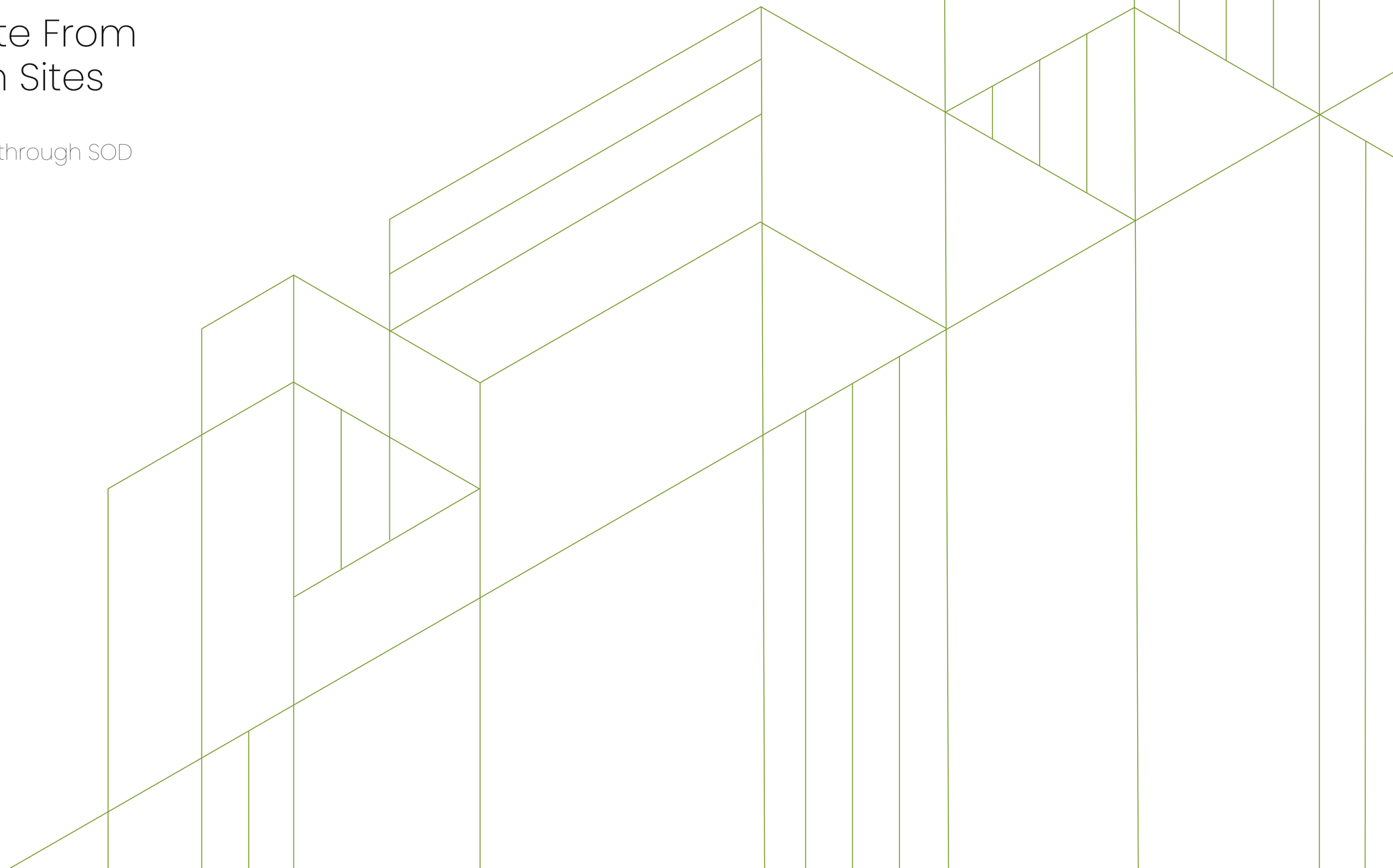
Utilizing Waste From Construction Sites

Exploring the Reuse of Construction Lumber through SOD



OSLOMET

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Master Thesis In Product Design /
Design For Complexity

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Term Clarification

Construction wood
Construction wood is graded according to its strength, appearance, and other factors, and is commonly sold in standardized sizes such as 2x4”, 2x6”, and 4x4” (inches).
Construction wood is used for a variety of applications in construction, such as framing, roofing, flooring, and sheathing. It is also used for making various types of furniture, decks, and fences.
Construction wood can be treated with preservatives to make it resistant to decay and insect damage, which can increase its lifespan and durability.

Lumber
Lumber typically refers to wood that has been processed as a building material (boards and planks). Elsewhere, especially in the UK, the word timber is used to mean the same thing as lumber.

Timber
In the US and Canada, timber is typically used to collectively refer to trees—or the wood of such trees—that have yet to be cut or processed

Off cuts
Smaller pieces cut from standard planks of construction lumber used on building sites.

Impregnated / treated wood
Treated wood is lumber or plywood that has undergone a pressure treatment process to treat it with a preservative, making it more resistant to decay and termites.

CU impregnation
Pressure impregnated wood with copper salts to increase the durability of the wood. The surface gets a green tint and has increased durability compared to untreated wood. This makes it suitable for use where durability is extra important.

Formwork
Formwork, also known as shuttering, is a temporary structure used to support the weight of wet concrete and other construction materials until they have hardened and can support themselves.

Refurbishing
Refurbishing is the process of cleaning materials so that said materials can be put to use.

TEK
The building code (Byggteknisk forskrift; Tek17) sets the limit for the minimum technical demands for a building. The goal is to ensure high quality buildings.

Classification
C14, C16, C18, C24, C30. These are classifications on the firmness/strength of the wood defined in the Norwegian Standard NS-EN 338.

C14
The most common application is simpler constructions or formwork work where there are not such high demands on strength. Not to be used as load-bearing construction.

C16
For the same use as C14, just stronger.

C18
Can be used as load-bearing construction, but not as strong as C24

C24
Standard classification in the Norwegian construction industry, and suitable for most of the load-bearing structures.

C30
Same as C24, just stronger.

TEK 10
The regulation on technical requirements for construction works draws up the limit for the minimum characteristics a construction must have in order to be legally erected in Norway. If you do not follow TEK10, you can receive large daily fines until you improve your building.

TEK 17
TEK17 draw up the limit for the minimum characteristics a building must have in order to be legally erected. The main purpose is to contribute to high-quality construction in accordance with planning and building legislation. TEK17 is an upgrade on TEK10.

SAK (Byggesakforskriften) 10
The rules in the building regulations firstly apply to the processing of building applications, including which measures require permission, requirements for the content of applications, and deadlines. Furthermore, the regulations contain detailed provisions on the various responsibility roles in construction matters (applicant, designer, executioner and controller), as well as rules on central approval for liability law. In addition, the rules determine how municipalities must carry out control and supervision, in addition to certain clarifications about reimbursement, development agreements and buildings worthy of preservation.

Foreword

The group consists of Jon, Sebastian and Torstein. We are friends who met while studying for our bachelor's degree, also in product design. This was our last assignment as students and we wanted to address issues in society with a degree of complexity and the possibility of challenging established paradigms.

We had previously collaborated in a project that introduced us to System Oriented Design. This methodology was exciting because we could spend more time on defining the problem, rather than to design a solution without sufficient knowledge. When introduced to the MinTre project, we became interested because it took a holistic approach to the issues in the building and construction industry.

This was an industry where we had no prior knowledge, but we relied on interviews and Gigamapping as a tool to collect information and make the information accessible. We knew that revolutionizing the building industry was a daunting task, so our goal was to increase circularity and make a small contribution to the green shift to come.

Figure.1: "Team members"

Thanks!
To begin with, we would like to express our gratitude towards Kristin Støren Wigum, who served as our guide and supervisor throughout this project. We appreciate the valuable conversations we had with her and for introducing us to the complex issue of the topic of this thesis.

Additionally, we would like to extend our thanks to Omtre, Ø. M. Fjeld, Ove Skår Entreprenør, Norsk Massivtre, Link Arkitekter, Material Mapper, and Ragn Sells for generously sharing their time and expertise with us. We are grateful for the opportunity to discuss their work and knowledge regarding sustainability in the construction industry.

Finally, we would like to express our appreciation to our families, friends, girlfriends, and fellow students for supporting us throughout this process.

1 Abstract

In Norway, the building and construction industry is a large consumer of both energy and materials. In order for this sector to align with the green shift, we need to reduce emissions from energy use and embodied emissions from material use. MinTre is a research project that aims to reduce wood waste produced on construction sites and was our initial entry to this topic. As the project progressed we worked primarily with Omtre as a primary case, which work towards creating a reclaiming facility for wood waste.

Our research led to, in our opinion, a comprehensive overview of the different stages in the building process. This overview takes the form of a Gigamap that serves as an information tool to both actors inside and outside the reclaiming and building industry. In addition we have through our intervention points highlighted areas we think are important for facilitating an effective reclaiming process, with Omtre as our center of attention.

We think that reusing construction lumber on an industrial scale is possible in the near future. To achieve this, we think that new laws and regulations towards the building industry could make the reclaiming industry more profitable, together with new standards for reclaimed construction lumber. Wood waste from building and construction remains an issue where it’s difficult to pinpoint accountability between the building owner, contractor, architect and waste manager.

System Oriented Design, Gigamapping, Circular economy, Building- and construction industry, Construction lumber

Kanskje du bor i et trehus, eller har et trebord hjemme i stuen din? Eller kanskje terrassen din er bygget i tre? Da har du et karbonlager! Tar du godt vare på disse tingene, kan karbonet forbli lagret i produktene i mange år.

(TenkTre.no)

2 Introduction

In Norway, the building and construction industry is a large consumer of both energy and materials. In order for this sector to align with the green shift, we need to reduce emissions from energy use and embodied emissions from material use. MinTre is a research project that aims to reduce wood waste produced on construction sites and was our initial entry to this topic. As the project progressed we worked primarily with Omtre as a primary case, which work towards creating a reclaiming facility for wood waste..

Because of the broad complex problem of waste management in the building- and construction industry, we see that system oriented design methodology has a great potential to explore the possibilities to design a system that can safeguard the wood's potential, and all actors within the value chain.

Our project has revealed that many of the prominent contractors in the building and construction sector are seeking new solutions. Nevertheless, there is currently no system in place to support the innovative solutions emerging from smaller companies in the field.

Our goal for this project is to visualize this system and discover solutions for creating a more circular system for reusing construction lumber.

Figure.2: "Otside of Omtre's facilities"

3 Process and progress-plan

Early in the project we started to work out a progress plan. It was essentially a dated timeline where the main phases of our project were laid out. We described what we would do in the different phases and marked deadlines for when it was time to continue over to the next phase. This kept us aware of the needed progress towards delivery and gave us a feeling for time and an understanding of how long we expected tasks would take. This was amplified by moving a pin as a symbol of the remaining time throughout the project. The progress plan also proved to be an excellent tool for keeping track of important dates such as interviews and other deadlines.

MIRO
Our main medium for working with the Gigamap has been Miro. It is a digital whiteboard that is made to be efficient for creating text, post-its, frames, to gather images and connect objects via arrows. A Gigamap can get quite messy and to counteract it we created separate Miro boards to the project's different phases. These phases are discover, define, refine and deliver. The project phases are the same as being used in a Double Diamond design process and emphasizes an iterative process (DOGA, n.d.) We found that a SOD approach worked well within these phases and helped us structure the project. A recurring issue when generating vast amounts of content in a Miro board is that it gets slow and difficult to navigate. When moving from one phase to another, we take with us interesting findings, ZIP-points etc. and leave behind dead ends and excess information.

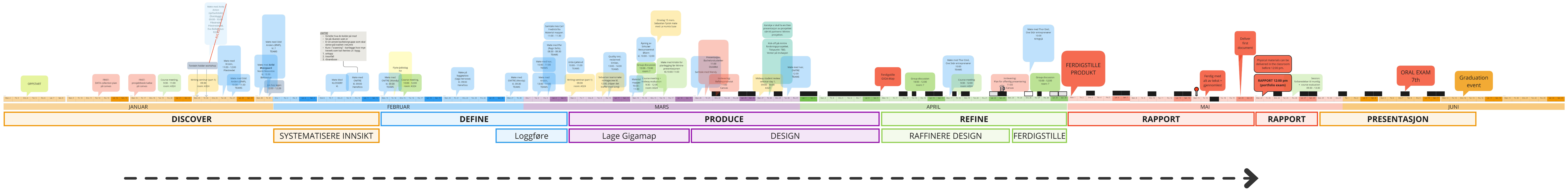


Figure.3: "Progress plan in MIRO"

4 Frames for the project

In the beginning of a project like this, we start out wide and have few limitations on what could be interesting to look further into. As the project progressed, it became natural to define our area of interest. This was in part due the duration of the project, but mainly because of interesting findings pulling us in a certain direction. Building projects generate large amounts of waste within many different waste fractions. With a focus on wood and circularity, we narrowed down the scope to construction lumber that generates a significant amount of waste in all building projects.

