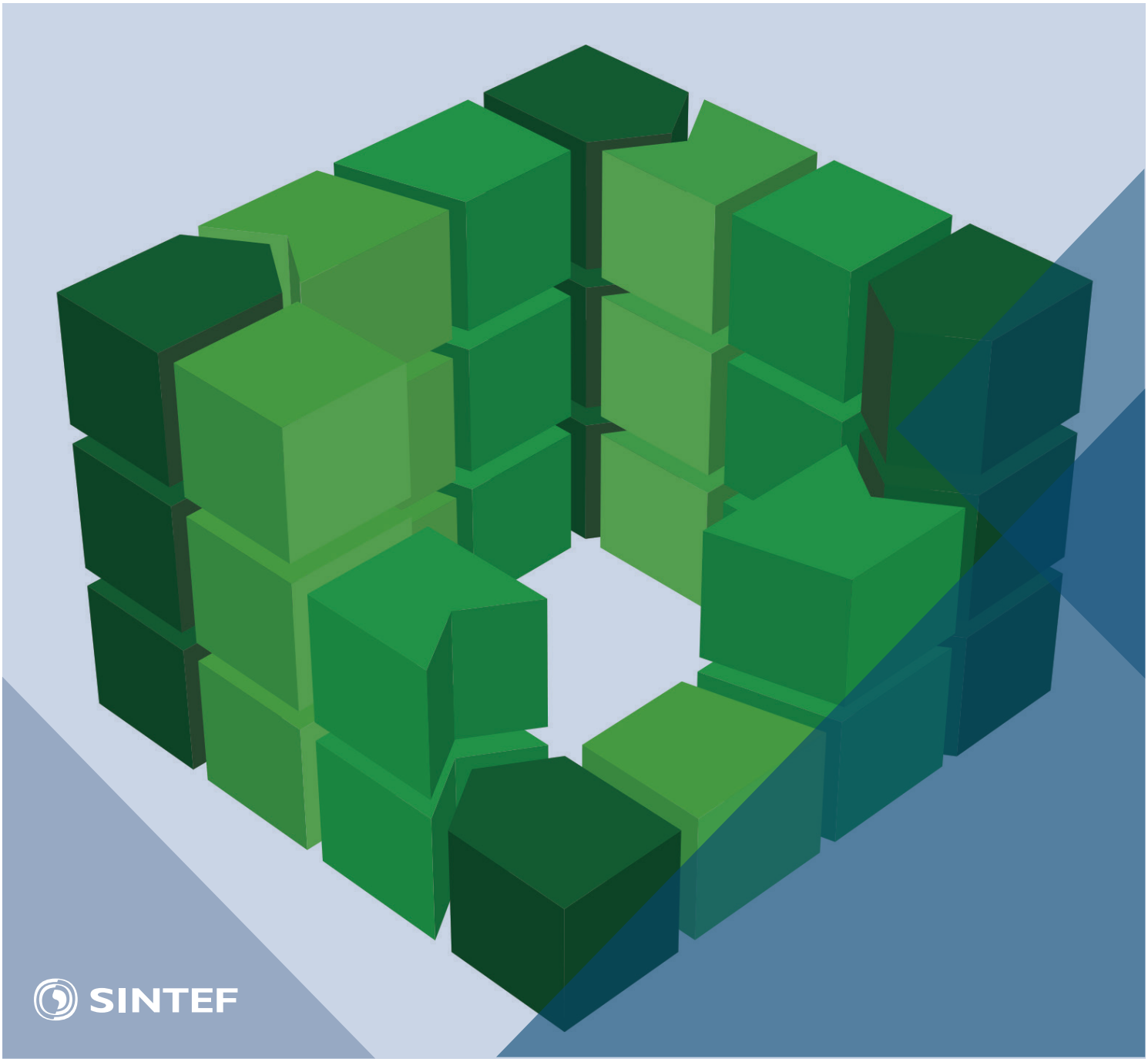
SINTEF RESEARCH 106

REBUS project (2020–2023)

FINAL REPORT



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Preface

This is the final report of the research project *REBUS – REuse of Building materials – a USer perspective*. The REBUS project was funded by the Research council of Norway through the Miljøforsk program under Grant number 302754 for a duration of four years (2020–2023). The project was a collaboration between SINTEF, Inland Norway university of Applied Sciences (INN), Boligbygg Oslo KF, FutureBuilt and Resirqel from Norway, Department of the Built Environment at Aalborg university (BUILD) and IVL Swedish Environmental Research Institute.

This report is compiled by Selamawit Mamo Fufa in collaboration with project partners who have contributed as authors on specific topics. Karolina Stråby has quality assured the report.

Oslo, 2024

Kristin Fjellheim
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Summary

REBUS project vision and objectives: The research project *REBUS – REuse of Building materials – a USer perspective* started in 2020 with a vision of developing a knowledge platform to enable the wider and more efficient implementation of reusable building materials. REBUS aimed to address the main barriers to reuse in the construction sector using research-based approach by identifying the need of different user groups (WP1), develop methods for assessing the technical performance (WP2) and sustainability of reuse products (WP3), and practical knowledge exchange from actual pilots (WP4) and use of network strategies (WP5).

Basic facts about REBUS: The REBUS project was an interdisciplinary collaboration between SINTEF, Inland Norway University of Applied Science, FutureBuilt, Resirqel, and Boligbygg Oslo KF from Norway, Department of the Built Environment at Aalborg university in Denmark (BUILD), and IVL Swedish Environmental Research Institute. The project was financed by the Research Council of Norway under the program Miljøforsk (grant number 302754), and in-kind contributions of industry partners, who provided their expertise and resources.

Main activities and results: The project started by screening the reuse potential of more than 50 construction product groups. This was done through input from experts from SINTEF as well as discussions in a series of workshops with REBUS partners (WP1). From this assessment, five construction products were chosen to be considered in REBUS: paving stone, doors and windows, glass partition wall, ventilation components, and sanitary equipment. To get more practical knowledge, the technical, environmental, and economic performance of reused paving stone was evaluated through laboratory testing, life cycle assessment (LCA) and life cycle costing (LCC) studies (WP2). A reuse guideline was then developed for the remaining four products (doors and windows, glass partition walls, ventilation components and sanitary equipment) giving advice to consultants, developers, and contractors on how to assess and document the properties of reusable building materials (WP2).

To understand the challenges, motivations, and potential measures for driving different user groups to reuse building materials in Norway, a national survey (WP1 & WP5) was conducted. In addition, semi-structured interviews (WP1 & WP4) were conducted with various actors in the building industry to identify practical challenges, barriers, and success factors related to the reuse of construction products in Norwegian pilot projects. To gather more practical knowledge on the reuse of construction materials, a comparative assessment of exemplary pilot projects from Norway, Denmark, and Belgium was conducted (WP1 &WP4). Moreover, a review of approaches to reuse of building materials was conducted through evaluation of the current state of circularity in the Norwegian building industry, including actors, approaches, and developments (WP4).

To address the research gap on the lack of harmonized life cycle sustainability assessment (LCSA) methods, a LCSA framework was developed (WP3). The framework was developed harmonizing environmental life cycle assessment (LCA), social LCA and life cycle costing (LCC) assessment methods to enable transparently assess the potential environmental, social and/or cost impacts of reused products in comparison to new ones.

A network strategy was used to facilitate exchange of knowledge developed through REBUS as well as the experiences of partners and other key players within the network members (WP5). This exchange of ideas and insights served as a valuable input to providing recommendations on how procurement and political instruments can affect sustainable reuse of building products.

The findings from REBUS project were made accessible to a wider audience through various channels aimed to achieve the ambition of creating research-based knowledge (WP6). Specifically, the project results were published in three peer-reviewed journals, one book chapter, and three reports and communicated through popular scientific articles, presentations at different events, webinars, and seminars.

Expected impacts:

- The research-based knowledge on reuse of existing construction products from different user aspects through a national survey, interviews, and comparative assessment of exemplary pilots from Norway, Denmark and Belgium can provide a better understanding of the status of reuse for different actors.
- The research on the technical performance of reused paving stone, through actual mapping, laboratory testing, LCA and LCC analysis can provide guidance for further development of testing, documentation, environmental and economic analysis of reusable products. Moreover, the reuse guidance document demonstrated how existing methods can be used to test and document reusable products, which can serve as a good example for developing routines for testing and documentation of reused products.
- The LCSA framework developed through REBUS can support transparent evaluation of the environmental, social, and/or economic impacts and benefits of reused products in comparison to new products.
- The review of material reuse approach and the practical knowledge collected from pilot projects can give better insight into historical developments as well as perspectives of professional actors involved in the limited pilot projects.
- The network established through REBUS helped to contribute towards influencing the participants' attitudes and actions for reuse of building materials.
- Furthermore, the results from REBUS contribute to several of the UN sustainable development goals including: SDG12 (Responsible production and consumption), SDG13 (Climate action), SDG14 (Life below water), SDG15 (Life on land), SDG11 (Sustainable cities and communities), SDG8 (Decent work and economic growth), and SDG9 (Industries, innovation, and infrastructure).

Sammendrag

REBUS-prosjektets visjon og mål: Forskningsprosjektet *REBUS – REuse of Building materials – a USer perspective* startet i 2020 med en visjon om å utvikle en kunnskapsplattform for å muliggjøre en bredere og mer effektiv implementering av ombrukbare byggematerialer. REBUS hadde som mål å adressere de viktigste barrierene for ombruk i byggesektoren ved å bruke forskningsbasert tilnærming for å identifisere behovet til ulike brukergrupper (WP1), utvikle metoder for å vurdere den tekniske ytelsen (WP2) og livssyklusevaluering (WP3), og praktisk kunnskapsutveksling fra piloter (WP4) og bruk av nettverksstrategier (WP5).

Fakta om REBUS: REBUS-prosjektet var et tverrfaglig samarbeid mellom SINTEF, Høgskolen i Innlandet, FutureBuilt, Resirqel og Boligbygg Oslo KF fra Norge, Institut for Byggeri, by og miljø ved Aalborg universitet i Danmark (BUILD) og IVL Svensk miljøforskning i Sverige. Prosjektet ble finansiert av Norges forskningsråd under programmet Miljøforsk (tilskuddsnummer 302754), og med bidrag fra industripartnere som stilte med sin kompetanse og ressurser.

Hovedaktiviteter og resultater: Prosjektet startet med å kartlegge ombrukspotensialet til mer enn 50 byggevarer. Det ble gjort gjennom innspill fra eksperter fra SINTEF samt diskusjoner med REBUS-partnere (WP1). Fra denne vurderingen ble det valgt fem byggeprodukter som skulle vurderes i REBUS: belegningsstein, dører og vinduer, glassvegger, ventilasjonskomponenter og sanitærutstyr. For å få mer praktisk kunnskap ble den tekniske, miljømessige og økonomiske ytelsen til ombrukt belegningsstein evaluert gjennom laboratoriprøving, livssyklusvurdering (LCA) og livssykluskostnadsstudier (LCC) (WP2). Deretter ble det utviklet en retningslinje for ombruk for de resterende fire produktene (dører og vinduer, glassvegger, ventilasjonskomponenter og sanitærutstyr) som gir råd til rådgivere, utviklere og entreprenører om hvordan man kan vurdere og dokumentere egenskapene til ombrukte byggematerialer (WP2).

For å forstå utfordringer, motivasjon og potensielle tiltak for å drive ulike brukergrupper til å ombruke byggematerialer i Norge ble det gjennomført en nasjonal undersøkelse (WP1 & WP5). I tillegg ble det gjennomført intervjuer (WP1 & WP4) med ulike aktører i byggebransjen for å identifisere praktiske utfordringer, barrierer og suksessfaktorer knyttet til ombruk av byggevarer i norske pilotprosjekter. For å samle mer praktisk kunnskap om ombruk av byggematerialer ble det gjennomført en komparativ vurdering av læringspunkter fra forbildeprosjekter fra Norge, Danmark og Belgia (WP1 &WP4). I tillegg ble det gjennomført en gjennomgang av tilnærminger til ombruk av byggematerialer gjennom evaluering av dagens sirkularitetstilstand i norsk byggenæring, inkludert aktører, tilnærminger og utvikling (WP4).