The flow of construction lumber from the construction site is a system with defined actors, existing logistics, a comprehensible scale and a material with set dimensions. Restricting ourself to a defined subsystem was important to be able to obtain an overview and limit the actors we needed to interact with. As a source of wood waste, the construction of new buildings was responsible for 101 939 tons, where demolition was responsible for 51 343 tons and rehabilitation of buildings was responsible for 81 972 tons in 2021 (Statistisk sentralbyrå, n.d.).

Being well aware that such a big portion of the waste comes from a construction site, we discovered potential for redirecting the material flow to a company that could reuse the wood. Omtre and their collection and refurbishing system for wood waste became the primary case for our research. Omtre was in the beginning phase of both the collecting and refurbishing system, and was positive towards sharing insights with us. We thought that we were more likely to be able to influence a relatively new company like Omtre and saw them as a company working towards innovation.

Building projects:
Norwegian building projects and rehabilitation projects

Waste from construction site:
Construction lumber

Refurbishing facility:
OMTRE

Product for reuse:
Wooden construction materials

Figure.4: "Frames"

5 Research Question

"How can system oriented design be a tool for creating a circular system for reusing construction lumber in the Norwegian building and construction industry?"

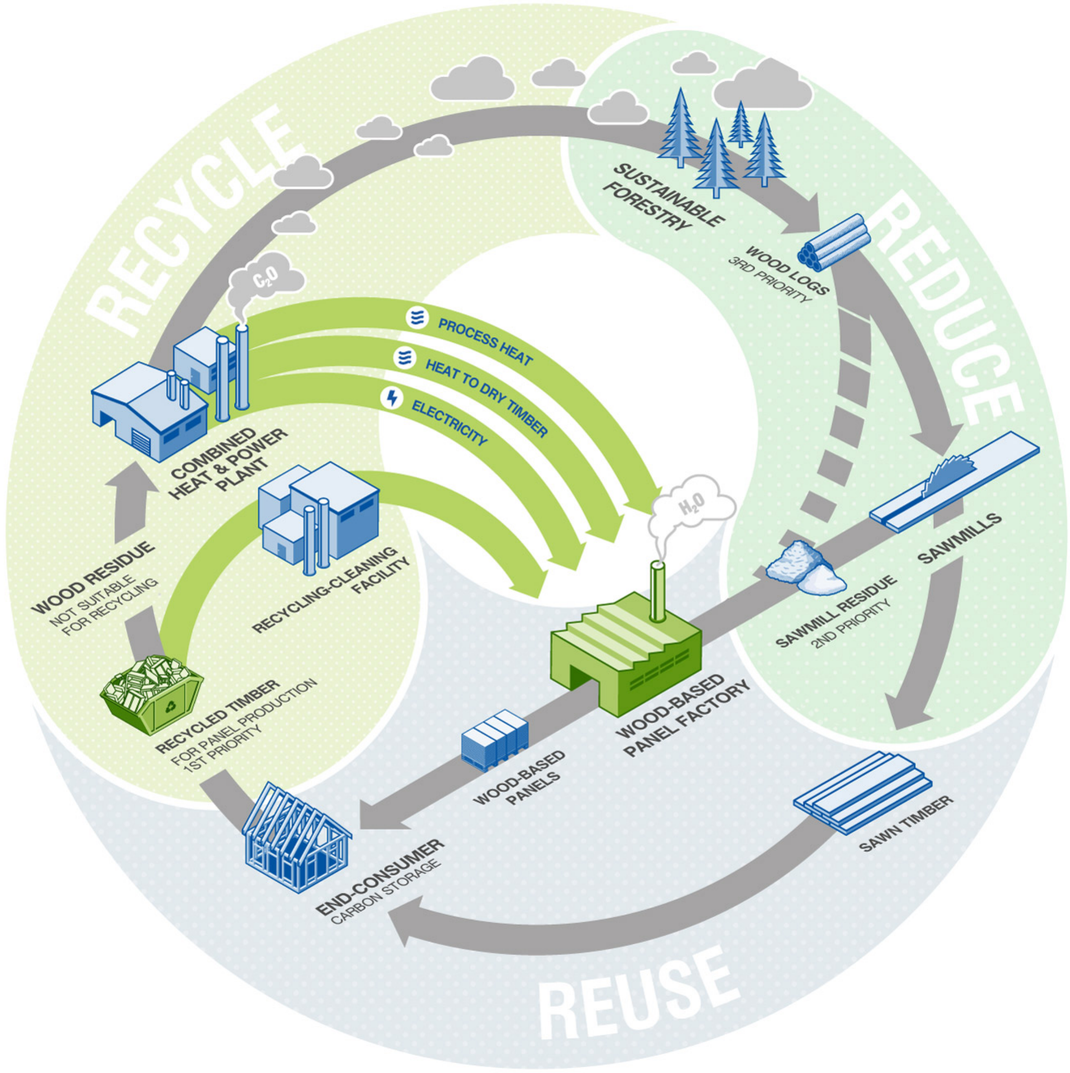


Figure.5: Illustration of a circular lumber production

6 Background

6.1 Climate challenges

Climate change is perhaps the biggest crisis humans have encountered in recent times. Since the 18th century, atmospheric CO2 levels have increased by 50% (NASA, n.d.). This has led to a globally increased temperature by 1,1 degrees celsius compared with pre industrial times. The world's glaciers melt causing mean sea levels to rise about 5 mm per year. 90% of the excess heat from global warming is absorbed by the ocean acting like a heatsink, while simultaneously becoming 26% more acidic compared to pre industrial revolutionary times (World Meteorological Organization, 2019).

WMO Secretary-General Petteri Taalas said the following: "It is highly important that we reduce greenhouse gas emissions, notably from energy production, industry and transport. This is critical if we are to mitigate climate change and meet the targets set out in the Paris Agreement" (World Meteorological Organization, 2019).

Some of the main challenges today are how we generate our power, manufacture goods and buildings, and how we manage the world's forests. The burning of oil, coal and gas remains the biggest fuel source for generating electricity. This practice is responsible for a substantial part of global emissions because of the nitrous oxide and CO2 gas being produced (United Nations, n.d.).

The world's forests are natural carbon storages and cutting them releases the carbon they have been storing. 12 million hectares of forest is cut down each year to make room for farms and pastures, amongst other things. Less forest reduces the amount of CO2 the trees take out of the atmosphere. Deforestation combined with agriculture is approximately the source for 25% of worldwide greenhouse emissions (United Nations, n.d.)

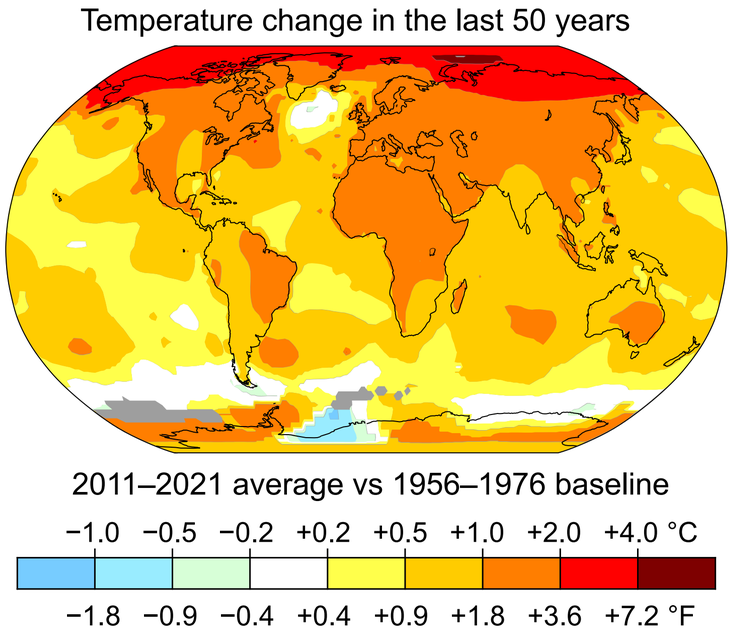


Figure.6: "Temperature change in the last 50 years"

6.2 The Global Building- and Construction Industry

6.2.1 Embodied Carbon Emissions

The building industry worldwide is responsible for 39% of global energy related Co2 emissions, where 28% comes from operational emissions and 11% is from materials and construction, also called embodied emissions (World Green Building Council, n.d.). It is therefore an industry that needs to undergo change to limit global warming to 1.5 degrees which is a key goal in the Paris agreement (European Commission, n.d.). The Global Status Report for Buildings and Construction found that 34% of the global energy demand went to the building and construction industry. The construction sector stands for 40% of European energy consumption and 80% of the energy used comes from fossil fuels.

6.2.2 Generated Waste

The use of concrete, steel and cement are massive sources of Co2 emissions and raw resource use is forecast to double in quantity by 2060. This in an industry where material use already is responsible for close to 9% of global energy related greenhouse emissions. Emissions from material extraction, processing and use needs to be lowered. Looking into alternative construction materials can help the building sector to reduce its negative carbon footprint (Causes and Effects of Climate Change | United Nations, n.d.).

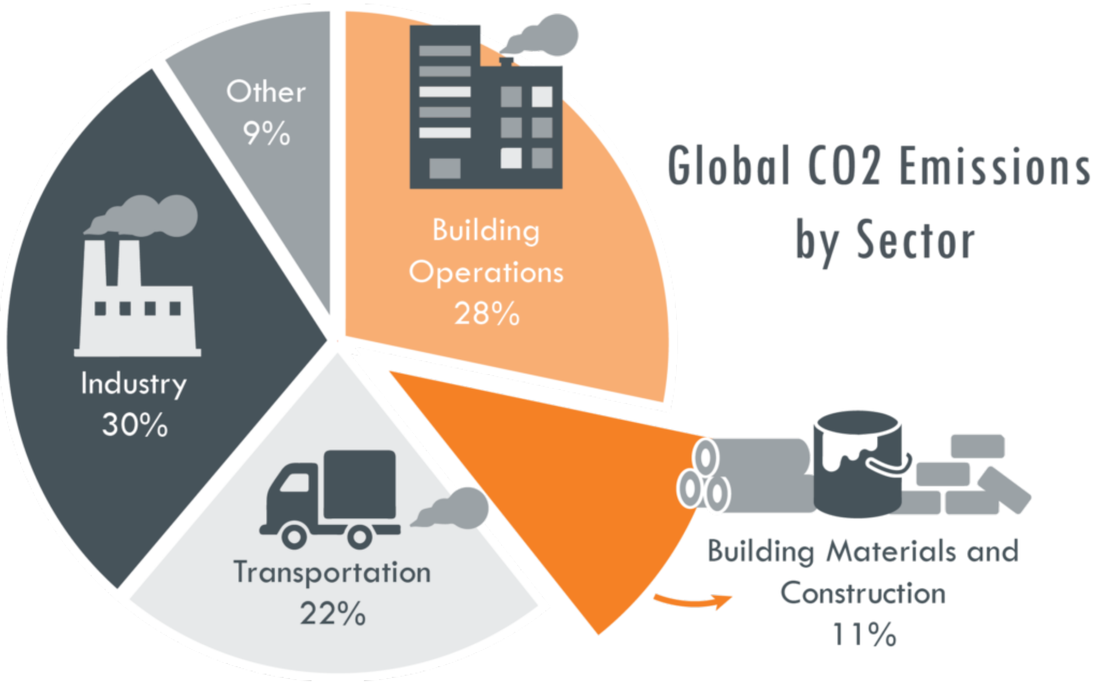


Figure.7: "Global CO2 emissions by sector"

6.3 The Norwegian Building- and Constructiuon Industry

6.3.1 Emissions In The Norwegian Industry

The construction industry in Norway plays an important part in the green shift. It is a sector that faces a number of environmental issues that have a significant impact on the environment and public health.The main roadblocks today is lack of knowledge about more sustainable possibilities, prejudices about environmental measures being costly, old habits and uncertainties about legal requirements (Grønn Byggallianse, n.d.).

Greenhouse emissions from the Norwegian construction and building industry are best understood by separating into direct and indirect emissions. The direct emissions are fairly low and come from construction site work and heating of buildings when fossil fuels are used. The indirect emissions are large because the building sector influences and creates emissions in other high emission sectors. These indirect emissions mainly come from three areas. When a building owner buys materials from the industry, concrete for example, how the building owner affects transport emissions and transport patterns through building placement and the energy requested from energy companies and what requirements the building owner puts on whether this energy comes from renewable sources (Grønn Byggallianse, n.d.).

When the Norwegian government calculates the emissions from the Norwegian construction and building industry, they base it on emissions from the electricity produced in Norway, which is primarily renewable and carbon neutral. Therefore, the climate emissions from energy use in the building sector only make up 1-2 percent of Norwegian emissions. But if we include the indirect emissions from transportation and materials to building and construction work, it accounts for 16% of Norway's total emissions. This is because the Norwegian construction and building industry stands for 40% of the society's material, 40% of the energy use and 19% of all traffic is related to building and construction. Over 50 percent of the emissions from a building use cycle comes from the transportation and production of materials (Grønn Byggallianse, n.d.).

The construction of new buildings are responsible for 70 percent of emissions from the building sector, if we calculate that our electricity is close to carbon neutral. This is why we have to demolish less buildings, rehabilitate them instead, reuse more materials, choose solutions with low emissions during the buildings use cycle, make construction sites fossil fuel independent and decrease existing buildings energy needs (Grønn Byggallianse, n.d.)

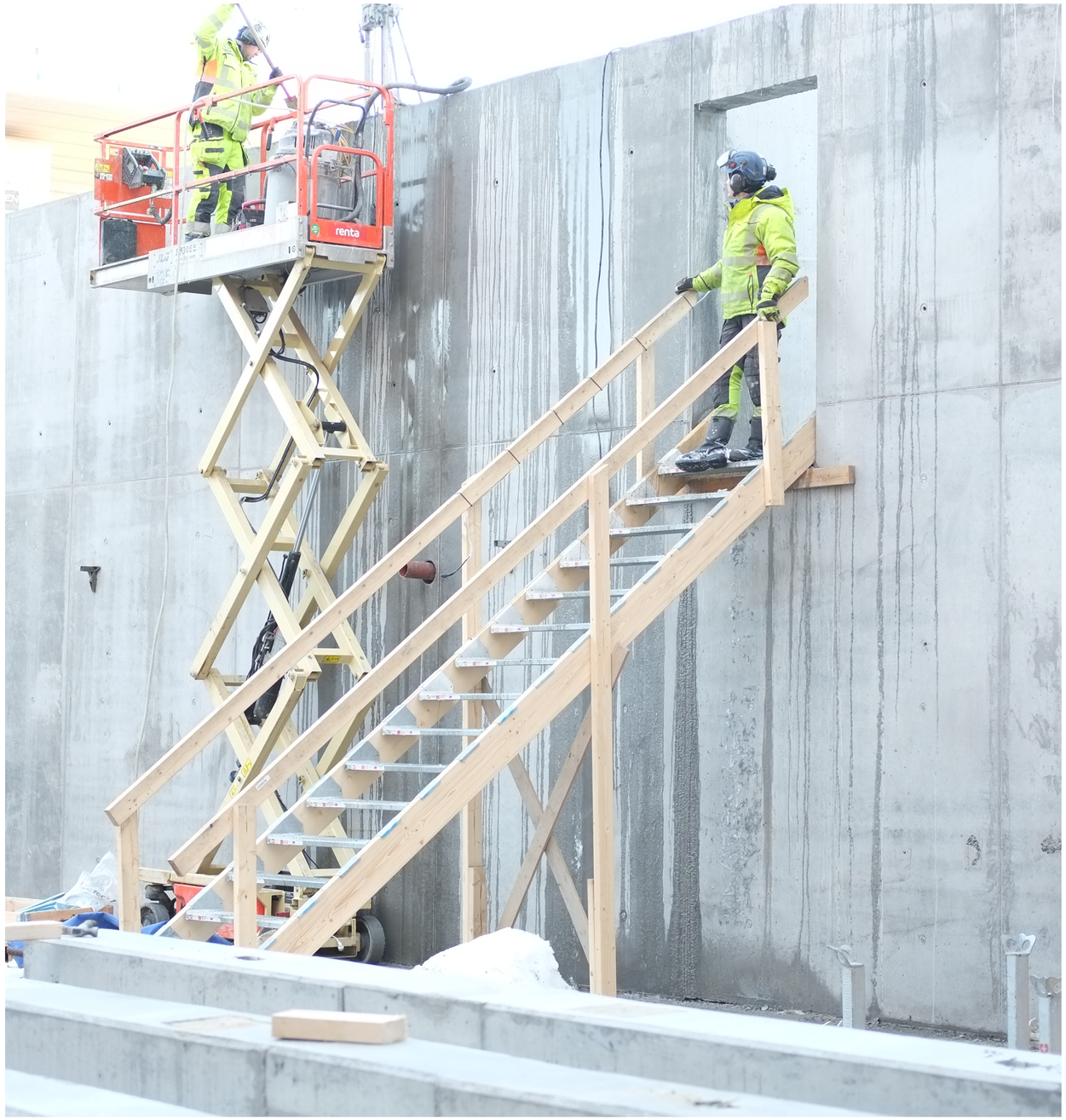


Figure.8: Saga Terrasse, Ø. M..Fjeld

6.3.2 Waste in the Norwegian construction industry

The Norwegian industry generated a total of 1,82 million tonnes of waste in 2021, of which 235 254 million tonnes (11,4%) is wood (Statistisk sentralbyrå, n.d.).
This leaves a great space for opportunities within reusing building materials, and for creating a circular system for the future of a circular economy within the industry.
The industry unanimously agrees that a circular economy will be important in the building- and construction industry in the future. However, it turns out that a thorough approach to circularity in the industry is difficult to achieve. This is mainly because of barriers related to timing of involving third-party initiators, budget constraints, laws and regulations, logistics, a limited market for circulation of reused building materials, and a constant higher adjusted expectations with unclear level of ambitions (Deloitte, 2023).

	Avfallsmengde							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Byggeaktivitet i alt								
Materialtyper i alt	1 813 092	1 785 533	1 875 994	1 896 557	1 845 161	1 948 641	2 135 747	1 821 963
Treavfall	250 605	253 335	259 613	253 529	245 815	253 629	267 447	235 254

Figure.9: "Avfall fra byggeaktivitet"

6.3.3 Wood VS concrete

Wood is a renewable building material that captures CO2 during its lifecycle and takes little energy to produce. Norway has a surplus of sustainable forest and the lumber being used in construction comes from FSC or PEFC certified forestry (Fremtidens Byggenæring, 2021).

Wood is a relatively light material and only weighs 20% of reinforced concrete. Lighter buildings give room for less complicated and cheaper foundations. Wooden prefabricated elements are fast to assemble resulting in quicker building times and lower construction cost. The construction site itself can become quieter leading to a calmer work environment. If a building is made with disassembly in mind, wood is a relevant material for reuse because it can be disassembled without losing the wood's unique characteristics (Tekna, 2019).

Concrete is one of the world's most applied materials, and the cement used to make it is estimated to contribute to 7-8% of global emission (SINTEF, 2020). With that said, concrete is a suitable and well used building material. It has a wide use area and is used to make foundations, walls and roofs. The concrete is often made locally of short traveled raw materials and is a relatively reasonably priced material. Reinforced concrete makes strong structures which require little maintenance over time (Fremtidens Byggenæring, 2021)

The emissions from concrete have been strongly reduced in the last couple of years and FABEKO - Norwegian concrete association is working towards climate neutral concrete within 2030. There has been developed a Norwegian concrete type called "low carbon concrete" and work is continuously being done towards a carbon neutral product (Fremtidens Byggenæring, 2021).

There are pros and cons with using both materials. Using wood often results in a building with a low climate footprint. The material used is often locally sourced and we have long traditions working with wood. On the downside, wood is a flammable material and its lightness is not effective at stopping sounds traveling through the building. An organic material like wood is susceptible to moisture and rot in the right conditions.

As said, concrete is strong and is structurally sound,especially in building tall buildings. It is not flammable and evens out fluctuations in temperature. Because of the concrete mass, it becomes an effective sound barrier separating building floors. One of the big challenges for concrete use stated by the CEO of FABEKO, Jan Eldegard Hjelle, is to make sure that knowledge about climate friendly concrete solutions gets described in coming building projects (Fremtidens Byggenæring, 2021).

Figure.10: "Mjøstårnet"

Tree-based materials are in a unique position for green transformation. Production of timber materials generates low emissions, while these materials store CO2. In our high-quality forests, there is a potential for green economic growth of approximately 25% of today's value on oil-based products.

(Trærne inn i fremtiden, NTNU)

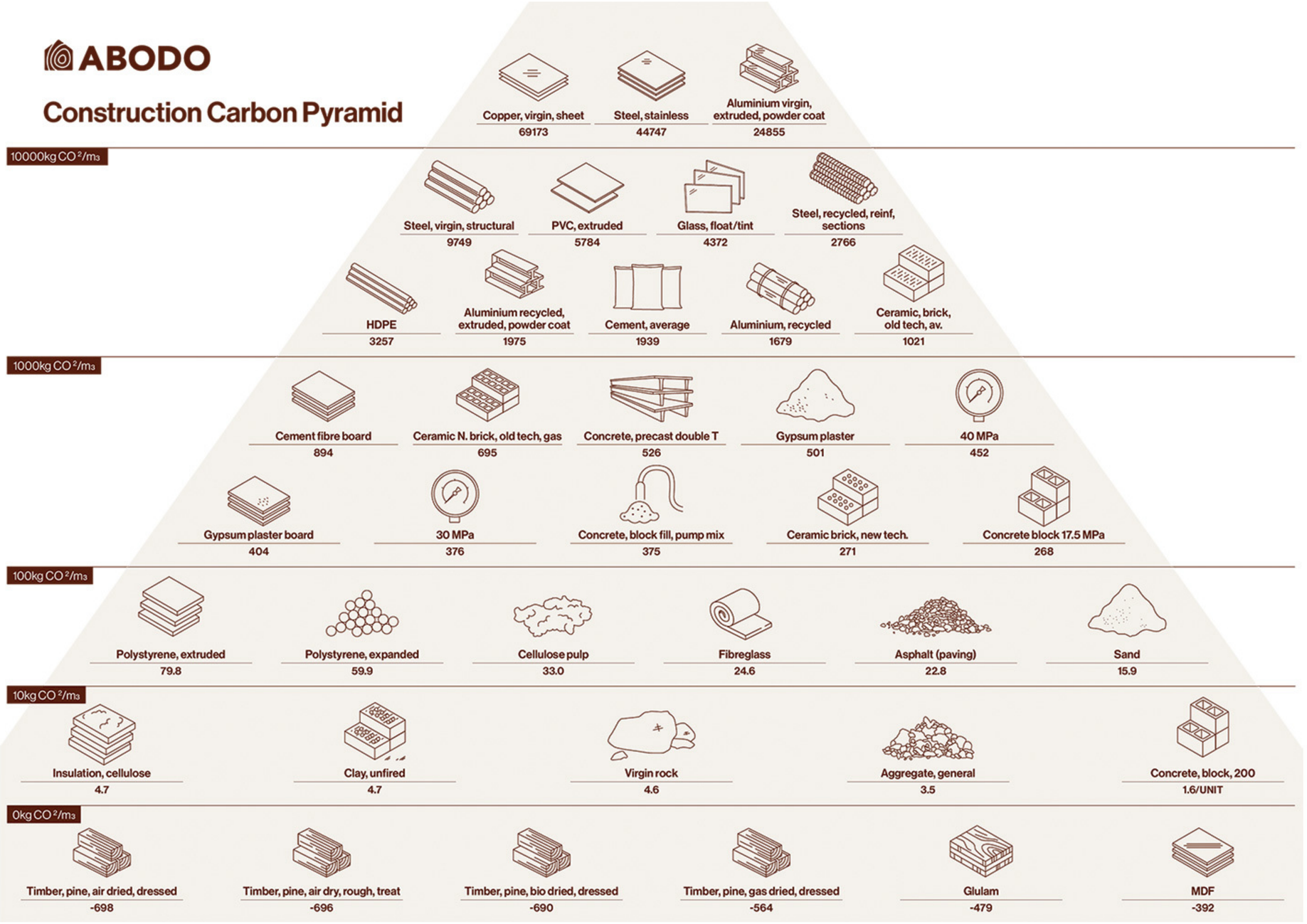


Figure.12: "Construction carbon pyramid"

6.3.4 Homes In Oslo - A scarcity

Today we see a great gap between the demographic housing need and the number of homes being built in Oslo. The reason behind this is the ever-increasing differences in population and numbers of homes being built. The demographic demand for new homes in Oslo is calculated to be around 30.000 each year, while the sales are well under 20.000. At the same, we know that Oslo has a housing deficit that has accumulated over several decades. (Dagens Næringsliv, 2023) Housing is a unique product that requires a considerable amount of time to bring housing projects to fruition. It is not uncommon for the development of housing to take up to a decade from the initial purchase of land to the completion of homes. This extended timeline can result in changes in the market, causing the planned and built housing to become less suitable for the current market conditions (Dagens Næringsliv, 2023).