Når det gjelder mangelen på harmoniserte metoder for livssyklus-bærekraftsvurdering (LCSA), ble det utviklet et LCSA-rammeverk (WP3). Rammeverket ble utviklet for å harmonisere miljømessige LCA, sosiale S-LCA og livssykluskostnadsvurderingsmetoder (LCC) for å muliggjøre transparent vurdering av potensielle miljømessige, sosiale og/eller kostnadsmessige konsekvenser av ombrukte produkter sammenliknet med nye.

En nettverksstrategi ble brukt for å tilrettelegge for utveksling av kunnskap utviklet gjennom REBUS samt erfaringer fra partnere og andre sentrale aktører innenfor nettverksmedlemmene (WP5). Denne utvekslingen av ideer og innsikt fungerte som et verdifullt innspill til å gi anbefalinger om hvordan anskaffelser og politiske virkemidler kan påvirke bærekraftig ombruk av byggeprodukter.

Funnene fra REBUS-prosjektet ble gjort tilgjengelig for et bredere publikum gjennom ulike kanaler for å nå ambisjonen om å skape forskningsbasert kunnskap (WP6). Prosjektresultatene

er publisert i tre fagfellevurderte tidsskrifter, ett bokkapittel og tre rapporter samt formidlet gjennom populærvitenskapelige artikler, presentasjoner ved ulike arrangementer, webinarer og seminarer.

Forventede effekter:

- Den forskningsbaserte kunnskapen om ombruk av eksisterende byggevarer fra ulike brukeraspekter gjennom en nasjonal undersøkelse, intervjuer og sammenliknende vurdering av forbildeprosjekter fra Norge, Danmark og Belgia kan gi en bedre forståelse av ombruk fra erfaringer av forbildeprosjekter fra flere land.
- Forskningen på den tekniske ytelsen til ombrukt belegningsstein, gjennom faktisk kartlegging, laboratorieprøving, LCA- og LCC-analyse, kan gi veiledning for videreutvikling av prøving, dokumentasjon og miljømessige og økonomiske analyser av ombruksprodukter. Videre viste veiledningsdokumentet for ombruk hvordan eksisterende metoder kan brukes til å teste og dokumentere ombruksprodukter, som kan tjene som et godt eksempel for å utvikle rutiner for testing og dokumentasjon av ombruksprodukter.
- Rammeverket for livssyklus-bærekraftsvurdering utviklet gjennom REBUS kan støtte transparent evaluering av de miljømessige, sosiale og/eller økonomiske konsekvensene og fordelene ved gjenbrukte produkter sammenliknet med nye produkter.
- Gjennomgang av tilnærming for materialgjenbruk og praktisk kunnskap samlet inn fra pilotprosjekter kan gi bedre innsikt i historisk utvikling samt perspektiver til profesjonelle aktører involvert i de begrensede pilotprosjektene.
- Nettverket etablert gjennom REBUS bidro til å påvirke deltakernes holdninger og handlinger for ombruk av byggematerialer.
- Videre bidrar resultatene fra REBUS til flere av FNs bærekraftsmål, inkludert Mål 12 (Ansvarlig forbruk og produksjon), Mål 13 (Stoppe klimaendringene), Mål 14 (Livet i havet), Mål 15 (Livet på land), Mål 11 (Bærekraftige byer og lokalsamfunn), Mål 8 (Anstendig arbeid og økonomisk vekst) og Mål 9 (Industrier, innovasjon og infrastruktur).

Table of Contents

1. Introduction

Selamawit Mamo Fufa, Senior Research Scientist, SINTEF
Project and work package leader, REBUS

This is the final project report of the research project REBUS – REuse of Building materials – a USer perspective (REBUS, 2020). REBUS was a collaboration project, running from 2020 to 2023. The project was financed by the Research Council of Norway under the program Miljøforsk (grant number 302754), and in-kind contributions of industry partners, who provided their expertise and resources. The project was an interdisciplinary collaboration between research institutes and universities from Norway, Denmark and Sweden, and industrial partners from Norway. The partners in REBUS were SINTEF, Inland Norway University of Applied Science, FutureBuilt, Resirqel, and Boligbygg Oslo KF from Norway, Department of the Built Environment at Aalborg university in Denmark (BUILD), and IVL Swedish Environmental Research Institute.

This report provides a comprehensive overview of the research activities conducted, key findings, and potential future research perspectives. The first introduction gives an overview of the objectives, main research activities and findings of the REBUS project. Chapter 3 to 7 present detailed descriptions of the project activities conducted. Chapter 8 compiles a summary of valuable insights shared by national industry partners, while Chapter 9 provides a summary from international research partners.

1.1 REBUS project overview

Reuse is not a new concept, and it is widely believed to offer large environmental and economic benefits. At the start of the REBUS project idea development in 2019, there has been limited activities and ongoing initiatives in Norway related to reuse of construction products. Even though reuse is a well-known concept, several factors hindered the reuse of construction products. Some of these factors, which were highlighted at the project development phase, include: 1) the complexity and involvement of several actors with different needs and practices (Yuan & Shen, 2011; Jin et al., 2019); 2) the lack of guidelines for testing and documentations of reusable products; 3) the lack of harmonised methods and studies on the life cycle assessment of reusable products (Bovea & Powell, 2016), considering all three aspects of sustainability (environmental, social and economic); 4) insufficient or fragmented regulations (Høibye & Sand, 2018); and 5) the absence of research and scientific work related to reuse (Nordby, 2019) (e.g., research on network strategies) in Norway. The research project REBUS aimed to address some of the above-mentioned challenges in collaboration with experts who have practical experience in the field.

The vision of REBUS project was to develop a knowledge platform that enables the wider and more efficient implementation of reusable building materials, facilitating the transition towards a circular built environment. This platform aimed to reduce potential environmental impacts and promote sustainable resource utilization by addressing some of the aforementioned challenges from various users' perspectives. The project specific objectives, which support the realization of this vision, were as follows:

1. Analyze user awareness, knowledge, needs and social practice to find solutions and create a knowledge platform
2. Identify best methods for assessing the technical performance of reusable products
3. Identify how existing evaluation methods can be developed for communicating the sustainability of reusable materials in a life cycle perspective
4. Practical knowledge exchange from actual pilot projects
5. Develop network strategies and provide recommendations to motivate a faster implementation of reusable building materials through procurement processes and regulatory frameworks

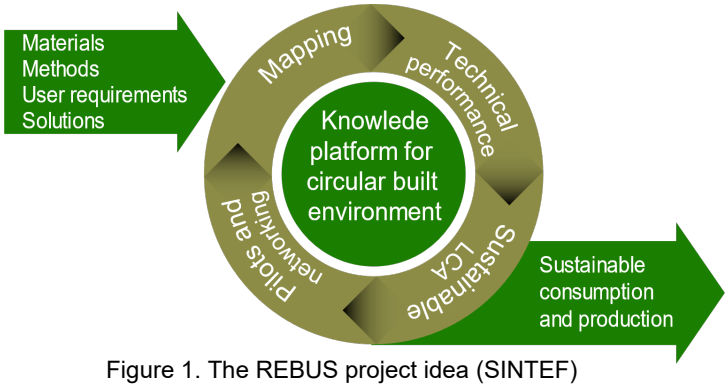

Figure 1. The REBUS project idea (SINTEF)

1.2 Main research activities and outputs

The REBUS project was structured in six main work packages (WP1–WP6) to realize the project vision. WP1–WP5 focused on scientific activities, whereas WP0 was dedicated to project management and WP6 focused on dissemination and exploitation of the project findings. Figure 2 represents the structure of the WP.

The work started by selecting user groups and five reusable construction materials that could be considered in REBUS (WP1). National survey (WP1 & WP5) and interviews (WP1 & WP4) were conducted to identify, barriers and success factors for reuse of construction materials in Norway from different users' perspectives. Technical performance evaluation methods for the products selected in REBUS (WP2) as well as sustainability assessment (WP3) methods were developed. More practical knowledge was collected through pilot projects and review of historical and on-going activities (WP4). A network strategy (WP5) was used for sharing the knowledge developed through the project as well as the experiences of partners and other key players with network members and provide input for decision makers. A wider dissemination of the results was conducted using different channels (WP6).

The following section provides an overview of the objectives, main research activities (WP1–WP5), including their outcome and deliverables (WP6).

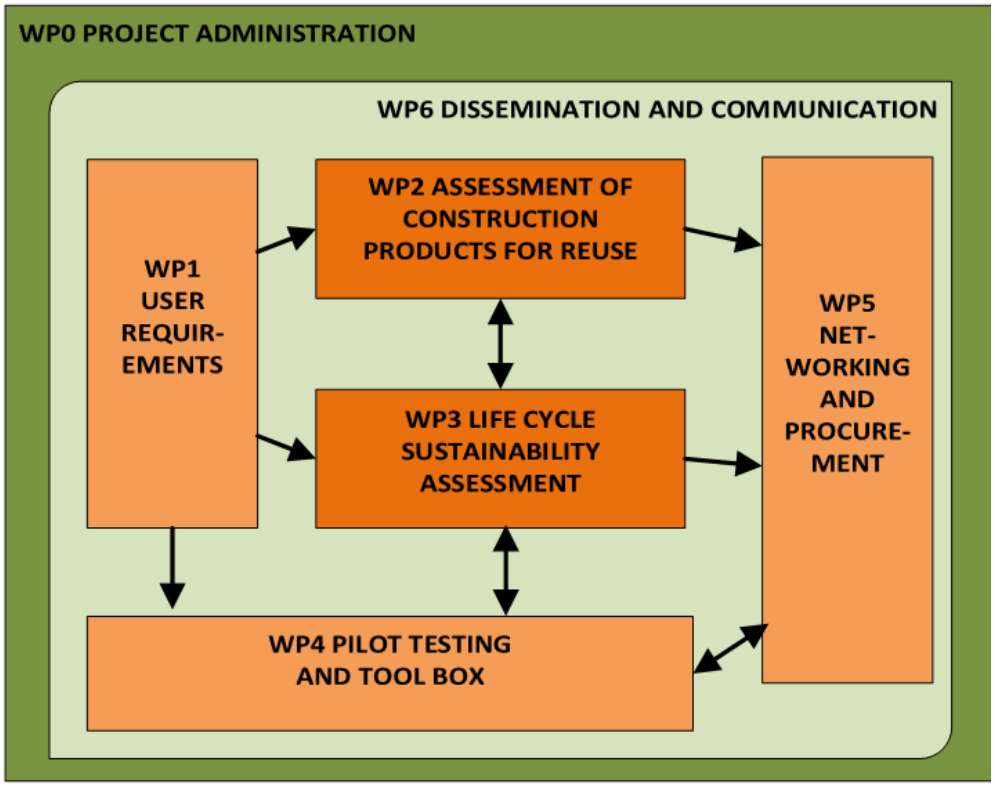

Figure 2. REBUS project organization plan (SINTEF)

WP1 User requirements: The main objective of WP1 was to map and analyze user knowledge, behavior, and social practice towards reuse of construction materials by involving different user groups. The work started by selecting reusable construction product groups that could be considered in REBUS, in collaboration with all work packages. This screening and selection process involved input from experts from SINTEF, as well as discussions with REBUS partners in workshops. Through this screening process, five construction products, namely paving stone, doors and windows, glass partition wall, ventilation components and sanitary equipment, were selected for further evaluation in REBUS. To investigate the challenges and motivations that drive or hinder different stakeholders in reusing building materials, and potential measures that can enable to increase reuse of construction products in Norway, a combination of quantitative and qualitative methods, such as national survey and interviews, were conducted. The expected output of this research was to provide a comprehensive understanding of the status of reuse, which can assist different actors to address challenges, as well as promoting collaboration within the value chain. The results from the national survey (Fufa et al., 2023) and interviews (Knoth et al., 2022) are published in two separate scientific journal articles which can serve as valuable resources for different actors. A comprehensive overview can be obtained in Chapter 2.