Figure.13: "Taubanekrise i skogbruket"

6.4 Norwegian forestry

The timber resources in the forest are renewable, which means that the forest can be harvested repeatedly if new forests are planted after logging. Even if we look at today's timber resources in isolation, it is possible to harvest more forest than we have done so far without degrading the timber resources. To achieve this, we must actively work to plant new forests, both to ensure future forests and to maintain the forest's role in a climate context. This requires sufficient knowledge about the environment and the biodiversity in the forests (NIBIO, n.d.).

6.4.1 Wood, a natural resource and an important carbon absorber

In Norway, the productive forest area has timber worth of 879 million M3. It has increased by 6 million M3 in one year, but this is only half of what was expected. Since 2017, the volume of timber has been decreasing because of various factors such as lower growth, more logging, better forest protection, a larger part of old forests, and the dry summer of 2018, which resulted in more dry trees and dead wood. This has led to a larger amount of old wood in Norwegian forests, which is less capable of absorbing CO2 from the atmosphere than younger trees (Treindustrien, n.d.).

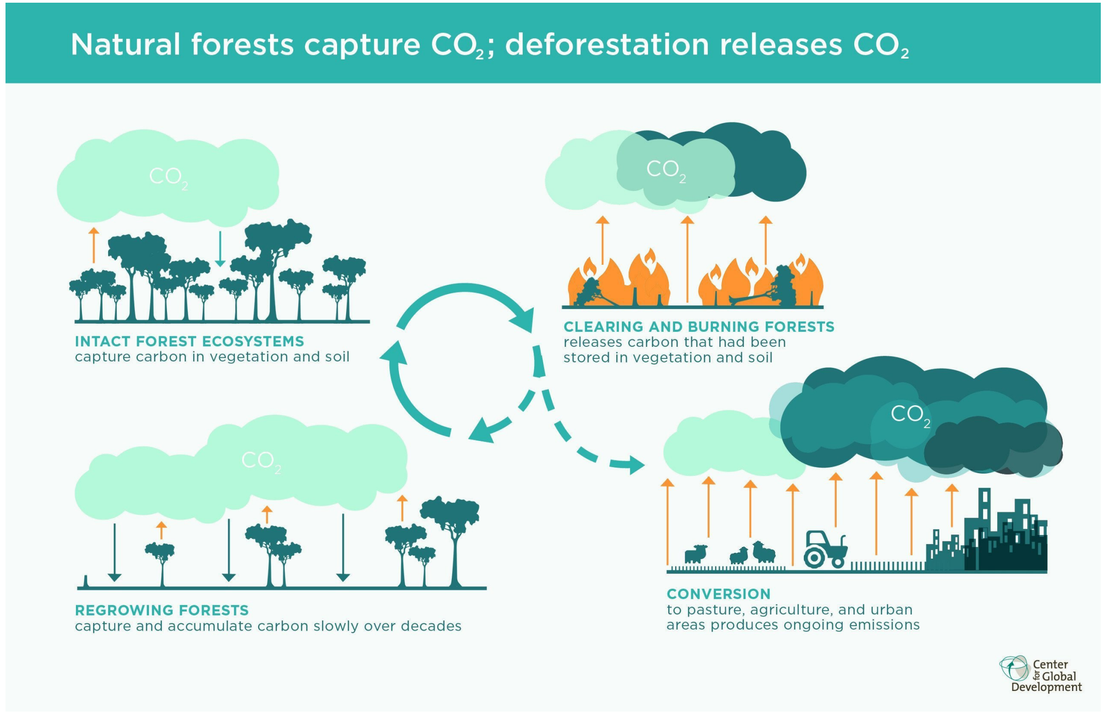


Figure.14: "Deforestation and Reforestation"

6.5 Research Projects and Stakeholder

There are great numbers of initiators on topics regarding sustainable development within the built environment sector. Research projects, innovation projects, pilot projects, and startup companies are all important initiatives for discovering new methods for creating a more sustainable industry in the near future.

6.5.1 MinTre (research project)

MinTre is a research project, initiated by Ø.M. Fjeld, one of Norway's leading contractors. Ø.M. Fjeld produced approximately 2000 tonnes of wood waste back in 2020, and states that 30-50% of their waste fractions can be directly linked to the early planning stages. The project aims towards the highest level on the waste pyramid, waste reduction. Creating less waste does not only have environmental advantages, but can also reduce costs related to bought materials, transportation, and waste management. (Prosjektbeskrivelse MinTre, 2023)

Partners:
Ø.M. Fjeld, Multiconsult, Optimera, Link Arkitektur, OMTRE, Klosser innovasjon
FoU / R&D:
OsloMet, Sintef
Other:
Statsbygg, Sør-Odal Kommune, Kongsvinger Kommune, Forskningsrådet

6.5.2 SirkTre (innovation project)

An innovation project which aims towards increased reuse and more effective recycling of wood-based materials. The project will establish a value chain for wood by facilitating and demonstrating the reuse and material recycling of reclaimed wood in practice.

Some of them are:
Viken Skog, Ragn Sells, Forestia, Standard Norge, Future Built, Norsk Massivtre, Norwegian Wood Cluster, Statsbygg, NIBIO, TreFokus, and OMTRE.

In this project, all partners are responsible for different work packages, with a specific area of interest. (Omtre, Interview appendix nr. 7, 2023)

6.5.3 OMTRE

Omtre is a company which was founded in 2020 by Kristine Nore. The team consists of 11 employees with a wide range of roles, such as legal advisor, civil engineer, material expert, sustainability advisor, administrative coordinator, and partners.
OMTRE is working on creating a platform for industrial processing of construction wood, and to make it easy to choose used wood instead of virgin materials in the future of the building industry. They are also managing SirkTre, where they are leading projects on mapping standing building structures and processing used wood, among many other exciting things. (OMTRE AS, n.d.)

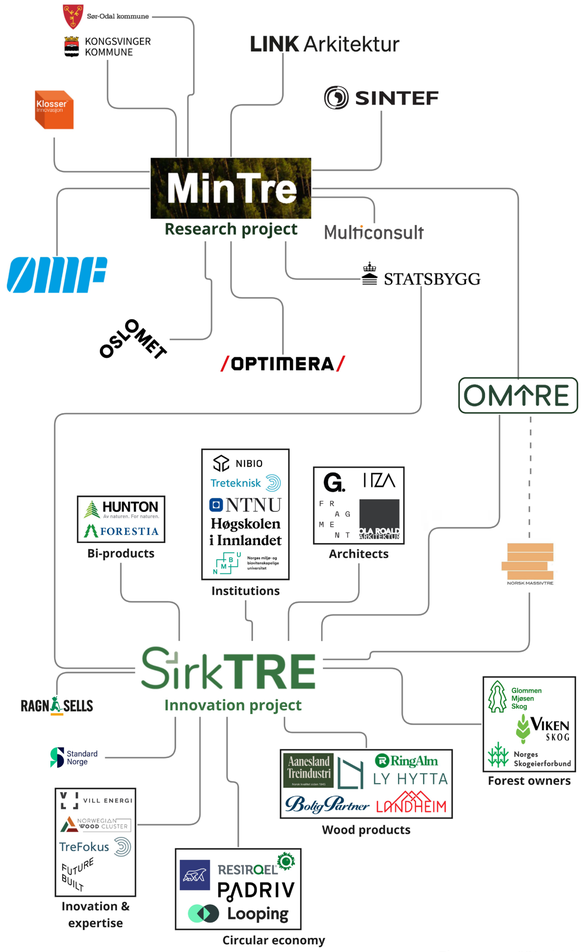


Figure.15: "Stakeholder map"

6.6 Value of the project

By the very nature of our project, generating value is not solely obtained by us recommending a set of actions. The value is achieved by combining clear insights with the power of implementation. The power lies with the system's key actors, in this case ØMF, Omtre and Ragn Sells, amongst others.

The insights leading to interventions affect the systems in ways we think are important for Omtres ability to reach an industrial scale, a stable supply chain and an effective refurbishing process. By Omtres services, ØMF could get closer to its ever pursuing goal of reducing the waste generated per m2 and possibly free up much needed space on the construction site.

By the industrialized refurbishing process and the waste reduction caused by it, we see some improvements to the building and construction industry's environmental impact. Of course, reducing the waste from one material stream does not solve the problem, but we see potential reduction in timber extraction, reducing the effects on local ecosystems, prolonging the time construction lumber acts as a natural carbon storage, and maybe a contribution to a shift in mindset where wood is never labeled as waste, but instead as a material going through different stages of usability. If Omtres business model is economically sustainable, there may be an incentive for other actors to copy Omtres ways of working and implement it in other parts of the country.

Figure.16: "Hasletre, joint"

6.7 UN Sustainable Development Goals

The UN sustainability goals are sentral when we speak about sustainability. It is important that our effort aligns with the sustainability goals because they are represented as a set of defined problems that deserve global attention. Our work aims towards improving the problems described in sustainability goals 9.4, 11,6, 12.2 and 15.2 .

6.7.1 (9.4) Industry, innovation og infrastructure and (12.2) Responsible Consumption and Production

9

"By 2030, upgrade infrastructure and transform the business world to become more sustainable, with more efficient use of resources and more extensive use of clean and environmentally friendly forms of technology and industrial processes, where all countries make an effort according to their own ability and capacity" (FN-Sambandet, 2023)

12

"By 2030 achieve sustainable management and efficient use of natural resources" (FN-Sambandet, 2023).

We are contributing towards facilitating an infrastructure that enables efficient use of reused lumber from construction sites. This includes suggesting which technology is suitable to reach an industrial sized process of reusing lumber from the construction and building industry. This industry would take advantage of wood's natural ability to store carbon and keep it in the material for as long as possible. In the current Norwegian construction industry, it does not take long before usable lumber is turned into wood chips and burned. We want to implement changes that extend the wood's use cycle and maintain its material properties in the process, for as long as possible.

6.7.2 (11.6) Sustainable Cities and Communities

"By 2030, reduce the negative impact of cities and local communities on the environment (measured per inhabitant), with particular emphasis on air quality and waste management in public or private sector" (FN-Sambandet, 2023).

We challenge the idea that "wood waste" is a term that should be in use and instead think of leftover materials as a nutrient to be used in a biological or technological circular system. This way of thinking challenges the linear structure of the construction and building industry and looks for possibilities to make it more circular (McDonough & Braungart, 2009, p. 90-100)

6.7.3 (15.2) Life On Land

"By 2020, promote the introduction of sustainable management of all types of forests, halt deforestation, restore degraded forests, and significantly increase the restoration and replanting of forests at a global level"

When prolonging the use cycle of the wood material, we reduce the need for extracting new timber from the forests. This potentially reduces the amount of clearcutting of forests and harm on local ecosystems caused by it.

Figure.17: "UN sustainability development goals"

7 Methods

7.1 Introduction To Methods

This chapter will talk about the different methods used throughout the master thesis. System Oriented Design and Giga-mapping was a central part of the design process, but there were different methods within the topic of Giga-mapping that we also used. The ZIP-analysis was essential to document interesting areas, problems discovered, possibilities and ideas. Miro online whiteboard was our primary calibration tool and the birthplace of our Gigamap.

7.2 System Oriented Design

7.2.1 What Is System Oriented Design?

System oriented design is a methodology used to deal with complex problems. It is based on design methods and design thinking and is supported by systems thinking and systems practice. In design thinking the designer takes a human centered approach to problem solving where the user is involved in an iterative process. In systems thinking the designer views the world not only as a set of independent objects, but looks at how the objects are related. Systems practice is the mindset and skills used to implement changes into systems in order to drive desired change (Sevaldson, 2022, 27-28).

SOD tries to close the gap between design and systems, and is a methodology without fixed methods. Instead of following prescribed methods, system oriented design puts emphasis on skills, mindsets and the development of competencies (Sevaldson, 2022, 4). The designer chooses methods suited for the specific problem and changes the methods at will. With that said, Gigamapping remains the most central tool in SOD.

7.2.2 Gigamapping

In our project, Gigamapping was used to summarize and visualize data. We chose this method to be able to see the “Gestalt” (whole system) of reclaiming wood in Norway. When we looked at all the gathered data at once, we saw the interconnections between the different stakeholders and used this data to find possibilities to guide and steer the system in a desired direction through interventions. (Sevaldson, 2022)

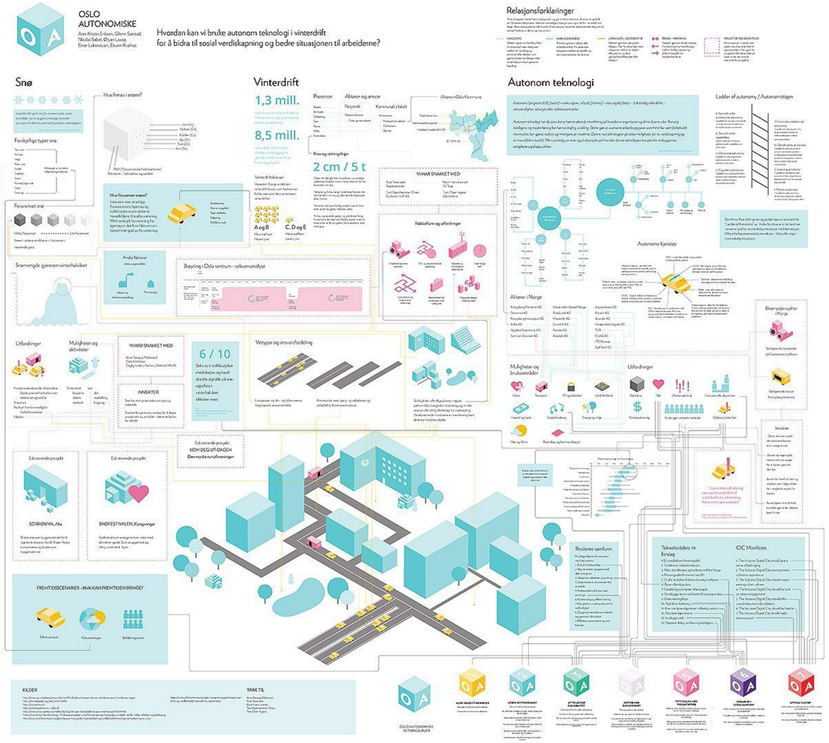


Figure.18: ”LAVE 2019”

7.2.3 Zip analysis

This method consists of placing ZIP-points to highlight interesting areas divided into Zoom in`s, interventions and pain points or possibilities. Using ZIP points throughout the project was helpful to keep track of all the discoveries.

The different letters are used in different ways for different people, but we chose these meanings of the letters.

Zoom: Z-points were used to highlight areas in our map that needed more research.

Intervention: I-points marked ideas that had the potential to change the system.

Pain point: P-points marked areas that did not currently work in the system (Designing complexity s. 275).

Possibilities: We used possibilities as a way of exploring new ideas that are directly or indirectly connected to the system we have mapped out.

7.2.4 Leverage Points

Our main objective is to introduce change in the systems we work with, to achieve overall desired results. The impact these changes create is usually based on where in the system they intervene. System thinker, Donella Meadows have made an structured overview of the major parts in a system: parameters, feedback loops, system structure and mental models. Within these parts you have a number of so-called leverage points that mainly affect one of the system's parts. The idea is that changes in the parameters does not necessarily have the power to change systems to a high degree, but changes in the mental models can lead to monumental results. When the leverage points get further and further away from the pivot point. The further a leverage point is from the pivot, the more leverage or power does it have to change the system (Meadows, 2015, 145).

When we implement change in for example a systems structure, it is important to consider if and how the change affects the systems feedback loops and parameters. These secondary effects are called ripple effects and are important to monitor so that you don't end up with unwanted results.

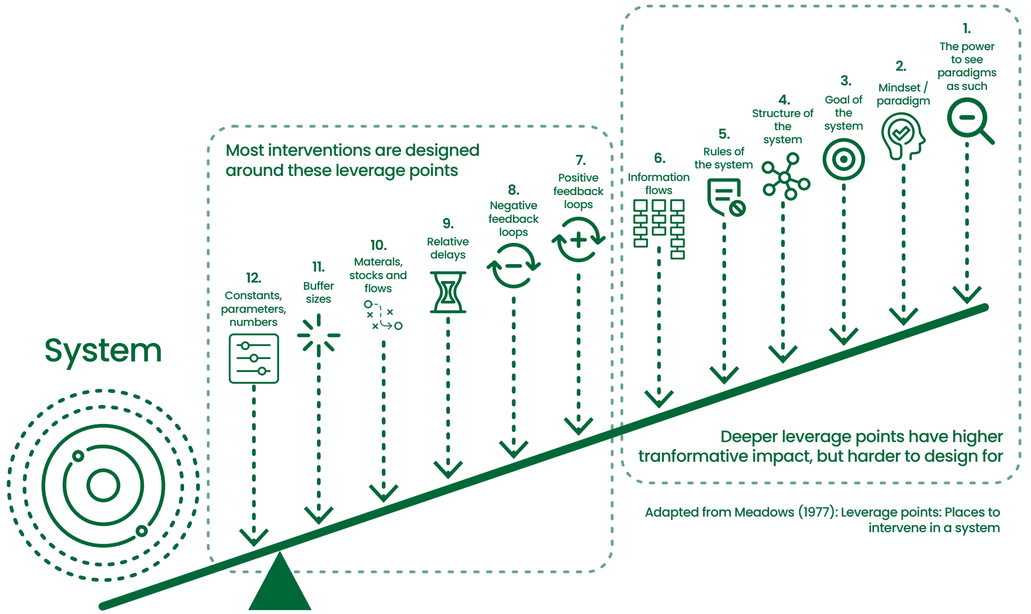


Figure.19: "Leverage points", Donalle Meadows

7.3 Research Method

7.3.1 Data Collection- and Storage Plan (SIKT)

When processing data from interviewees, we are obligated to store information in a responsible way and give insight to the person we have stored data about, upon request. For this reason we have filled in a Data Management Plan, which has been approved by SIKT. The form addresses to which degree or data is sensitive and how we store it (Sikt, n.d.)

When we have conducted an interview we have given the interviewee a ”information letter” which contains information about the aim of the project, the responsible partner for the research project, information of the participants privacy rights and information about how participants can contact us and the project leader. Also the information letter contains a declaration of consent that gets signed by the participants. For more information look in the attachments for the information letter, declaration of consent and the interview guide.

7.3.2 Desktop Research

Desktop research has been a major source of information through this project. We began to work within the topic of reusing wood before the rest of the research partners in the Mintre project had started to collect data. Therefore we had to start fresh on a lot of topics and look for relevant information on the world wide web. Statistics, articles, infographics, etc were collected in order to fill in the missing information in our ever growing Gigamap.

7.3.3 Semi-Structured Interviews

The interviews were usually done with experts from their respective fields, with whom we wanted more knowledge on a specific topic. A subject for the interviews was agreed upon beforehand with the interviewee, together with planned questions. As the conversation progressed we also made time for open ended conversation.

During the interviews, we usually had roles where one or two was the main interviewer and the other took notes. This left us with a comprehensive summary, where the content often led to concrete information placed in the Gigamap, more questions or contradicting information/pain points. These summaries were placed in a separate document working as an information bank and were helpful for cross referencing information.

Being outsiders to the building and construction industry, we were in a position where we had to trust the information coming from our interviews. This is because of the information being inaccessible otherwise or that fact checking wouldn’t be feasible due to time concerns or lack of contradicting information. Nevertheless we tried to be critical and often discussed the viability of the presented information.

7.3.4 Observations

Observations is a method where we document findings when visiting locations or listening to relevant information. We often document findings by notetaking together with photographs. Observations often give insights that are hard to obtain elsewhere and offer unique insight, but are limited by the number of locations we could visit and generalization based on the findings should be avoided

8 Findings

The building- and construction industry is a massive and complex system which consists of many other sub-systems, such as material production, material flow, laws and regulations, engineering, architecture, waste management, contractors, builders, and many more.

An important part of being designers is to gain knowledge about the systems, stakeholders and users within the scope of the field we investigate. We have talked to many established stakeholders within the sector, but also with new and innovative businesses which are addressing the environmental issues in the future of the building industry. In total 17 meetings, both digital and physical.

A visit at Saga Terrasse, Jessheim (initiated by Ø. M. Fjeld) gave us the opportunity to observe the construction process on a large (concrete) building project. It gave us a deeper knowledge on the use of construction lumber in cement-based building projects.

We met with OMTRE at their locations in Hønefoss, Norway, several members of the OMTRE-team have contributed greatly on many occasions.

In general, we have conducted many important interviews with many interesting businesses and people, such as Ragn Sells (waste manager), Ove Skår (contractor), Norsk Massivtre (CLT-producer), Material Mapper (a digital platform for mapping materials in buildings), and Link Arkitektur.

Figure.20: "Visits at Saga terrasse and OMTRE"

8.1 Observations

8.1.1 Omtre

The wood they have refurbished is planned to go into making new products. One product we were presented with was a wooden building block. It would work similarly to a Leca block, but made of reclaimed lumber. We know that there are more products planned, but they are confidential. We got to see the area where they sort and store the reclaimed wood. The process of refurbishing waste wood is in its beginning phase and is mostly done with hand tools (Omtre, Interview appendix nr. 18, 2023).

8.1.2 Saga terrasser, Jessheim

To get insight into modern building practices, we visited the "Saga Terrasser" construction project. It consists of 13 apartment buildings, of which nine were built and four remained. This project was especially interesting to us because the different buildings were in separate building phases. The digging was all done, but we could see bare concrete structures without external or internal cladding, all the way to close to finished buildings. These phases of the construction project all use wood that circulates through the construction site (Sage terrasser, Interview appendix nr. 19, 2023).

A key finding from the visit is that it's assumed that construction lumber used in formwork is possibly the larger contributor to wood waste produced during construction. When creating formwork, you usually use a combination of construction lumber and plywood sheets. The plywood can be used more than once, but quickly turns unusable due to wear and concrete residue. It is unknown to us if the construction lumber goes through more use cycles, but it is fair to say that both the used plywood and construction lumber is thrown in a container by the end of the project. Amongst other things, wooden framework is favored because of its flexibility and because the wood grain structure leaves an aesthetically pleasing appearance in the concrete. ØMF also uses a modular formwork system that can be reused multiple times. This is often used where people can't see the concrete and when there is need for little flexibility (Sage terrasser, Interview appendix nr. 19, 2023).

Construction lumber was also widely used for temporary constructions, such as stairs, railing, doors, and storage solutions for materials and tools. A lot of 2x4" and 2x2" was observed in these construction, but if they were classified as load-bearing construction lumber is still unsure. Also, we need to consider how many times these materials were- or could be used for this purpose (Sage terrasser, Interview appendix nr. 19, 2023).

During our discussion with representatives from ØMF, we got into the subject of communication between ØMF and the architects they work with. It appeared to us that the architects would draw buildings that could not be built without creating excessive waste. Later we talked to an architect from Link Arkitektur who said that it is not the architect's job to choose the final materials for construction. This leads to a situation where it seems like the architect does not think about material waste in the designs and ØMF has to buy materials that leave a high degree of waste during use. We see a potential in early communication where the architect and ØMF compare the designs with the available materials and choose options where little waste is produced (Sage terrasser, Interview appendix nr. 19, 2023).

Omtre had a concept where they wanted to use a wooden box to transport wood waste from where the construction worker worked, to the main wood containers. One of the problems from ØMFs side was that the wood box was not made to be lifted by crane, so it could not reach the high above floors where the wood was being used. They were also unsure about how long a wooden box would last outside exposed to the elements and heavy work loads. This made us unsure if the wood collection box was something to look further into, or if it was better to look at existing metal containers when thinking about interventions (Sage terrasser, Interview appendix nr. 19, 2023).

8.2 Barriers for reusing wood in the construction industry

8.2.1 Documentation on building materials

CE-marking and Declaration of Performance
Ensures free flow of building materials in the EEA (European Economic Area).
All building materials must have documentation that meets the requirements of the Building Product Regulation / Byggvareforskriften (DOK), which includes the requirements of the Construction Products Regulation (CE-marking and Declaration of Performance (DoP). CE marking is a must-have for all building materials. This ensures free flow of materials within the European Economic Area (EEA), and to meet this standard, the product needs a declaration of performance (DoP). DoP assures the buyer/contractor that the product is safe to use for construction according to standards (Direktoratet for byggkvalitet, n.d.).

Unfortunately, the Construction Products Regulation currently does not address the reuse of building materials, and there are standards that describe how new building materials should be tested or controlled to meet these requirements. These standards have been developed for new building materials, and it is difficult to demonstrate that old / reused building materials are able to meet the requirements according to standards today (Direktoratet for byggkvalitet, n.d.).