WP2 Assessment of construction products for reuse: The primary goal of WP2 was to identify how existing methods used to evaluate new construction products further could be developed to evaluate the technical performance of reuse construction products. The findings from the screening work conducted under WP1 served as a foundation for further evaluation of the technical performance of the five materials selected. To gain practical knowledge, actual laboratory testing and evaluation of reused paving stone was conducted. In addition, the environmental, and economic performance of the reused paving stone was evaluated using life cycle assessment and life cycle costing studies, through the internal funding obtained from SINTEF (Fufa et al., 2021). A guidance document, both in Norwegian (Kron et al., 2022a) and English (Kron et al., 2022b), was developed giving advice on how to assess the reuse potential of doors and windows, glass partition walls, sanitary equipment and ventilation components.

The output from this work can be used as a valuable example for developing a routine for testing and documentation of reusable construction products. A comprehensive overview of WP2 can be obtained in Chapter 3.

WP3 Life cycle sustainability assessment: The primary goal of WP3 was to establish an analytical and procedural method to assess the sustainability of reusable building materials throughout their life cycle. The work started by mapping and evaluating existing life cycle sustainability assessment methods to determine their suitability for evaluating the environmental, social, and economic impacts and benefits of reused products. A life cycle sustainability assessment framework was developed by harmonizing environmental life cycle assessment (LCA), social LCA (SLCA) and life cycle costing (LCC) methods. The framework aimed to enable evaluating the environmental and social benefits or burdens, as well as the cost saving or additional costs, associated with reusable materials when compared to new materials. The framework can be used as a guidance and a template to collect data, transparently present the actual environmental, economic and social consequences of reused products in comparison of new products. This can support different stakeholders to avoid problem shifting, encourage stakeholders to prioritize reuse over traditional construction methods and make informed decisions. A comprehensive overview of WP3 can be obtained in Chapter 4.

WP4 Pilot testing and toolbox: The aim of WP4 was to collect practical information from actual pilots and ongoing activities as an input to the project. To gain insight into experiences and perspectives of professional actors involved in the limited pilot projects, the knowledge from real case pilot projects from FutureBuilt was extracted through interviews and document analysis (the joint study conducted through WP1 and WP4) (Knoth et al., 2022). Additionally, a comparative assessment of exemplary pilot projects from Norway, Denmark and Belgium was conducted (the joint work conducted through WP1 and WP4) to gain a better understanding of the experiences of exemplary projects in several countries (Sandberg et al., 2022). Furthermore, a review of approaches to reuse of building materials was conducted through evaluation of the current state of circularity in the Norwegian building industry, including actors, approaches, and developments. Even if there was a plan in the project proposal to develop a material toolbox as a decision support framework, the findings from REBUS (specially, the technical performance evaluation of building materials conducted under WP2) showed that materials and product reuse is very complicated and dependent on many variables. So, developing a simple scalable "toolbox" to help "decision makers to evaluate the technical performance and impact of different types of products" was never a feasible project goal. However, the guideline for technical performance evaluation (WP2) and the framework for sustainability assessment (WP3) developed aimed to help decision makers to evaluate the technical performance and impact of different products. A short overview of WP4 can be obtained in Chapter 2 and Chapter 5.

WP5 Networking and procurement: The main objective of WP5 was to evaluate how network strategies affect users' attitude and behaviour regarding the reuse of building materials that can lead to more sustainable consumption. To achieve this, a network led by Boligbygg consisting of 8 firms was established. Through the course of a year, 4 workshops were conducted with the network members, each focusing on different topics such as introduction or REBUS project and the network members, barriers/drivers and network mechanisms, reuse guides, and policy framework. To evaluate the impact of the network approach, group interviews were conducted with the network members before the start of the workshops and after the fourth workshop. In addition, focus group interviews were conducted with network participants to gather their input and provide recommendations for public procurement and policy framework (Hauge et al., 2023). In REBUS, network strategy has been used as a means of facilitating collaboration and knowledge exchange among actors to promote the reuse of construction products. The work was led by INN with help from a PhD student hired through REBUS. The main output of this research is the learning and the sharing

of experiences on reuse and contribute to providing recommendations for procurement and regulations. A comprehensive overview of WP5 can be obtained in Chapter 6.

WP6 Dissemination and communication: The main objective of WP6 was to ensure efficient dissemination of the project findings among key partners, the scientific community, policy makers and other relevant stakeholders in the construction industry. A detailed communication and dissemination plan was developed at the start of the project, including strategies for disseminating the knowledge developed through the project to a broader audience within the construction industry. The results from REBUS have been disseminated through different channels to achieve the ambition of knowledge creation. The results from each work package were published in 3 peer-reviewed journals, 1 book chapter, and 3 reports. In addition, there are two conference papers and two journal papers in the pipeline. Furthermore, to reach a wider audience, presentations of the findings were done through open webinars, seminar and presentations in different arenas.

1.3 Impacts of the research results

REBUS aimed to address the main barriers to reuse in the construction sector by creating knowledge, methodologies, and a network that promotes and supports the wider implementtation of reusable building materials. The research results from REBUS are expected to benefit different actors to work towards realisation of the wider implementation of reuse solutions.

The research-based knowledge on reuse of existing construction products from different user aspects through a national survey (Fufa et al., 2023), interviews (Knoth et al., 2022) and comparative assessment of exemplary pilots from Norway, Denmark and Belgium (Sandberg et al., 2022) can provide a better understanding of the current status of reuse for different actors in the Norwegian industry. These findings can also serve as a background for the building industry and policy makers to enforce effective measures.

The research on the technical performance of reused paving stone, through actual mapping, laboratory testing, LCA and economic analysis can provide guidance for further development of testing, documentation, environmental and economic analysis of reusable products. Moreover, the guidance document demonstrated how existing methods can be used to test and document reusable products. It can serve as a good example for developing routines for testing and documentation of reused products. The guidance document has been well accepted by the industry, receiving positive feedback, and being referenced as a reliable resource (e.g., by DiBK). The life cycle sustainability assessment framework developed through REBUS can support evaluation of the environmental, social, and/or economic impacts and benefits of reused products in comparison of new products. The framework can guide decision-making and encourage stakeholders to prioritize reuse over traditional construction methods.

The practical knowledge collected from pilot projects can give better insight into experiences and perspectives of professional actors involved in the limited pilot projects. Furthermore, the review of materials reuse approaches through evaluation of the current state of circularity in the Norwegian building industry, including actors, approaches, and developments are expected to have high practical relevance to implement reuse strategies. The network established through REBUS facilitates the sharing of information and knowledge exchange. The network strategy helped to contribute towards influencing the participants attitudes and actions for reuse of building materials.

The findings from REBUS also identified areas which need more attention in the future for wider implementation of reuse.

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2. Barriers, motivations and success factors for reuse of construction products

Even though reuse is a well-known concept, and a growing interest is seen in industry, reuse in construction is still scarce. One of the main challenges is related to the high complexity of the construction industry, which arises from various factors including the involvement of many stakeholders and disciplines with diverse needs and practices, a complex supply chain, rapid technological advancements, and economic factors. The importance of human factors, and the need for more research addressing perceptions, attitudes, behaviors, and expectations of multiple stakeholders is emphasized in literature (Yuan & Shen, 2011; Jin et al., 2019).

The research project REBUS (2020) addresses the aforementioned gaps by conducting, among others, a national survey (Fufa et al., 2023) and interviews (Knoth et al., 2022) to collect research-based insights into different user aspects. Moreover, a comparative assessment of exemplary projects from Norway, Denmark and Belgium has been conducted to get better insight and more understanding of reuse potentials from the experience of the three countries (Sandberg et al., 2022). The analysis included type of reuse, documentation and certification, legal and policy framework, costs and time used, and procurement procedures. The interviews and comparative assessment were conducted through a collaboration between WP1 and WP4 contributing to the REBUS objective of promoting effective reuse practices in the construction industry. This chapter summarizes the findings from the national survey and interviews.

2.1 A national survey

Selamawit Mamo Fufa, Senior Research Scientist, SINTEF
Project leader and work package 1 leader, REBUS

2.1.1 Background

International (Hobbs & Adams, 2017; Hart et al., 2019; Rakhshan et al., 2020; Condotta & Zatta, 2021) and national (Nordby, 2019) studies on barriers and challenges for reuse of construction products have been conducted to identify possible pathways to increase reuse. However, limited scientific literature exists regarding the factors which drive or hinder reuse of construction products in Norway. Moreover, a research gap exists when it comes to identification of drivers and barriers from the perspective of users and investigating the differences between groups of actors in the building industry.

2.1.2 Goal and scope

The main objective of the national survey conducted through REBUS (Fufa et al., 2023) was to investigate the challenges (barriers), motivations (drivers and success factors), and potential measures that can contribute to increased reuse of construction products in Norway, revealed through a national survey. Secondary objectives are: 1) to gain better insight of the perspectives of different user groups in the Norwegian construction industry regarding challenges and motivations related to reuse of construction products, 2) to classify these challenges and motivations into categories and compare among different user groups.

2.1.3 Method

The national survey was distributed through different channels to cover the main actors in the Norwegian construction industry. The survey included 20 multiple-choice questions and three open-ended questions, divided into four sections: 1) gathering general information about respondents, 2) assessing respondents experience with reuse, 3) identifying ambitions and challenges for reuse, and 4) gathering opinions on reuse of construction products. The findings from the national survey are divided into technical and psychological aspects, where the summary of the technical part (Fufa et al., 2023) is covered here.

2.1.4 Main findings

Out of the 260 valid respondents who participated in the national survey, a majority were designers/architects (17%), manufacturers/suppliers of new construction products (15.3%) and consultants (14.4%). Additionally, most of the respondents also work at large companies located in central or Eastern Norway, holding positions as a project leaders or middle managers. Furthermore, most of the respondents indicated having an intermediate or limited knowledge on reuse of construction products. The limited representation of manufacturers/ suppliers of reused products, medium and small size companies, and employees with operative role could be due to lack of experience in reuse, and limited involvement in reuse related activities within small and medium sized companies. This highlights the need for more expertise in reuse, pilot projects that provide practical knowledge, and collaboration among different actors in the value chain. Moreover, dominance of respondents from large companies suggests that the motivation for reuse of building materials is primarily driven by private actors due to market competition rather than regulations and public incentives.