8.2.2 Politics - Laws and regulations

Government incentives and regulations
The government has an ability to introduce change to our system by regulations and incentives. The Norwegian Green Building Council has proposed a set of incentives and regulations that could drive the construction industry towards building greener buildings. These incentives are lowering the property tax, removing VAT costs from rehabilitation, lower construction fee and fast-tracking construction proceedings. Regulations aimed at onboarding every actor was to make specific TEK-demands in the construction proceedings, change document fee rules to make rehabilitation more desirable instead of demolition, making documentation demands for used materials simpler and CO2 limits in TEK (Grønn Byggallianse, n.d.).

Existing laws
In a report from Samfunnsøkonomisk analyse AS and NIBIO they wrote that both the EU's CE-Sertification, byggevareforskriften (DOK) and TEK17 are barriers for the sale and reuse of used materials. If surplus materials would keep their certifications after resale to another builder, these frameworks would no longer be barriers (Samfunnsøkonomisk analyse AS & NIBIO, 2020)

New standard for reused wood in construction
The work towards a new standard for reused wood was initiated by the SirkTre project. The aim is to make the use of reused wood materials as easy as using virgin lumber. The responsible committee will first look at standards for construction lumber, because this material is the most sought after in the market. In May 2022, there was a change in the requirements for the redistribution of used building materials. Used materials still have to have the right technical abilities and comply with Byggteknisk Forskrift. For new building materials, it is the manufacturer of said materials who provide the statement of performance. When it comes to used materials the responsibility may shift to the reseller or builder. That is one of the reasons we need a standard that specifies critical technical abilities, what should be documented and how (Byggeindustrien, 2022).

8.2.3 Energy Recoevy VS Reuse

Today, almost 90 percent of all wood waste is used for energy recovery in Norway. Research has shown that this proportion can be reduced to well below 60% (Skaper Verdier Av Treavfall Og Restprodukter Fra Treindustri, 2018). But why do we want to reduce the percentage and not just do business as usual?

Proponents of burning wood waste argue that it replaces carbon emissions from fossil fuels. The carbon dioxide from wood is to be considered carbon neutral because it is a part of the short carbon cycle, where a tree takes up CO2 during its lifetime and releases it when burned. Viewed over a relatively short time period, the CO2 balances out because the added carbon is also taken out of the atmosphere (Geminor-Rapport: Svært Lave CO2-utslipp Fra Energigjenvinning Av Trevirke. On the other hand, carbon emissions from fossil fuel are a part of the long carbon cycle. This adds new CO2 to the atmosphere, disturbs the climate and does not balance out, but floods the atmosphere with carbon dioxide the trees can't soak up, leading to global warming. (Raven, 2021)

If we are going to emit carbon, it seems preferable to release CO2 from the short carbon cycle. With that said, immediate emissions from burning wood creates more CO2 per energy output in comparison to coal. In addition, if we are to reach our goals in the Paris agreement, we can't continue to add more carbon to the atmosphere due to the short amount of time to reduce our carbon emissions. The question should not be whether to burn coal or wood, but on what renewable energy sources that could replace them. (Trevirke Som Energibærer – Er Det Så Lurt I Klimasammenheng?, 2017)

The waste pyramid is a term in Norwegian waste politics and in EUs framework directive for waste. The goal is to treat waste as high up in the pyramid as possible and avoid burning and landfill. Here we see that reuse lies within the waste reduction bracket and avoids further processing (Om Bransjen, n.d.).

Figure.21: "Waste Hierarchy"

8.2.4 Circularity lifespan of wood

Based on the waste pyramid and reluctance to add more CO2 to the atmosphere, the most viable option seems to be to reuse the lumber as many times as possible. This point is shown in the “circularity lifespan of wood” illustration. The longer we are able to keep the wood in use, the longer we maintain its ability to store carbon. A desired scenario would be if the construction lumber went from one building project to another, enabled by a reclaiming company like Omtre. The quality of the wood is expected to drop after each use cycle due to factors such as storing, transportation, humidity, structural changes etc. When this happens lumber can be ground down and made into OSB and fiber boards. Eventually the wood fibers will get so worn and short that burning for energy recovery will be a suitable option.

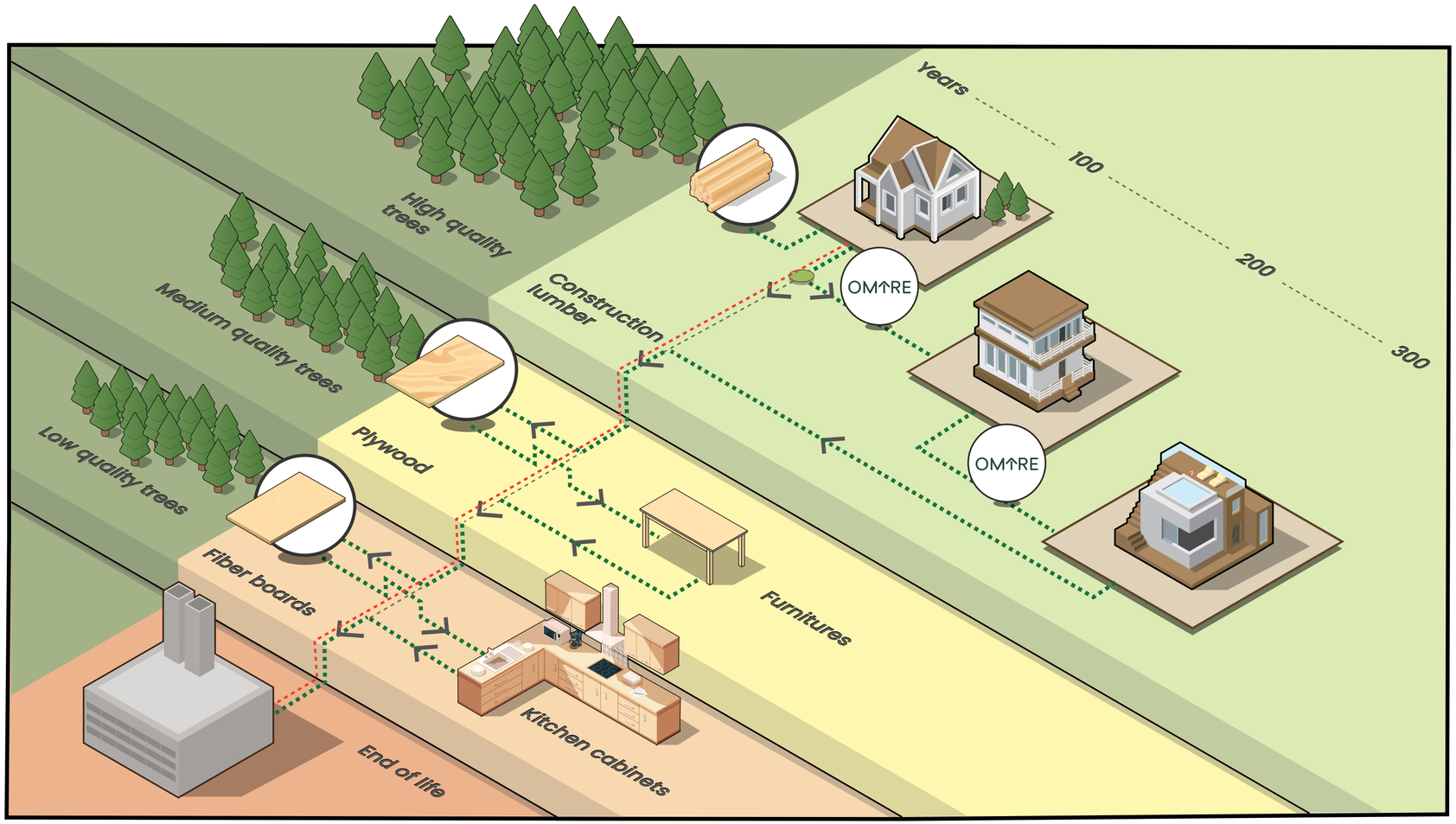


Figure.22: “Circular lifespan of wood”

8.2.5 High energy prices makes burning wood profitable

The common structure of wood waste management we have observed on construction sites today goes something like what follows: wood waste is produced on a construction site, a waste management company picks up the wood waste, sorts it, grinds it down and sells it to be used as a fuel to heat up various things. ØMF pays its waste manager Ragn Sells for containers and collection of wood waste, later Ragn Sells receives additional payment for having ground down the wood and sold it as a fuel source.(Ø.M.Fjeld, Interview appendix nr. 1-2, 2023)

Ragn Sells handles approximately 100 000 tons of wood waste per year. 75% is ground up and sold as a fuel source, and 25% is chipped up and turned into wood sheets. Research shows that around 50% of this wood can be labeled fit for reuse, so why aren't more wood reused and why is burning the preferred method by Ragn sells? (Ragn Sells, Interview appendix nr. 11, 17. May 2023)

We think that this choice correlates with increased electrical prices. When electricity is expensive it gives Ragn Sells an incentive to sell wood chips to companies seeking to reduce their electricity bill. When more wood waste goes to burning, less is available for reuse and the approximate 50 000 tons of usable wood gets out of reach for a company wanting to reuse it. A generalization that can be drawn from this is that increased energy prices leads to less reuse of wood waste. (Ragn Sells, Interview appendix nr. 11, 17. May 2023)

8.2.6 Material Prices

During the first year of the Covid-19 pandemic, we saw an increase in the cost of construction lumber and wood products in general. There are multiple reasons for this, first and foremost because of an unbalance between supply and demand, together with strong competition in the international market. Reasons for the lack of supply could be explained by a severe pine beetle infestation in both Canada and Europe and the pandemic. The Covid-19 pandemic increased operational cost connected to sick leave, infection control, transportation costs and cost influenced by lack of workers able to do maintenance (Regn Med Fortsatt Høye Priser På Trevarer – NRK Norge – Oversikt Over Nyheter Fra Ulike Deler Av Landet, 2021).

Russia, Belarus and Ukraine exported 10% of Europe's total demand in 2021. This ability was greatly reduced when Russia declared war on Ukraine, contributing to the supply shortage (War in Ukraine Tightens Lumber Markets Worldwide: Report - Wood Business, 2022).

We have found that when the material price of construction wood is high, that there is less wood waste produced on the construction site. The simple answer is that the more you use, the more you spend. So when the material price drops we can expect the amount of wood waste produced on construction sites to rise. High material prices can result in less available materials for reclaiming companies, but will reduce the immediate wood waste produced on construction sites.

Both energy prices and material prices seem to regulate the amount and availability of waste wood in Norway. In our current capitalist economy system, actors are inclined to capitalize on high electrical prices to make more money, reducing the amount of available waste wood. Increased material prices also reduce the availability of waste wood for reuse, but also reduce the amount of waste wood being produced in the first place

8.2.7 Tight space on construction sites

Organization and responsibilities in the construction project are crucial for achieving good results on waste management. This aspect is intricately linked to the strategic placement and orderly arrangement of containers within the building site, in accordance with available space and taking into account the requirements of tower cranes and the trucks utilized for container transportation. (Nordby & Wærner, 2017)

Unfortunately, this remains a major issue on many construction sites, particularly in cities like Oslo where available space is a limited and valuable resource. As the construction project advances and buildings start to take shape, the available space becomes even more constrained. Consequently, there is inadequate room to meet the necessary requirements for waste material sorting. This shortage of space can lead to suboptimal sorting practices and a reduced amount of materials being recycled (Ove Skår, Interview appendix nr.17, 17. May 2023; Ø.M.Fjeld, Interview appendix nr.19, 21. February 2023).

Figure.23: "Wood container at Saga terrasse"

8.2.8 Sorting percentage VS waste per m2

It has been interesting for us to talk about what progress would look like in the construction and building industry, in relation to our research question. We of course want to facilitate a circular system for reused wood and reduce wood waste as a result, but how do we measure progress and how does the industry itself think about progress?

There are two measures of good building practices that have surfaced multiple times when talking to ØMF and Ove Skår. These are sorting percentages and waste per square meter. Sorting percentage meaning how good the contractor is to place the right material in the right container and waste per square meter means how much waste in kg is produced per m2 of constructed building. (Ø.M.Fjeld, Interview appendix nr.19, 21. February 2023)

ØMF is obligated by the planning and construction law (plan- og bygningsloven) to have a sorting percentage above 60% but exceeds this by having above 90% on most of the building projects. A high degree of sorting is better than a low degree, but it does not say anything about how much waste is being produced and is therefore not a good measure of progress in our opinion. Reduction in waste per kg/m2 is a more precise way of measuring success, but only when you know the percentage of wood waste in the total figure. ØMF receives its waste numbers from Ragn Sells based on the different waste fractions (Clean wood, mixed wood, impregnated wood, plaster etc), so this should be easy enough to track.