User groups/stakeholders	Drivers							Barriers									Success factors					
	Cost saving	Emission reduction	Increase resource efficiency	Company profiling	New emerging markets	Financial incentments	Regulations	High cost	Time consuming	Lack of documentation	Lack of regulation	Lack of testing methods	Lack of available products	Lack of market	Lack of storage capacity	Low status of reuse	Competition with other strategies	Good planning	Procurement	Availability	Testing quality	Evaluation methods	Collaboration
Manufacturer /supplier of reused construction products	3.60	5.00	5.00	4.40	4.75	3.80	4.20	3.60	3.20	3.20	3.00	2.40	2.00	3.20	2.60	3.20	2.40	4.60	4.00	4.00	4.00	4.40	4.80
Municipal building owner/ developer	3.83	4.42	4.33	3.50	2.82	3.58	3.42	4.33	4.33	4.42	4.17	3.83	3.83	3.92	3.75	2.50	2.25	4.58	3.55	4.42	4.33	3.92	4.50
Contractor	3.25	4.35	4.05	4.30	3.40	3.00	3.30	3.90	4.05	4.15	4.06	3.58	3.80	3.90	3.40	3.05	2.84	4.40	3.79	4.20	4.30	3.95	4.21
Private building owner/ developer	3.63	4.42	4.21	3.89	3.79	3.47	3.47	3.47	4.00	4.47	4.05	4.06	3.53	3.74	3.74	3.16	3.11	4.79	3.63	4.42	4.26	4.11	4.47
Public/governmental building owner/developer	3.60	4.24	4.13	3.83	3.23	3.23	3.57	3.73	4.03	4.17	4.03	3.77	3.90	4.10	3.67	3.21	3.00	4.30	3.47	4.23	4.24	3.69	4.07
Other	3.53	4.60	4.35	3.95	3.79	3.81	3.77	4.14	4.30	4.55	4.36	3.95	3.57	3.98	3.64	3.09	3.09	4.61	4.00	4.51	4.43	3.89	4.32
Manufacturer/supplier of construction products	3.56	4.24	4.00	4.03	3.63	3.38	3.90	3.90	3.92	4.31	4.00	3.82	3.78	3.73	3.38	3.28	3.38	4.25	3.58	4.10	4.23	4.05	4.15
Designer, Architect	3.50	4.60	4.18	3.90	3.78	3.66	3.76	3.82	3.98	4.40	4.33	3.98	3.86	3.82	3.60	3.12	3.45	4.71	3.88	4.46	4.40	4.06	4.22

Figure 3. Drivers, barriers and success factors per user groups (modified from Fufa et al. (2023))

The survey results highlighted emission reduction as a main driver for reuse of building materials by all user groups. All respondents, except suppliers of reuse products, mentioned lack of documentation and good planning as the main barrier and success factor, respectively. Whilst the reuse suppliers highlighted high cost and collaboration as the main challenges and success factors, respectively. The high values given by all actors for 'good planning', and 'collaboration' as success factors shows the importance of collaboration and involvement of different actors in the value chain to increase the application of reuse of building materials. In addition to lack of documentation, high values given to lack of regulations and time consuming highlighted the need for improvement of regulations and practices.

All respondents expressed optimism that availability, regulation, testing and documentation of reuse building materials will be in place within a time frame of less than 7 years. However, they had drought about availability of highly developed marketplace and cheaper reuse products, which they believed would take longer. The survey results also revealed that there was little difference in how different user groups rated drivers, success factors, optimism, suitability, and barriers for reuse. In general, all listed barriers were seen as challenging, and all drivers and success factors were considered important. However, suppliers of reused construction products scored significantly lower on barriers compared to other professions, indicating that they perceived the barriers to be less challenging than other user groups.

2.1.5 Potential areas for future research

The survey results show lack of experience in reuse, limited reuse related activities in small and medium sized companies, and limited activities focused on strategic level. Future research should follow the development of reuse and see how the different user groups perception

differs from what has been reported here. Conducting a survey with a wider scope covering how different countries at Nordic or EU levels work in this area could be interesting.

2.2 Interviews

Katrin Knoth, Senior Research Scientist, SINTEF

2.2.1 Background

Reusing construction materials and products has a great potential to reduce the environmental footprint of buildings. Anyhow, the concept of reuse is not yet widely applied in the construction sector and there is still a long way to go before the potential for climate and resource savings is tapped. In the framework of the REBUS project, interviews with different actors in the building industry were conducted to get an overview of perspectives, experiences and lessons learnt from pilot projects focusing on the reuse of construction materials in Norway (Knoth et al., 2022).

2.2.2 Goal and scope

The main objective of the study was to identify practical challenges, barriers, and success factors related to the reuse of construction products in Norwegian pilot projects. Secondary objectives were to (i) gain insight into the experience of different actors directly involved in the reuse process, (ii) capture their perceptions on reuse potential of construction products, and (iii) identify general areas of concern and factors causing observed challenges and potential solutions.

2.2.3 Method

Thirteen semi-structured interviews were conducted with REBUS project partners, toolbox (digital platforms, marketplaces and/or digital databases) experts, actors from pilot projects focusing on reuse, and construction product manufacturers. Interview subjects have various backgrounds and hold different roles in pilot projects. This approach was taken to gain an understanding whether perceptions, experiences, and mindset towards reuse of building material differ depending on a person's background, role, and responsibilities.

2.2.4 Main findings

The thematic analysis of the interviews resulted in four main themes (Figure 4), each with its own set of barriers and success factors: (i) mindset and knowledge, (ii) reuse infrastructure, (iii) business framework, and (iv) procurement and legal framework. The main drivers identified for the adoption of reuse in Norway are GHG emissions reduction, fulfilling FutureBuilt criteria, and enhancing company image.

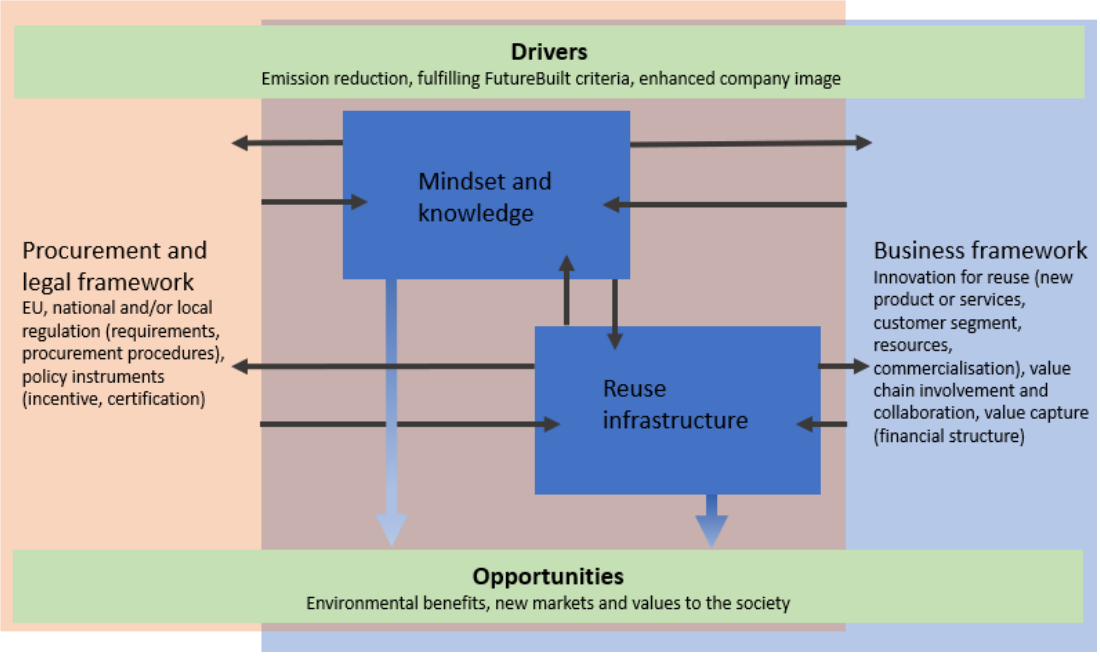

Figure 4. Conceptualization of the data pattern and relationships/interactions between main themes (Knoth et al., 2022)

The results show that there is a general awareness that the existing building stock represents an important source for reusable materials. The results also indicate that while there is awareness of the need for and willingness to change throughout the value chain, lack of knowledge, absence of incentives, and lack of an institutional framework to facilitate reuse are important barriers to the increased reuse of construction materials and products. A lack of established digital and physical infrastructure to source and view reclaimed building products and materials, uncertainties concerning documentation for used products, and challenges concerning the logistics are some of the main factors hindering a wider adoption of reuse in the Norwegian building sector. Pilot projects were found to be a good tool to gain experiences, create more awareness, and showcase the possibilities for reused materials that lie in the existing building stock.

2.2.5 Potential areas for future research

Further studies on barriers in pilot projects and large-scale reuse are needed to help establish necessary processes and infrastructure for efficient reuse and resource valorisation. Standardized processes for mapping of reuse materials need to be developed as well as a "dictionary" for alternative areas of usage of different materials to increase the reuse of products where possibilities for re-approval of technical performance is limited. The findings from this study highlight the need for more incentives and adapted regulations to stimulate the adoption of reuse in the construction sector.

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3. Guidance for testing and documentation

Thale Plesser, Senior Research Scientist, SINTEF
Work package 2 leader REBUS

3.1 Background

The modern construction industry relies heavily on construction products that are reliably produced to specification and have well characterized properties. Further, the industry relies on products that are delivered to the construction sites on time, in the necessary quantities and with documentation of performance. For new construction products all elements are in place. For reuse construction products all elements are poorly developed.

Figure 5. Reuse of construction products – supply chain (SINTEF)

A central barrier to reuse in Norway today, is the lack of methods for redocumentation of reuse products. Most products will change during use, because of climate stress, load forces, contact with chemicals or other stresses causing deterioration of the materials. Reused construction products must meet the same technical requirements as new products. Redocumentation is necessary to ensure that the completed construction work complies with requirements in current regulations.

3.2 Goal and scope of work

In REBUS, we have investigated how we can use or repurpose the current system for assessment and verification of performance for new construction products, as enforced by the EU's Construction Product Regulation, to document reuse construction products. The Construction Product Regulation, which is valid in Norway through the EEA agreement, requires that individual construction products are tested as described in the harmonised standards. The standards are developed by the European Committee for Standardization. Upon testing, the products are CE-marked and provided with a declaration of performance. The declaration of performance lists the properties of the product, such as U-value, water vapor resistance, strength, or frost resistance, allowing the buyer to make informed decisions about which product to choose. This ensures that the final building meets the performance requirements outlined in the building code and in the specifications set by the building owner. For construction products that are not covered by a harmonized product standard the manufacturer still has to document the relevant essential characteristics to be able to market and sell the product in Norway.

3.3 Method

The work on guidance for testing and documentation was carried out in two steps.

Step 1: Screening of construction products, and evaluation of their suitability for reuse

In step 1, we made a list of almost 50 candidate reuse construction products and evaluated their suitability for reuse. The products were rated according to suitability on a scale from 1 to 5.

The screening was based on four criteria:

1. availability in the existing reuse market
2. ease of removal from an existing building and ease of transportation to a new building
3. availability of a harmonised standard or, in the absence of a harmonised standard, a guideline for documentation
4. availability of expert knowledge on the use and documentation of the product as a new

Step 1 was conducted through meetings in the REBUS project group as well as evaluations by SINTEF experts on the documentation and use of the specific product groups.

Step 2: Development of the REBUS guideline on testing and documentation of reuse products

In step 2, we selected four product groups, comprising ten product types, for the REBUS guideline on testing and documentation. SINTEF experts on the selected product groups and their use developed the guideline. Additionally, we selected paving setts made from natural stone for testing of reused setts according to the harmonised product standard, as well as life cycle analysis (LCA) and life cycle costs (LCC) of reuse (Fufa et al., 2021). The LCA and LCC analysis evaluated the potential environmental impacts and cost implications of new and reused paving setts, from the production (A1–A3), transport (A4) and installation (A5) life cycle stages in accordance with the NS-EN 15978:2011 (Standard Norge, 2011) and NS 3454:2013 (Standard Norge, 2013) standards, respectively.

3.4 Main findings and contribution to the construction industry

The REBUS guideline on testing and documentation contains advice on the reuse evaluation for ten product groups (Kron et al., 2022a; 2022b): Interior glass partition walls, windows, and doors (patio doors, exterior doors and interior doors), ventilation (air duct systems – ducts and fittings, dampers and other regulating units and air terminal devices) and sanitary equipment (wash basins, bathtubs and WC suits). For each product type the guideline provides:

1. a general description of the product type, including use areas and typical requirements in use
2. advice for assessment of reuse and a table listing ageing. The section includes advice for repair of damage.
3. documentation of properties in connection with reuse. This section lists important properties and gives advice on documentation method.

The work on paving setts revealed that the standardised testing protocol for new paving setts can effectively assess the quality of reuse paving setts as well (Fufa et al., 2021). The cost analysis showed that reuse is more expensive than using new paving setts but revealed areas for cost reduction (Figure 6). Reuse of paving setts leads to a substantial reduction of green-house gas emissions, particularly if the reuse is local and does not require transportation over long distances.

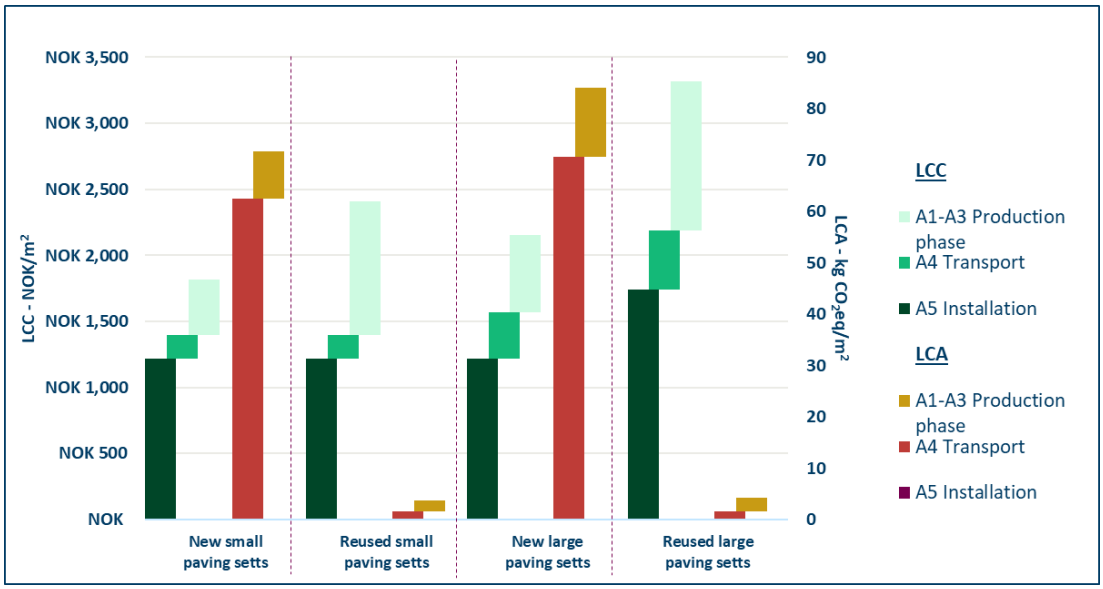

Figure 6. Total cost and greenhouse gas emissions per life cycle stages of new and reused paving setts (adopted from Fufa et al. (2021))

In REBUS we have demonstrated, through our work on the reuse guideline and the work on reused paving setts, that the existing system for documentation of new construction products can be repurposed, to work for reuse products as well as new products. An important recommendation from REBUS, is that the system for documentation of reuse products follows the same overall principles as the system for same or similar new construction products. The Norwegian Building Authority, Direktoratet for byggkvalitet (DiBK), has linked to the REBUS reuse guideline from their guide on reuse.

The reuse guideline serves as a valuable tool for conducting reuse mapping of buildings undergoing redevelopment or demolition. Since July 1, 2023, reuse mapping has become mandatory for larger buildings undergoing redevelopment or demolition.

3.5 Areas for future research

An important area for future research, is to further develop the documentation methods for individual reuse construction products. The research in this area should be developed within a supply chain for reuse starting with procedures for removal and ending with procedures for documentation before the reuse product is returned to the market, see Figure 5.

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4. A framework for sustainable life cycle assessment

Kristin Fjellheim, Research manager, and Camille Vandervaeren, Researcher, SINTEF
Work package 3 leader, REBUS

4.1 Introduction

To evaluate the effect of implementation of reuse products, life cycle sustainability assessment (LCSA) can be used (Figure 7). This assessment approach can also assist decision makers in the process of selecting new vs. reused products in their construction projects.

In literature, at the start of the REBUS project, there was limited LCA research addressing construction waste issues, few studies including end of life stages, and the focus of most articles is solely on environmental performance (Larsen et al., 2022). It was therefore identified a need to develop a framework that include the assessment of all three dimensions of sustainability – Life cycle assessment (LCA), Social life cycle assessment (S-LCA) and Life cycle costing (LCC) (Visentin et al., 2020).

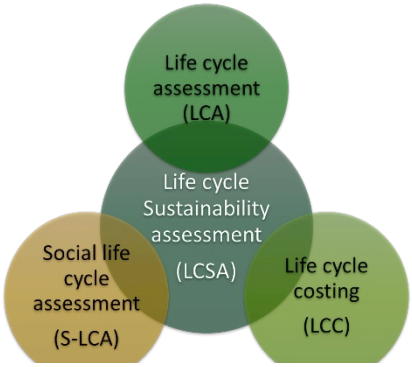

Figure 7. Life cycle sustainability assessment (SINTEF)

Sustainable LCA methods for reuse, by adding the social and cost layers to the traditional environmental dimension, will contribute to new knowledge to the LCA research field.

4.2 Goal and scope

The aim of this part of the REBUS project was to develop an analytical and procedural framework for life cycle sustainability assessment of construction products intended for reuse. The framework combines current methods for environmental LCA, social LCA (S-LCA) and life cycle costing (LCC) to include all three pillars of sustainability. In addition, the framework helps with the use of these existing methods in the context of new and reused construction products. The framework helps users with evaluating the environmental and social benefits and cost changes of different reuse strategies and solutions, hence giving them a better understanding of the effects of their choices of construction products.

4.3 Method

In the development of the LCSA framework in REBUS, a literature review was performed to identify the state-of-the-art assessment approach within each dimension (LCA, LCC and S-LCA) as well as for a complete LCSA framework. Within this work the existing standards for LCA – NS-EN ISO 14040:2006 (Standard Norge, 2006), NS-EN 15978:2011 (Standard Norge, 2011), NS-EN 15804:2012 (Standard Norge, 2012) – and LCC – NS 3454:2013 (Standard Norge, 2013) – as well as guidelines for SLCA (UNEP, 2020) were reviewed. The framework was further developed through semi-structured and iterative working meetings with the research institutes (IVL, BUILD and SINTEF) and tested with the other partners and in pilots to get user feedback.

4.4 Main findings

There have been several tasks and important research outputs done on this topic during the research period in close collaboration between IVL, BUILD and SINTEF. Through literature review, workshops, working meetings and framework development there are three main findings from this work:

1. Common understanding of scope, methods approach, system boundaries, allocation approaches and life cycle stages between LCA, S-LCA and LCC methodologies
2. Development of a common and comprehensive framework for LCSA

3. Development of a functional framework in Excel developed for users of reused products

Figure 8 shows the LSCA framework that was developed in the REBUS project based on the standard for LCA, NS-EN ISO 14040:2006 (Standard Norge, 2006). The first step is to set the goal of the assessment and make methodological choices that will be common (or not common) for the LCA, S-LCA and LCC. Next step will be to perform an inventory analysis (LCI) for each dimension using specific databases for LCA, S-LCA and LCC. Further, an impact assessment must be performed for each dimension, and, lastly, the results can be shown and interpreted.

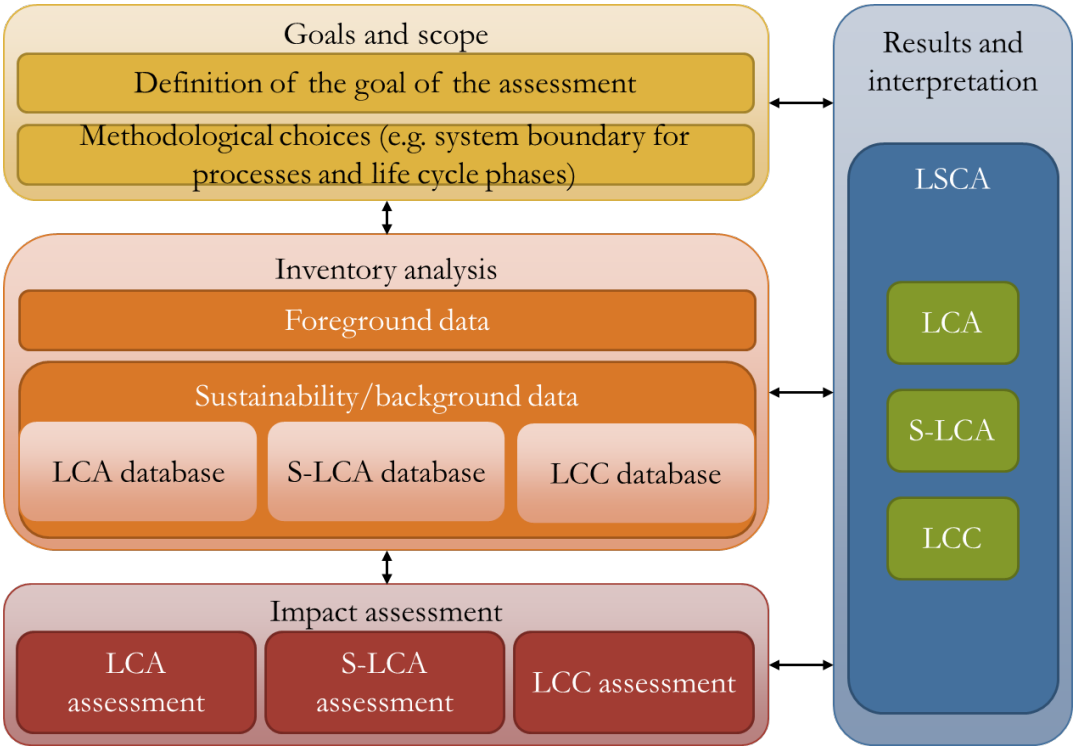

Figure 8. LSCA framework

The REBUS framework and Excel tool has focused on the 'goals and scope', 'inventory analysis' and the 'results and interpretation' parts. The Excel tool assists the users in gathering the right information in the inventory analysis stage so they can perform an impact assessment in a separate designated tool. The Excel tool further takes the results from the impact assessment and shows these in a common results file combining results for LCA, S-LCA and LCC. The framework was tested and refined using the paving stone LCA and LCC study conducted by Fufa et al. (2021) as a background. A forthcoming conference paper is under development, describing the framework and methodological choices established during the work in REBUS.

4.5 Future research

The S-LCA framework can be further developed through extending the harmonization between the social, cost, and environmental dimensions, including environmental aspects other than Greenhouse gas emissions, and standardizing and agreeing on allocation and cut-off approaches. This further work should be continued in a collaborative process between researchers and the industry through implementation of the assessment method into decision making tools and through performing S-LCA assessment on the reuse of several other product categories and for different user segments.

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5. The renaissance of reuse in Norway

James Kallaos, Research Scientist, SINTEF
Work package 4, REBUS

5.1 Introduction

The aim of WP4 was to collect practical information from actual pilots and ongoing activities as inputs to the project. Two tasks were completed within the stated goals of WP4, resulting in the publication of two articles in collaboration with WP1, as previously described in sections 2.2 and Sandberg et al. (2022). The original project proposal included a plan to develop a scalable material toolbox as a decision support framework. As the project progressed, the concurrent findings from REBUS in WP2 (see section 3) showed that materials and product reuse is very complicated, dependent on many variables, and changing rapidly. During the short REBUS project lifetime, the landscape surrounding reuse in Norway changed more rapidly than could either be expected or reliably documented. New laws have been enacted requiring reuse mapping of building projects, the FutureBuilt circular criteria were released, a surge in digital platforms for matchmaking between supply and demand of reused and reusable building materials and elements entered the market, and new physical spaces, including the circular resource centre (Sirkulær Ressurssentral) were inaugurated.

Developing a simple scalable "toolbox" to help "decision makers to evaluate the technical performance and impact of different types of products" was unlikely to be a feasible project goal or provide any utility to a system with such variability, and under such rapid change. In addition, most of the technical expectations for the toolbox were already addressed in the guideline for technical performance evaluation (WP2 – Section 3) and the framework for sustainability assessment (WP3 – Section 4).

It was therefore deemed to be illuminating to consider the historical setting that led Norway to the present situation regarding construction, waste, and reuse. Through a literature review, two areas of further analysis were developed and pursued. These two papers are nearing completion, and each has been submitted to a conference for presentation in 2024.