There are some limitations of measuring success based on the reduction of waste in kg produced per m2. It only takes into account materials purchased, used and thrown away from the construction site, and does not consider waste produced before the construction stage. An example could be a building constructed mainly by prefabricated building elements made out of wood. This type of construction produces little wood waste on the construction site and would result in a reduced waste in kg per m2, but the waste is produced during the production of the wooden building elements instead. ØMF could think of this as reduced wood waste in kg per m2, but this conclusion could be failing to see the bigger picture. Further research would be needed to see if there is a significant waste reduction between prefabricated wooden building elements and contemporary building practices.

Another potentially wrong turn in measuring success could be if ØMF gave its wood waste away to be reused and only a small percentage turned out to actually be reused. In this scenario ØMF could write off everything that goes to reuse as not waste and greatly reduce its wooden waste in kg per m2 fraction. An example could be ØMFs cooperation with Omtre where wood waste is gathered in containers and sent to Omtre for reuse. If Omtre is able to reuse all the collected material, then ØMF could write off all the waste as reused. But if Omtre has an imagined reuse percentage of say 40%, then this should be reflected in ØMFs waste reduction. So how could this be done in practice? Well, Ragn Sells weighs the collected wood waste when it comes from ØMF, Ragn Sells then transports the wood to Omtre, Omtre processes the wood, produces waste and reports the waste back to ØMF. (Ø.M.Fjeld, Interview appendix nr.19, 21. February 2023)

This way we have a number on how much wood comes from ØMF in kilograms and how much waste is produced by Omtre in kilograms. Omtres waste will then be subtracted from ØMF reuse fraction and we will be left with a more accurate number of how much waste is reduced per m2. The mathematics will of course get more difficult because Omtre has more material inflows then just from ØMF and the waste originating from ØMF could be hard to separate from other sources.

8.2.9 The Building Owner

There are opportunities to create a great design with green materials, but the decisions are often based on time and cost efficiency, and not on sustainability with a long-term perspective. To build with sustainable materials can potentially be more costly for the building owner, which very often has an interest in capitalizing in the near future

8. 3 Possibilities in the construction industry

8.3.1 Architecture

“Design for disassembly” is a well established design-method in the world of industrial design. It is based on the idea of efficient disassembly of parts, either during repair or at the end of the product’s life cycle. We can see that the same principle has been added to a few modern building projects, such as “HasleTre”.

HasleTre

HasleTre is a 3000 sq.m office building, designed as a wooden building from the first sketch. The facade consists of chipboard cladding, and the construction is designed as a dismantled and reusable building set. The building is carefully designed to be able to safely dismantle without damaging the materials, construction, the surroundings and workers. This way of thinking could be a great way to give the materials a long (and circular) life and to make sure that the stored carbon stays in the cell-walls of the wood. (Hasletre – Office Building – Oslotre, n.d.; Oslotre, n.d.)

Figure.24: ”HasleTre”

8.3.2 Redesign of containers

On construction sites

Ragn Sells's standard containers (suited for wood waste) varies between 8 m3 and 35 m3 in size, but the one which is most common to see is the 10 m3 container. The size and design of the container will determine not only volume and weight, but also how it is collected and how much space the truck needs for collection and delivering. The containers we see today are not necessarily best suited for optimized collection of reusable building materials. Ove Skår, a Norwegian entrepreneur mentions in an interview that from time to time they have as many as 13 different fractions and 8 different containers at the same time on their construction site at Kringsjå, Oslo. This is not always an issue for spacious building sites, especially not in the early building stages, but is very often a general issue for building sites in cities and tight neighborhoods. The project's phase determines the different needs for containers, both numbers and types, and it's not always necessary that all containers are of the size that is available for the contractor. This can also contribute to better utilization of transportation and logistics for Ragn-Sells or other waste management companies (Ove Skår, Interview appendix nr. 17, 2023).

More efficient sorting and refurbishment of materials at OMTRE

When OMTRE collects or receives off-cuts or old wooden building materials, they need to inspect and sort everything themself. This work demands manual labor and expertise on materials and many types of tools. OMTRE has been developing their own collection- and return box for wooden materials, but containers for construction sites must meet high standards regarding constructional strength and lifting. Their containers; "Ivar-kassa" and "Thoralf-kassa" are both made of wood and do not currently meet the standards to be able to use any of them in an industrial context.

Even though their designs are not suited for the industry, it raises a great question on the topic. Are the containers designed with reusing materials in mind?, and what could the containers look like with the intent of maximizing the reuse of materials, especially wood (Omtre, Interview appendix, nr. 9 ,2023)?

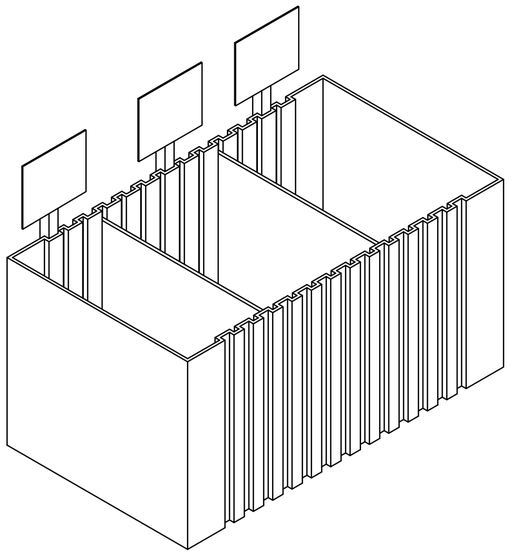


Figure.25: Redesigning container

8.3.3 The Building Owners - Incentives for building sustainable

BREEAM (Building Research Establishment Environmental Assessment Method)
BREEAM is an environmental assessment method and rating system for buildings. It addresses environmental issues through a scoring system based on the buildings energy use, management, health and wellbeing e.g., noise and air quality, transport-related CO2, water consumption, embodied carbon of building materials, waste, pollution, land use, and ecological value. It makes the building more visible in the marketplace.

The score is translated into a rating scale of:
Pass
Good
Very Good
Excellent
Outstanding

(BRE Globa, n.d.) (Referere til PDF: BREEAM_Brochure)

What are the incentives?
1. High return on capital investment: In many cases, the BREEAM Assessment's incremental cost can be recovered through lower utility expenses within 2-5 years, which makes it a cost-effective investment.

2. Increased asset value: The sustainability rating can be used to attract investors, buyers, and tenants. Additionally, according to the World Green Building Council, green-certified buildings can have sale prices that are up to around 30% higher than those of conventional code-compliant buildings.

3. Reduced operational cost: Buildings that are certified by BREEAM are designed with a focus on energy efficiency, leading to potential long-term operational cost savings throughout the building's lifespan.

4. Access to green finance: For green projects, many banks supply better interest rates and can in some cases cover parts of the project costs.

(What Financial Incentives Does Being Able to Produce a Life Cycle..., 2023)

TAXONOMY - Sustainable financial activities
The taxonomy is a classification system developed by the EU. It is meant to help the financial markets channel capital towards sustainable financial activities and projects for organizations which are even listed or have over 500 employees. The taxonomy is there to prevent greenwashing and to set the foundation for standards and labeling for green financial products and projects. It contributes to better terms for both loans and insurances
(Taksonomien for Bærekraftig øKonomisk Aktivitet - Regjeringen.no, 2023).

SVANEMERKET
The swan label is a label for sustainable homes, kindergartens, and schools. A number of different criteria are asked for based on energy, climate and long-term sustainability, and the project must meet 15-17 out of 39-44 possible points to achieve the label.
Not only does it bring financial benefits, but modern clients and potential building tenants have sustainable buildings high on their list of priorities (Svanemerket I Fremgang, 2022).

8.3.4 Reclaimed wood today

Internal vs public waste stream

We have seen examples of reclaimed lumber being used today. Most of these projects are produced on a small scale and often in the form of DIY (do it yourself) projects. Examples can be sofas made by pallets and other types of furniture made in the home with accessible tools. Less examples can be found where waste wood is being refurbished and reused on an industrial scale. This is especially true when the wood waste comes from the public waste stream (demolition or recycling stations) and not from a company's internal waste stream. A company that reuses wood from an internal waste stream is Vyrk, a producer of wooden panels, flooring, cladding amongst other things. Their "Bærekraftpanel", a wooden indoor panel, can be returned to Vyrk after use and turned into filling material used in new panels. We thought of this as an internal waste stream because Vyrk was the producer and had planned the reuse during the production of the panels. In this example, Vyrk has full control of the material composition and a highly specialized recycling process (Bærekraftpanel - Vyrk, 2022).

Reusing waste from the public waste stream has opposite preconditions. There is little control of the material composition because of nails, screws and treatments like paint and oils. There is no planning between the wood products becoming waste and the material refurbishing. This makes it hard to plan for reuse because a specialized recycling or refurbishing process won't be able to adapt to the variations from the public waste stream.

Stavneblokka

"Stavneblokka" was an attempt to make a wooden building block from reused lumber. It was produced from local wood waste and put together using wooden plugs, keeping the material free of metal nails and glue. It does not seem like this project has had much development since 2012, the reasons being unknown to us. The project report described the possibilities forward as: a statement project in the direction of art or critical design, building packages like, grill huts or sheds in a commercial setting and cabin concepts, and approved certification as a building element (Tekst Håndbok 23112012, n.d.).

Norsk Massivtre

Norsk Massivtre AS is a producer of solid wood elements to cabins and houses. They are a partner in the SirkTre project and have received reclaimed wood from the public waste stream, which they have used in their products. They are exploring ways of making technical certified wooden building elements and have designed and produced wall elements with one third new construction lumber and three parts reused lumber. The way that Norsk Massivtre is using the wood in their building elements allows them to use planks with holes and screws without having to do any milling, because they're using standardized construction lumber (e.g. 2"x2" and 2"x4"; Øvergård, 2022).

Genbyg

Genbyg is a Danish company selling primarily reused building materials. They have a fully functional workshop where they refurbish reclaimed wood and make it into new products. Some of their reclaimed products are planks and timber, wooden flooring, bookshelves, shelf jacks, wall decoration modules and legs and tabletops made by reclaimed wood. Even though Genbyg specializes in selling and making products from reclaimed wood, they do also sell locally produced doors and various other locally made products. We think Genbyg gives a good example of how one can make business reselling and refurbishing reclaimed wood, and other locally made products (Genbyg A/S, n.d.)

Figure.26: "Visit at Norsk Massivtre

8.3.5 Scan and artificial intelligence

The industry is increasingly becoming more digital. Even sawmills are now integrating modern scanning-technology combined with artificial intelligence in their production practices. CT-scanners create a 3D image of a wooden log, for example, which can detect all kinds of different defects inside of the logs that otherwise are not possible to predict without cutting the wood open.

In California, USA, we can find Urban Machine, a brand new business developing robotic and automated machines that removes nails, screws and makes it ready for reuse. The same tools and machines can be integrated in the refurbishing process at OMTRE and other wood-reclaiming companies, contributing to a smooth and time-effective process . (Urban Machines, n.d.)

Figure.27: "AI, logging"

Figure.28: " MicroTec"

9 Results

9.1 Introduction to the Gigamap

The map we're showcasing in the results part of this project is a culmination of the research done in the project. The main goal of the map has been to get an understanding of the life of construction wood, how it's made, how it's used, and what happens to it when it becomes waste - or not waste. It has also been important to map out all the stakeholders, and how they work together. From the understanding of the whole system we wanted to explore options for how things might be done differently to increase circularity in the more or less linear material use we have today.

For the reader to understand the complexity of the map we will start by showing the whole system and then zoom in to the important processes to talk about the details. After zooming in on the interesting processes we have used ZIP-analysis to get a better understanding of specific processes, suggest interventions or just raise questions about how things are done today. The goal with the ZIP's are to find how changing different processes can make greater changes to bigger parts of the system towards increased circularity.

The system is not fixed, but dynamic and changing. The map would need constant updating to be accurate, but will still give an understanding of the main structures and stakeholders in the system today.