5.2 The renaissance of reuse in Norway – what's old is new again (abstract)

Throughout history, society has valued labor and resources, as well as the materials, products, and assemblies produced through them. Wasting effort, squandering resources, and discarding materials were historically activities to be avoided. Artifacts which were intact but no longer fit for purpose were reused or repurposed, and the labor embedded in products or assemblies was conserved. With the rise of industry and the dawn of mass production, this tradition was rapidly lost in many western countries, leading towards a more rapid turnover approach whereby materials quickly went from cradle to grave, in a linear system or economy. There has been a recent resurgence in the idea of moving back from the linear model, however, with increasing pressures from environmental degradation, climate change, material scarcity, and population growth. With the linear model in mind, this tradition is now referred to as circularity. Once full of proud circular traditions, Norway is one of the countries that lost its way but is now showing renewed interest – not only expressed by the public, but within companies and academia, as well as through public policy. This paper critically addresses the current state of circularity in the Norwegian building industry, considering the relative flows to construction and arising from the waste stream. (TBD, accepted for full-paper submission to the 2024 RILEM Conference on Sustainable Materials & Structures in Toulouse, France).

5.3 The renaissance of reuse in Norway –the future is back (abstract)

Society has historically valued labor and resources, including the intermediate and end products produced through them. Discarding these artifacts was seen as squandering valuable effort and resources, and waste was historically an activity to be avoided. This tradition was rapidly lost in many western countries, replaced by a more rapid throughput approach whereby

materials quickly went from cradle to grave in a linear system or economy. There has been a recent revival of the idea of moving back from this linear model, however, with increasing pressures from environmental degradation, climate change, material scarcity, and population growth. The move toward a more circular model, and the recent resurgence in interest in circularity in Norway is assessed with an eye toward potential pitfalls, based on the past 75 years of modern building methods. How can society expect to move away from the linear approach if the buildings themselves were created within that paradigm. (TBD, accepted for full-paper submission to the Net-Zero Future 2024 Conference in Oslo, Norway).

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6. Network strategies

Åshild Hauge, Associate professor, UiO/INN
Marin Kristine Brown, PhD candidate, INN

6.1 Introduction

Work package 5 on Network strategies was led by Prof. Åshild Lappegard Hauge at the Department of Psychology at Inland University College (INN). The main work was carried out by PhD candidate Marin Kristine Brown, in collaboration with the REBUS research team and partners. While the PhD candidate was on maternity leave in 2023, the research continues with certain aspects already completed and some ongoing sub-projects. Some initial findings will be presented shortly.

Work Package 5 in the REBUS project focused on three main research areas. Firstly, in cooperation with researchers from SINTEF, we conducted a survey in 2020 as presented in WP 1 (Fufa et al., 2023). This survey explored barriers, drivers, and norms for reuse in the building industry. Marin Brown is currently working on an article that focuses on the psychological aspects of the survey, particularly on norms for reuse.

Secondly, we designed and conducted a one-year network (2021–2022) to study the reuse of building materials. We interviewed participants both before and after the network period to understand the significance of their involvement in the network in shaping norms related to reuse (WP 5). This network was conducted in collaboration with Boligbygg (Oslo municipality). Most of the publications resulting from this research are still being finalized. However, a book chapter has been written on the topic of psychological perspectives on innovation and sustainable development in organizations, providing a theoretical foundation for the importance of networks in driving innovation and establishing reuse norms (Brown et al., 2023).

Finally, we conducted group interviews with network members who are leading the way in reuse of building materials. These interviews aimed to gather their perspectives on policy and incentives for reuse in Norway (WP 5) (Hauge et al., 2023).

6.2 Network research

The REBUS network was led by Boligbygg (Oslo municipality) in cooperation with us at INN. Boligbygg invited their collaborators in the building sector to join this network through their website. To ensure the knowledge was effectively brought back to each firm, two participants from each firm were included. In total, the network had 18 participants from 8 consultant and entrepreneur firms.

Throughout the year, we organized four seminars with assigned tasks in between. The seminar program focused on group work and the sharing of experiences. Additionally, we had external presentations on various reuse topics. During the assigned tasks, participants were expected to actively engage with their respective firms.

Qualitative interviews were conducted with the participants before and after their participation in the network to gather insights on their motivation and expectations to participate and experiences of participating in the network. The interviews also focused on attitudes and norms for reuse. To mention a few examples, preliminary findings from the interviews suggest that:

- The network members were highly motivated to participate in the network because they saw it as, amongst others, an arena for learning, collaboration, reducing risk, and being at the forefront of reuse.
- Few felt a strong attachment to the network, but there was still a high degree of trust and sharing culture between participants.

- The network seems to increase motivation and self-esteem about own knowledge – "we are facing the same challenges".
- There could have been a more diverse group with users/stakeholders from the whole value chain – especially decision makers.
- There could have been more focus on practical perspectives, actual problem-solving, and concrete experiences.
- The excursion and tour of a building with reused materials was a positive experience.
- Homework between gatherings increased engagement.

6.3 Master thesis on attitudes towards reuse aesthetics

The interviews revealed that attitudes towards the aesthetic aspects of both interior and exterior office buildings pose a barrier to reuse. Consultants and building owners tend to believe that customers prefer new and pristine buildings. As one participant explained, "you have had an attitude about (…) that it should look completely new and fresh (…). You have a certain attitude about how things should look when the construction project is completed" (Female, company 6). This finding led to an invitation to explore the topic further in a master's thesis. Gjerdbakken (2023) conducted a survey to assess the aesthetic evaluations of office building facades, specifically whether office workers' knowledge about reuse could influence their aesthetic judgments.

The aim of Gjerdbakken's (2023) thesis was to determine if aesthetic evaluations of reused facades and new-build facades in buildings could be influenced by information about the type of facade. The study included 301 office workers with no prior knowledge of reuse or the construction industry. Six pictures were used, including three of conventional office building facades and three of facades constructed using reused materials. In one survey (Survey A), information was provided indicating whether the building facade in the image consisted of reused or new materials. In the other survey (Survey B), no information about the materials was given.

The results showed that participants who were informed about the facade type (Survey A) rated the reused facades as more friendly, exciting, unusual, and engaging compared to those who were not provided with this information (Survey B). This suggests that informing customers about reuse could positively influence their attitude towards the aesthetic quality of buildings.

6.4 Reuse of building materials – feedback on policy and incitements

A series of group interviews were conducted within the established network. Including Oslobygg, nine firms and organizations in Norway were interviewed to gather input and opinions on policies and incentives for reuse. It is worth noting that the majority of these firms were consultant firms with a specific interest in the reuse of building materials.

These interviews took place during the final network seminar. The seminar's program for the day focused on the societal frameworks for reuse in Norway and included presentations on policy. This ensured that the participants were updated on the latest policy changes before the interviews took place. During the seminar, a representative from Enova provided a presentation on opportunities for financial support, a representative from DiBK shared the latest updates on TEK17 and DOK, and a representative from DFØ presented a new guide for environmentally friendly public procurement. These are the informants' main opinions:

- The firms expressed that project partnering, specifically "samspillsentreprise," is the most effective type of contracting for achieving success with reuse. The environmental focus can be maintained from start, in the development phase. You can plan for reuse in cooperation with the stakeholders, before detailed decisions are made.

- Warehouses for building materials should sell both new and used building materials.
- While the firms are supportive of policies for mapping reuse opportunities, they noted that these reports often go unused and unread. They recommend making these reports accessible to the public by publishing them online. Common digital marketplace for reused materials, like a public "EN TUR"-app. Also, for publishing reuse mapping-reports
- The firms believe that policies should not only focus on mapping and planning reuse but also include requirements for actual reuse.
- Additionally, the firms emphasized that policies promoting reuse must be considered in conjunction with regulations on demolitions, recycling, area efficiency, and maintenance.

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7. Norwegian partners reuse related activities

Boligbygg, FutureBuilt and Resirqel were the national partners, representing a public building owner, an innovation programme operator, and a reuse consultant, respectively. This chapter gives an overview of their involvement in reuse activities, their perspective on potential application of the REBUS project results, and areas that need further research.

7.1 Resirqel

Olav Sunde, Resirqel

Resirqel is a consultancy specializing in the reuse of building materials. Since 2013, Resirqel has been exploring new ways of circularity, engaging in practical projects, developing new practices, and sharing knowledge. As one of Norway's few reuse specialists, Resirqel strive to realize reuse in building projects and try to contribute to making reuse practice a natural part of the building industry.

The REBUS project aims to address important challenges for more sustainable resource utilization through promoting reuse of building materials. Resirqel therefore joined the REBUS project as a partner with the aim to contribute with experiences form various projects and sharing practical knowledge.

During the course of the REBUS project there has been some significant developments:

- Reuse mapping ("ombrukskartlegging"), a method for identifying and documenting reusable materials and components in existing buildings (GBA & Statsbygg, 2021; SINTEF, 2023), has developed from testing in a few ambitious projects to become a more developed and standardized process, offered by several consultancies (Future-Built, 2022).
- The Norwegian Building Technical Regulations (TEK17) now requires a reuse mapping of building components to be removed during demolition, renovation, or transformation, to assess whether any of them are suitable for reuse (Kommunal- og distriktsdepartementet, 2022).
- Several cities throughout Norway are establishing reuse centrals, to offer logistical solutions and a physical marketplace for reuse of building components (Askvik, 2024). In the past three years Resirqel have been involved in establishing a reuse central, Sirkulær Ressurssentral, in Oslo (SRAS, 2022). Sirkulær Ressurssentral opened in March 2023, thanks to cooperation between several private and public partners in the real estate industry.
- Cooperations, partnerships and knowledge sharing arenas, among others the REBUS project, are contributing to push the development of reuse and circular practices in the building industry. The development for a more sustainable building industry seems to engage the various organizations to open up and share knowledge and development.

The status of reuse in Norway is still challenging, as there is a lack of a large-scale functioning reuse market, with predictable volume and documentation for a secure delivery in large-scale projects. There is also a need for more and better information on how to make the most sustainable choices when selecting materials and designing a building. Existing legislation and assessment methods are still geared towards new materials and products, and a linear economy model.

The application of reuse of building materials and a circular practice in the building industry may be one of the most effective methods of quickly and efficiently reducing emissions, as well as reducing natural resource depletion. The REBUS project helps to develop and share knowledge to further promote that practice, both in the Norwegian context and also through

partners in Sweden and Denmark. An interesting next step would be to further explore the developments and experience in various countries in Europe, to draw on achievements and best practices developed.

7.2 A REBUS puzzle, FutureBuilt

Erlend Seilskjær, FutureBuilt, WP leader in REBUS

Have you heard the ancient Indian parable where a group of blind men encounters an elephant for the first time? With no prior knowledge of the majestic creature, they decide to explore it by touch. Each blind man, feeling a different part of the elephant's body, offers varied descriptions based on their limited experiences – ranging from a thick snake to a pillar resembling a tree trunk. The underlying lesson is clear: we often assert absolute truths based on our own experiences, disregarding the equally valid perspectives of others. This timeless parable came to mind as I tried to sum up the experiences from REBUS.

For it is often in the intersection of diverse traditions, cultures or disciplines that great ideas emerge. By connecting different academic fields, new connections and thoughts arise, providing us with a broader understanding of or a phenomenon like reuse in REBUS's case, not unlike the elephant from the parable. Circularity and reuse (in conventional construction, I must add) is a young discipline, and we grope like the blind men. We learn that reuse is not merely a technical challenge, nor is it solely architectural, legal, logistical, or cultural. It is all of these at once and must be addressed accordingly.

Circular construction and reuse have come to the fore the later years, paralleling the heightened attention to carbon emissions from the construction sector. Our attention is drawn towards building materials, where a GHG reduction from building materials gives instant effect (unlike other main GHG drivers such as transportation and energy use, where the emissions are spread out throughout the buildings' life span). In short, that leads to two feasible strategies: 1) build with low-carbon materials, or 2) limit the outtake of virgin materials by prolonging the life span of existing material resources and structures. Reuse, of course, sorts under the second category. And in addition to the GHG emission reduction, this strategy also offers solutions to other crucial challenges of our time. By keeping material resources that are already extracted in the loop we can save natural resources and limit land grab, we can minimize construction waste, and hopefully foster a more compelling architecture. In FutureBuilt, we therefore consider circularity in buildings an intrinsic value, not merely a climate measure.

Throughout the REBUS project period, FutureBuilt has, in cooperation with ambitious developers, completed three full scale circular buildings, Kristian Augusts gate 13 (Entra, 2021), Kristian Augusts gate 23 (FutureBuilt, 2023a) and Skur 38 (FutureBuilt, 2023b), all of which were dealing with transformation or retrofits of existing structures to varying degrees.

Figure 9. Skur 38 Oslo havn (FutureBuilt)

Figure 10. KA13 reception (Tove Lauluten)

Currently we are applying the circular method on the two first new constructions, Nedre Sem låve (Asker kommune) and TradLab tre (Norsk folkemuseum), built with reused (and re-usable) components to a large degree. Additionally, we work with several pilots in various stages of development, encompassing both individual buildings and more complex urban quarters.

Figure 11. TradLab TRE Norsk Folkemuseum Arkitekt Olav Vidvei

Figure 12. Nedre Sem Veidekke disassembeling donor building (FutureBuilt)

FutureBuilt's main contribution to REBUS has been the work with these pilots. Secondly, we have made the projects, its stakeholders, and their experiences available to the interdisciplinary researchers for them to dissect.

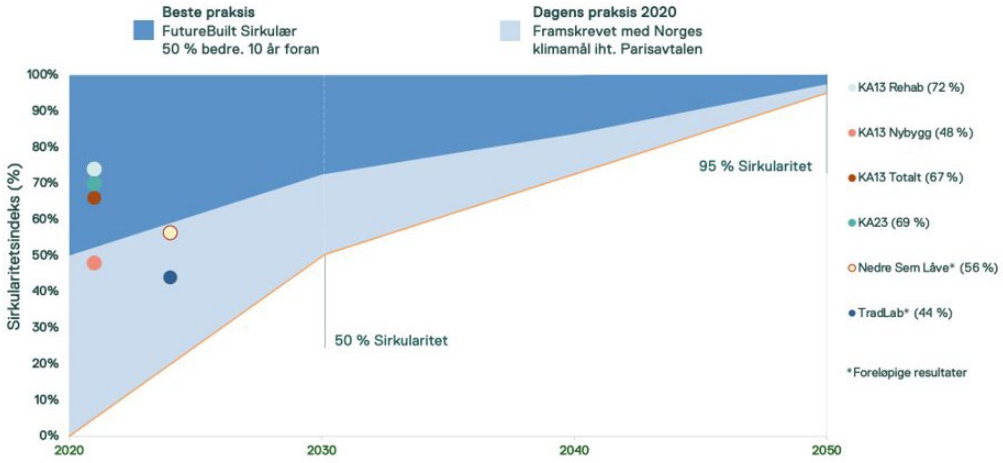

Figure 13. Rising ambitions towards 2050 (with preliminary values for ongoing pilots)

We have also used the experiences from the first pilots to do a third revision of our criteria set for circular buildings (Nordby et al., 2023). In short, a circular FutureBuilt pilot should by 2020 achieve a 50% degree of circularity. The requirement level is raised year by year in a dynamic curve, with a long-term ambition of a fully circular construction sector by 2050. The degree of circularity is calculated through the FutureBuilt Circularity Index, measuring circularity levels based on *present measures* such as conservation, reuse, surplus, recycling, and virgin materials, but also *future measures* such as reusability, recyclability, and waste production. The ambition level is aligned with both the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework. Please note that the criteria set as well as the circularity index are freely available for anyone to use. The criteria set is also translated to English (Nordby et al., 2023) and German.

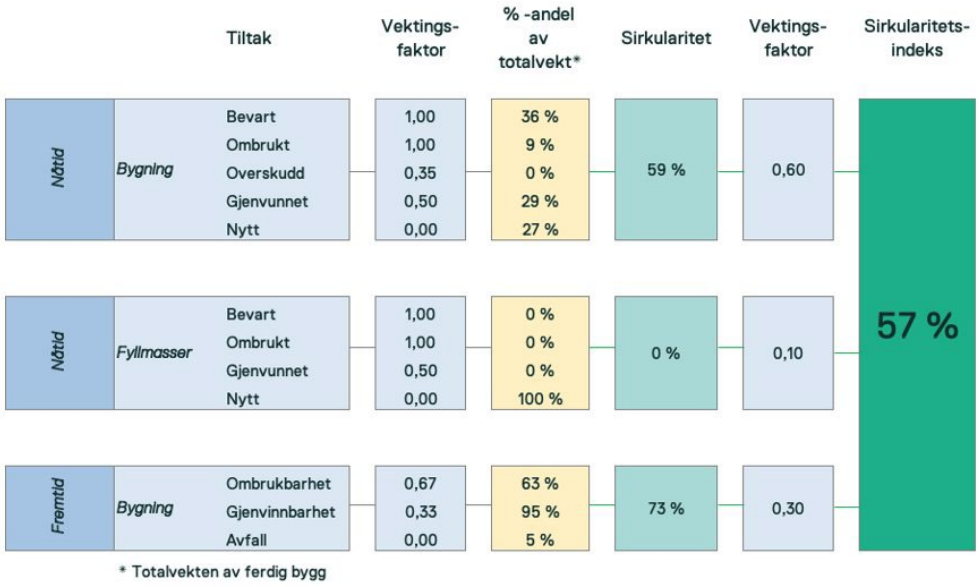

Figure 14. How to calculate circularity (FutureBuilt)

REBUS has not furnished us with a comprehensive set of solutions on how to scale up reuse in the building sector. However, REBUS has contributed to an enhanced comprehension of the current status and delineates the crucial roles various academic disciplines play in the substantial transformation we are currently undergoing. Returning to the story of the elephant and the blind men: we are still fumbling, but continuously gaining a clearer understanding of the elephant.

7.3 Reuse in Boligbygg Oslo KF

Bente Iren Larsen, Quality section head/*Seksjonsleder kvalitet, Boligbygg Oslo KF*

Boligbygg Oslo KF is a municipal enterprise that owns, manages, and rents out Oslo's municipal housing. Our social mission is to make housing available for people who have a need for and demand for housing.

Boligbygg owns approx. 11,500 homes, and our portfolio contains the following:

- Classic 1890 appartement buildings
- Large appartement buildings from the 1920s
- High-rise buildings from the 1960s and 1970s
- Modern new buildings with adapted housing
- Residential housing for people with substance abuse and psychiatric problems
- Small houses
- Detached apartments in housing associations/condominiums

Over 170 of these properties have been assessed as having conservation value, and the average age of the portfolio is approximately 75 years (2023).

7.3.1 Business and production

Boligbygg does not build new buildings, we rehabilitate. Examples of projects we carry out:

- Rehabilitation of facades, roofs, windows, wet rooms, replacement of lifts, etc.
- Full rehabilitation of apartments
- Partial rehabilitation of rooms in apartments
- Post-insulated roofs and walls

We have both large and small projects with this area.

Boligbygg is not responsible for household appliances and furniture in apartments, this is the tenant's responsibility, and is therefore not a large part of our work within reuse.

7.3.2 Reuse – where are we now?

We have recently started to focus more on reuse in Boligbygg. Requirements for reuse mapping in TEK 17 (Kommunal- og distriktsdepartementet, 2022) led us to start work on reuse in a larger scale. We have great opportunities for improvement. When we are renovating apartments, there has always been an assessment of the existing interior, whether something can be reused, especially in sanitary products, but also in kitchen furnishings. Today, if we do not use it ourselves, we deliver this to the Circular Resource Centre (Sirkulær Ressurssentral) in Økern (SRAS, 2022).

In the case of major rehabilitation of buildings, and reuse of existing materials in our buildings, it is a challenge that many of the buildings are of older vintage, with correspondingly older materials. This means that there is sometimes little that can be reused, due to the content of materials. We reuse some roof tiles and wood, but so far it is small amount of reuse in other projects.

Another challenge is that we do not have sufficient information about the materials that have been used in previous renovations, how old they are, the manufacturer, nor the expected lifespan. Our FDV (Forvaltning, drift og vedlikehold) system does not contain all the necessary information, which unfortunately contributes to the fact that some materials cannot be reused.

7.3.3 Reuse – going forward

Logistics: We need to provide a warehouse that is easily accessible to our suppliers, so that they can pick up the equipment we put away. Another option is to use the Circular Resource Centre at Økern. This also requires a good overview and documentation for every one of which products/materials are available, to easily find what you need.

Competence: We will increase competence in reuse. The organization must learn about the possibilities inherent in the various products we have, and what possibilities the products give us in relation to the products being able to be used in other buildings. We will make demands on our suppliers regarding assembly, to make it as easy as possible to dismantle for use elsewhere. We need experience to optimize the process of reuse and environmental work in general. Reuse mapping will be an important contribution to this.

Product: We must choose products and materials that can be reused. We will create detailed descriptions and environmental demands to our suppliers.

Culture: We must create a culture of environmental work in the organisation. Reuse is an area where we have opportunities, and communicating the importance is key, in addition to showing the value of our work, for example by quantifying our contribution to reuse in our projects.

Time, cost, and efficiency: We must learn from experience and introduce new methods in rehabilitation, which is demanding in several areas. We must accept that this can be somewhat more time-consuming and costly, which affects our deliveries and our budgets.

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8. Reuse in Sweden and Denmark

BUILD and IVL were international partners in REBUS involved in knowledge exchange on reuse and sustainability practices from their respective countries, Denmark, and Sweden. This chapter provides an overview of the status of reuse in both countries, highlighting their research activities related to reuse and identifying potential areas for future research and collaboration.

8.1 Status of reuse of building materials in Denmark

Regitze Kjær Zimmermann, PhD candidate, BUILD AAU
Harpa Birgisdottir, Professor, BUILD AAU

The Danish construction sector generates around 5 million tons of waste each year, which corresponds to about 40% of the total waste in Denmark (VCØB, 2021). The amount of waste is closely related to the activity level in the construction sector, which has been steadily increasing for many years, and is expected to continue in the coming years.

From the construction waste generated in Denmark, a little more than 1/3 is recycled, 52% is recovered (for instance as backfilling in roads), and the remaining 12% is incinerated or disposed of in landfills (VCØB, 2021). Mineral waste such as concrete, asphalt, and tiles make up half of the generated waste from the construction sector. Further, waste that is simply classified as "mixed waste" also make a significant part of the waste generated. This shows that there is still potential for better sorting of construction waste in Denmark. Furthermore, uncertainty is also significant in the current waste data due to limits in the reporting procedure (ibid.).

The amount of building materials that are *reused* are thought to be limited (VCØB, 2021). However, it has not been quantified, since it is not classified as waste and is thus not a part of waste statistics. The lack of reuse can, in part, be related to the legislative challenges of reusing materials in construction. However, some building materials that are successfully reused are bricks and roof tiles, wood structures and flooring, steel and concrete elements, and interior building materials (ibid.). In the last few years, studies have also shown the potential savings in climate impact from different scenarios for these materials such as reuse, recycling and recovery (VCØB, 2023; Andersen et al., 2019; Rambøll, 2020). These materials are all very common in existing buildings in Denmark.

The potential for reuse of building materials in Denmark is considered significant due to the high activity level in the sector, and its significant material use and climate impact. The construction sector is responsible for 32% of the *material* footprint of Denmark, using 38 million tonnes of non-metallic minerals, 3 million tonnes of fossil fuels, and 1.5 million tonnes of metal ores to produce national or imported materials for the construction sector – thus, accounting for 17% of the carbon footprint of Denmark (Circle Economy, 2023). Increasing the circularity within construction has recently been estimated to be one of the most effective strategies to increase the circularity in Denmark and can reduce carbon footprint by 12% (ibid.). Specifically, the increase in reuse of building materials and components along with increased renovation is one of the most effective strategies that can reduce the Danish carbon footprint by 3.6 %, and the material footprint by 6.9% (ibid.).

The transition towards more reuse and recycling in the building sector is ongoing. The current development is driven by frontrunners throughout the value chain, and multiple demonstration projects have been carried out in recent years such as Upcycle House (Realdania, 2014) and Circle House (Lejerbo, 2024). Furthermore, ongoing large-scale projects that also focus on

mapping available materials include The Resource Block (*Ressource Blokken*) (GXN, 2024), and Circle Bank (Circle Bank, 2024). Focus within the industry has also shifted in a way where waste is now considered a resource. However, scaling and commercializing reuse solutions are lacking (TI & CLEAN, 2023). Furthermore, most of the industry continues with business as usual (ibid.).

Climate declarations for buildings can be a driver for more reuse in Denmark. In 2023, the Danish building regulations were updated with a demand for climate declarations of all new construction (Social-, Bolig- og Ældreministeriet, 2022). Thus, all new buildings must perform a life cycle assessment (LCA) to determine the climate impact. Further, buildings over 1000 m^2 must stay below a limit value of 12 kg CO_2-eq/m^2/year, and this limit value is expected to lower every couple of years. According to the regulations, reused materials account for zero in the calculation of climate impact. Therefore, the regulation will significantly incentivize the reuse of building materials. The coming years will show if this affects the current practice in the building sector.

8.1.1 Overview of BUILD's research activities related to reuse

The focus in research within the research group of sustainability of buildings at BUILD has mainly been on how to evaluate the environmental impact and benefits of reuse, recycling, and other circular solutions such as design for disassembly.

- GHG-emissions from reuse of building materials
    - GHG emissions from circular and conventional building components (Andersen et al., 2020)
    - Livscyklusvurdering for cirkulære løsninger med fokus på klimapåvirkning: Forundersøgelse (Andersen et al., 2019)
- Design strategies for reuse in buildings and quantification methods through LCA:
    - Building design and construction strategies for a circular economy (Eberhardt et al., 2022)
    - Circular Economy potential within the building stock – mapping the embodied greenhouse gas emissions of four Danish examples (Eberhardt et al., 2021a)
    - Environmental Design Guidelines for Circular Building Components: The Case of the Circular Building Structure (Eberhardt et al., 2021b)
    - Development of a life cycle assessment allocation approach for circular economy in the built environment (Eberhardt et al., 2020)
    - Low-carbon design strategies for new residential buildings – lessons from architectural practice (Rasmussen et al., 2020)
    - Upcycling and Design for Disassembly – LCA of buildings employing circular design strategies (Rasmussen et al., 2019)
    - Building the future using the existing building stock: the environmental potential of reuse (Charlotte et al., 2022)
- Practical implementation
    - Good documentation for reused materials (Kock-Ørvad et al., 2023)
    - Guide for dialogue on reuse in the construction sector (Birgisdottir et al., 2019)

8.1.2 Use of results from REBUS and potential future research areas

The participation in the REBUS project has given the opportunity to share information, exchange knowledge and considerable amount of inspiration. Within life cycle assessment, development of methodology for this, there is a large potential for further Nordic collaboration. Also, in order to take the focus on a higher level, starting from the focus to avoid or minimize demolition of buildings. And still within the evaluation of potential benefits of reuse

and recycling through application of life cycle assessment, there is still large potential for further collaboration. Adding focus on resource consumption and biodiversity in our methods would be important for further research and development.

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8.2 Status on reuse of building materials in Sweden

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The construction sector is material-intensive, and within the EU accounts for 50% of global material use (European Commission, n.d.), while large amounts of waste are generated. In 2020 the Swedish building sector generated around 14,6 million tons of waste per year (Naturvårdsverket, 2022), 40% of all waste generated (Boverket 2023a) and emitted around 16 million tons of greenhouse gases (as CO_2-equivalents), approximately 21% of Sweden's total emissions of greenhouse gases (Boverket, 2023b). Today, approximately 2% of the Swedish construction and demolition waste goes to material recycling, while most (50%) is used as construction materials around landfills. Large fractions also go to landfill (31%) and to energy recovery (10%) (Naturvårdsverket, 2022). There are currently no reliable statistics or measurement methods on how much building material is reused.

The industry is far from circular. Working methods and business models are mostly linear. Sweden's resource use – all sectors – has been set at 3.4% in the Circularity Gap Report Sweden (RE:Source, 2022). And every year, materials to the value of SEK 19 billion disappear from the Swedish economy due to today's linear material flows in the construction sector (Material economics, 2018).

A study, conducted by IVL in 2020, identify key barriers to the increased reuse of high-quality construction products in the Swedish building sector. The results identify a lack of knowledge and an immature market as key barriers that must be removed to enable increased reuse in the Swedish building sector. Other main barriers identified for reuse: current habits and attitudes, a lack of time and resources, and uncertain quality of and lack of warranties for reusable

products. Many of these barriers are interconnected, meaning that if one barrier is overcome there is likely to be a concomitant impact on the others (Gerhardsson et al., 2020a).

Previous studies also show that reuse of building materials has enormous potential. Rydberg et al. (2022) have estimated that the potential annual savings from the reuse of construction products at the national level is 900,000 tons less construction waste and reduced emissions of 1.8 million tons of CO_2 equivalents. In the study, these and others are appreciated environmental aspects to a total annual environmental profit of 600 million euros. This potential is based on assumptions of share construction products in acceptable condition on Recycling centers. The actual potential is thus probably much greater if new working methods around recycling are realized.

Experiences from IVL's work with various development and research projects connected to the reuse of building materials show that building materials in Sweden are mainly about the reuse of interior building materials, that are reused within the same organization in the same building project. However, in the last year, we see an increase in the number of projects that try to implement the reuse of construction materials, such as steel and concrete. We also see a high demand for local reuse depots/hubs for reused building materials and a few has started through the country, and several is on their way, but the market is still very small. The last year we have seen a growing interest from material producers. A few material suppliers have started to offer reused products, such as bricks, light fittings, ceiling, ventilations ducts and steel beams/columns, but this market is still very small.

In a study, conducted by IVL in 2022, common flows of reused building materials were identified and summarized and are shown in the table below (Andersson et al., 2022).

Table 1. "Categories of building products and furniture that, based on current flows, may be suitable for reuse for the city of Stockholm to be handled via an imagined common intermediate storage location – a recycling center" (Andersson et al., 2022).

Materials/Products		
Ceiling	Wooden products	Other stone and concrete
Roof	Floor material	Building boards
Windows	Outdoor furniture	Insulation
Doors	Ground material	Construction fittings
Bricks	Lighting	Interior and furniture
Other facade such as stone and sheet metal	Appliances (White goods)	

That said, there are also a few pilot projects looking at heavier and more complex building elements, such as concrete and steel. Examples of research projects connected to this are ReCreate and Återhus.

8.2.1 IVLs research activities related to reuse (generally)

IVL Swedish Environmental Institute (IVL) has for several years taken a major role in the construction industry's knowledge building and research into sustainable construction. To support the transition to a circular construction sector, the Center for Circular Construction (CCBuild) is run under the leadership of IVL. It is a national platform that houses collaboration forums, knowledge dissemination and digital services linked to circular construction and management. The development of CCBuild has taken place between 2015 and 2022 through the program *Challenge-driven innovation* financed by the Swedish Innovation Agency, VINNOVA. CCBuild is now further driven by IVL in continued broad cooperation with affiliated actors. Currently, approximately 150 actors are connected to the collaboration in CCBuild[1].

[1] https://ccbuild.se/om-oss/organisation/

IVL has been and is active in several research and development projects linked to the reuse of building materials.

Selection of completed publications and projects:

- Calculation of climate effects of reuse in construction.
    - Guidance*:* Återbrukets klimateffekter vid byggnation: Handledning för klimatberäkningar i enlighet med EN 15978 (Gerhardsson et al., 2020b)
    - Klimateffekter av återbrukade byggprodukter och möbler. Metoder för värdering av klimateffekter samt produkter vid mellanlagring och försäljning (Moberg et al., 2022a)
    - Environmental and socio-economic benefits of circularity in real estate management (Rydberg et al., 2022)
    - Transitioning the Swedish building sector toward reuse and circularity (Gerhardsson et al., 2020b)
- Reuse potential of materials or areas:
    - Potential of reuse in the Gothenburg area (Wennesjö et al., 2021)
    - Potential of reuse end recycling in the glass industry (Moberg et al., 2022b
    - Action plan for circularity in the installation industry (Andersson et al., 2023)
- Guides for reuse:
    - Reuse and hazardous substances: Byggåterbruksguiden
    - Reuse in offices: Återbruk på kontor

Selection of ongoing projects related to reuse of building materials:

- Kraftsamling för cirkulärt byggande 2030: The overall goal is to increase the opportunities to scale up and implement solutions in circular construction. This takes place through participation from Sweden's three largest cities, the construction and property industry and then through dissemination to other municipalities and regions.
- Mot cirkulär projektering- utveckling av digitala arbetsflöden för effektivare återbruksprojektering: The goal is to enable circular design where reusable construction products are used to replace part of the linear flows with newly produced products that are currently part of regular workflow and design tools.
- **BRUKA Halland:** A broad initiative to initiate change for a circular transition with the goal of developing large-scale reuse in the construction and real estate industry in the Halland County. IVL is conducting a study inventing the climate-, reuse- and market potential of reus in the Halland County.
- Utveckling av policy för främjande av återbruk på plats: The goal is to get the construction and property sector to focus more on services in relation to materials than today, i.e. to promote reuse on site instead of new installation. By developing a model and method for guiding property owners in procurement for increased reuse on site and identifying and describing possible control instruments for increased circularity.
- Framtidens design – Återanvändning av träbyggnader i en cirkulär ekonomi: The goal is to develop wooden structures suitable for reassembly and reuse with specific functions that follow the value chain for increased environmental benefit. IVL is conducting climate calculation of reused wooden structures.

In addition to this, IVL is strong in several related areas:

- Climate calculation of building materials, several projects.
- EPD for the construction idustry. We make EPDs, we offer EPD tools for e.g. concrete and the wood industry and we have a program operator (EPD International) as a subsidiary.
- Climate benefit with material recycling of construction waste: Klimatnyttan med materialåtervinning av byggavfall
- Transformation of buildings: Bostadisering

8.2.2 Use of result from REBUS project

We see the following use of the result from REBUS-project:

- Use research methods and results from the survey and interviews as inspiration and comparison for future studies in Sweden.
- Use the completed interviews and survey as inspiration and comparison for future studies when we investigate similar ones in Sweden.
- Look into the possibilities to use the experiences from the developed ***Life cycle sustainability assessment – framework***. S-LCA may be of interest to be included in CCBuild's value analysis
- Spread and inform about guides, reports, and papers from the REBUS project to the Swedish construction industry via CCBuild´s various communication channels. The *Ombruk av byggematerialer. Veileder for dokumentasjon av ytelser* is of particular interest.

8.2.3 Suggestions for potential areas for future research and collaboration in Nordic countries

IVL suggest the following list as potential areas for further research and collaboration in the Nordic countries:

- Exchange of experience regarding reuse of building materials between the countries, in several areas, for example: Networking, knowledge sharing, good examples, study visits, etc.
- Nordic survey that compares and shows differences regarding reuse in the different countries.
- Further cooperation and exchange of experience regarding ***Life cycle sustainability assessment.***

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REBUS project (2020–2023)

FINAL REPORT

This is the final report of the research project REBUS (REuse of Building materials – a USer perspective). The main goal of the project was to develop a knowledge platform that enables the wider and more efficient implementation of reusable building materials. The report provides a comprehensive overview of the main research activities conducted by the project partners from January 2020 to December 2023, as well as the main outputs generated during this period. Moreover, the report suggests potential future research perspectives that could further be considered.

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