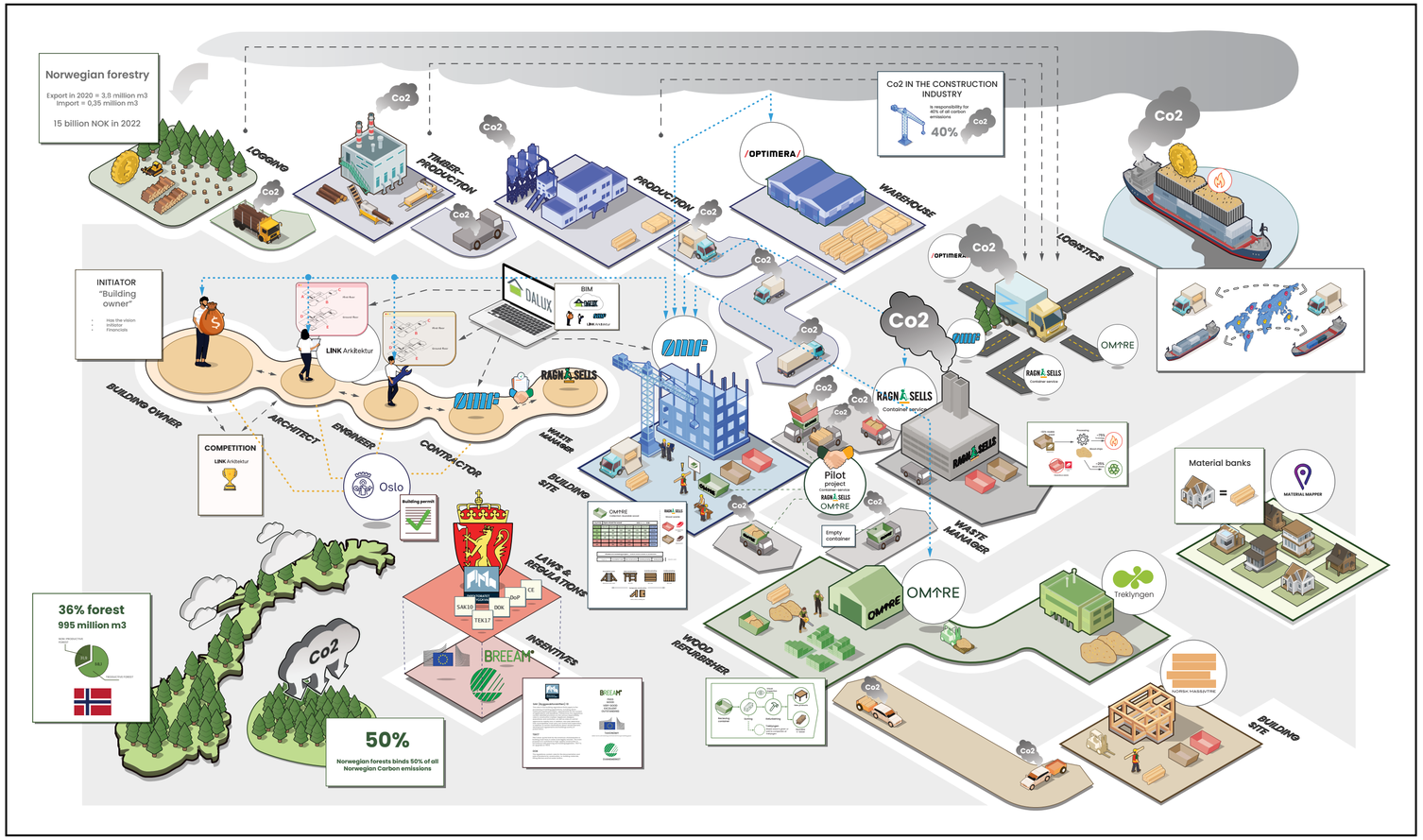
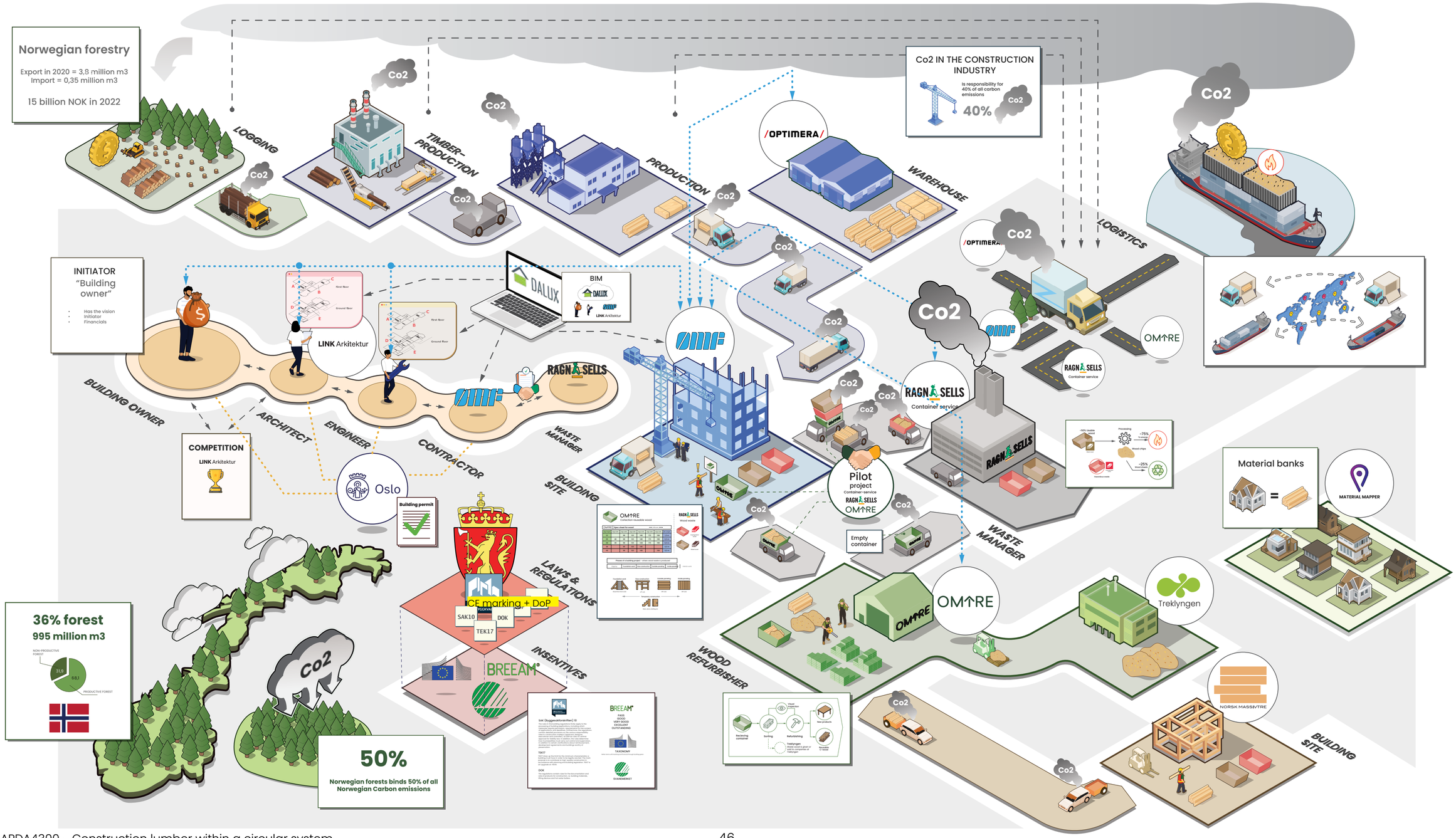


Figure.29: "Gigamap"

Link to MIRO-board

https://miro.com/app/board/uXjVMG2_5UE=/?share_link_id=562545903013


Norwegian forestry
Export in 2020 = 3,8 million m3
Import = 0,35 million m3
15 billion NOK in 2022
LOGGING
TIMBER-PRODUCTION
PRODUCTION
/OPTIMERA/
WAREHOUSE
Co2 IN THE CONSTRUCTION INDUSTRY
Is responsibility for 40% of all carbon emissions
40%
Co2
LOGISTICS
INITIATOR
"Building owner"
Has the vision
Initiator
Financials
DALUX
BIM
LINK Arkitektur
BUILDING OWNER
ARCHITECT
ENGINEER
CONTRACTOR
WASTE MANAGER
BUILDING SITE
RAGN SELLS
Container service
OMTRE
COMPETITION
LINK Arkitektur
Oslo
Building permit
Pilot project
Container-service
Empty container
Material banks
MATERIAL MAPPER
LAWS & REGULATIONS
CE marking + DoP
SAK10
DOK
TEK17
INSENTIVES
BREEAM
WOOD REFURBISHER
Treklyngen
NORSK MASSIVTRE
36% forest
995 million m3
NON-PRODUCTIVE FOREST
PRODUCTIVE FOREST
50%
Norwegian forests binds 50% of all Norwegian Carbon emissions

9.2 Production of construction lumber

This is the process where the trees in the forest become construction lumber to be used at construction sites. This isn't something we have gone into detail with, but it is still an important step of the life-cycle of construction lumber. In this part of the map we're showcasing the different processors that the wood goes through until they're sold to the contractors. It starts with the trees being cut down, and the timber being transported to the saw mill. While the map shows that the sawmill and lumber production is two different processes, most sawmills in Norway today are a combined business where they're doing both the initial processing of the timber, and also the production of e.g. construction lumber. Some companies are also selling even more prepared materials, like finger joint timber, pre-painted and pre-cut elements. (Foslie, 2020)

The material, specifically construction lumber, is then sold to e.g. hardware stores or distributors that might sell the lumber to a contractor. This is where we chose to use Optimera as an example because they are the one that are selling materials to Ø.M.Fjeld, who we have been in close contact with throughout this project.

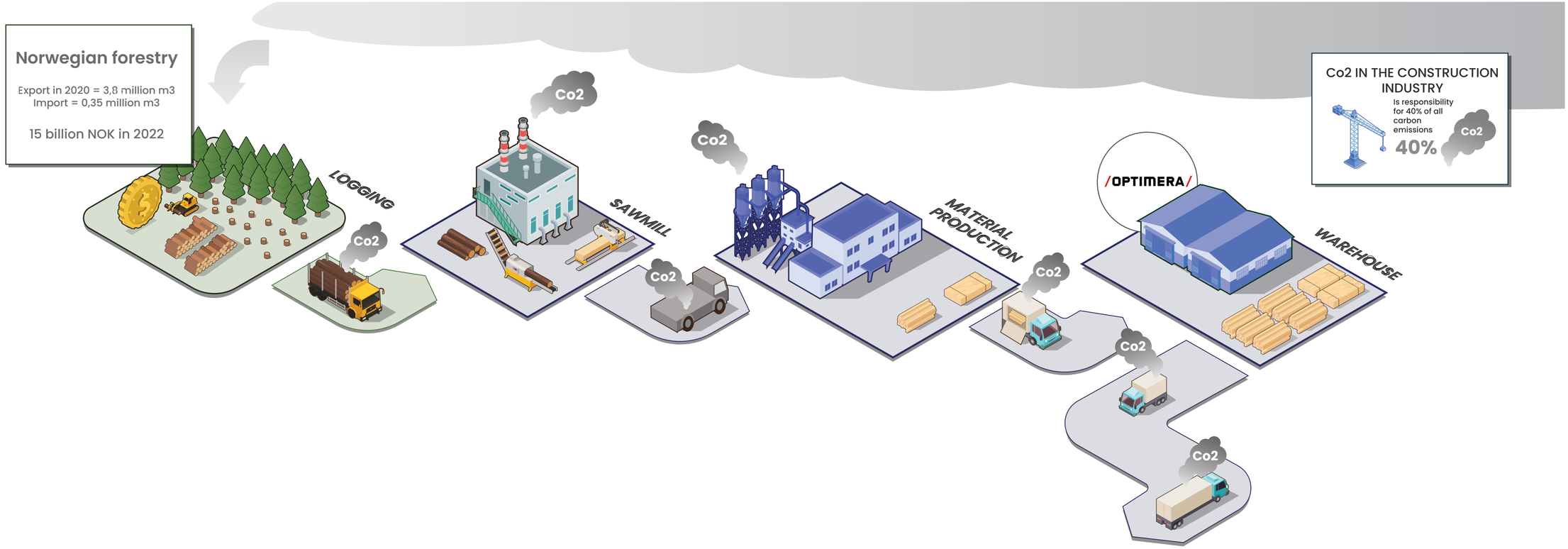


Figure.30: "Production of constructiion lumber"

9.3 Planning

This is the initial stage of a construction project, and where different stakeholders come together to plan a construction of a building and make sure it's within the laws and regulations that is set by the government. The process that is mapped out here is a general look at how it might be, but this will look different from different projects. It often starts with a building owner needing a building to be built. After this they might contact architects or contractors, to help them develop and plan the construction of the building. One example is what Ø.M.Fjeld is doing called "total enterprise". This is where the contractor is doing all the planning of their own construction project. They have architects and building engineers on their side, and the building owner paying for this service.

During this planning stage there will also be contracts being made with companies like Ragn Sells, who are doing waste management and Optimera, who are delivering construction material. (Codex Advokat, n.d.)
During the modeling of the building BIM (Building Information Modeling) is introduced. BIM is used to communicate between the architects, contractor, suppliers etc. to be able to synchronize the work. It's also used throughout the construction process.

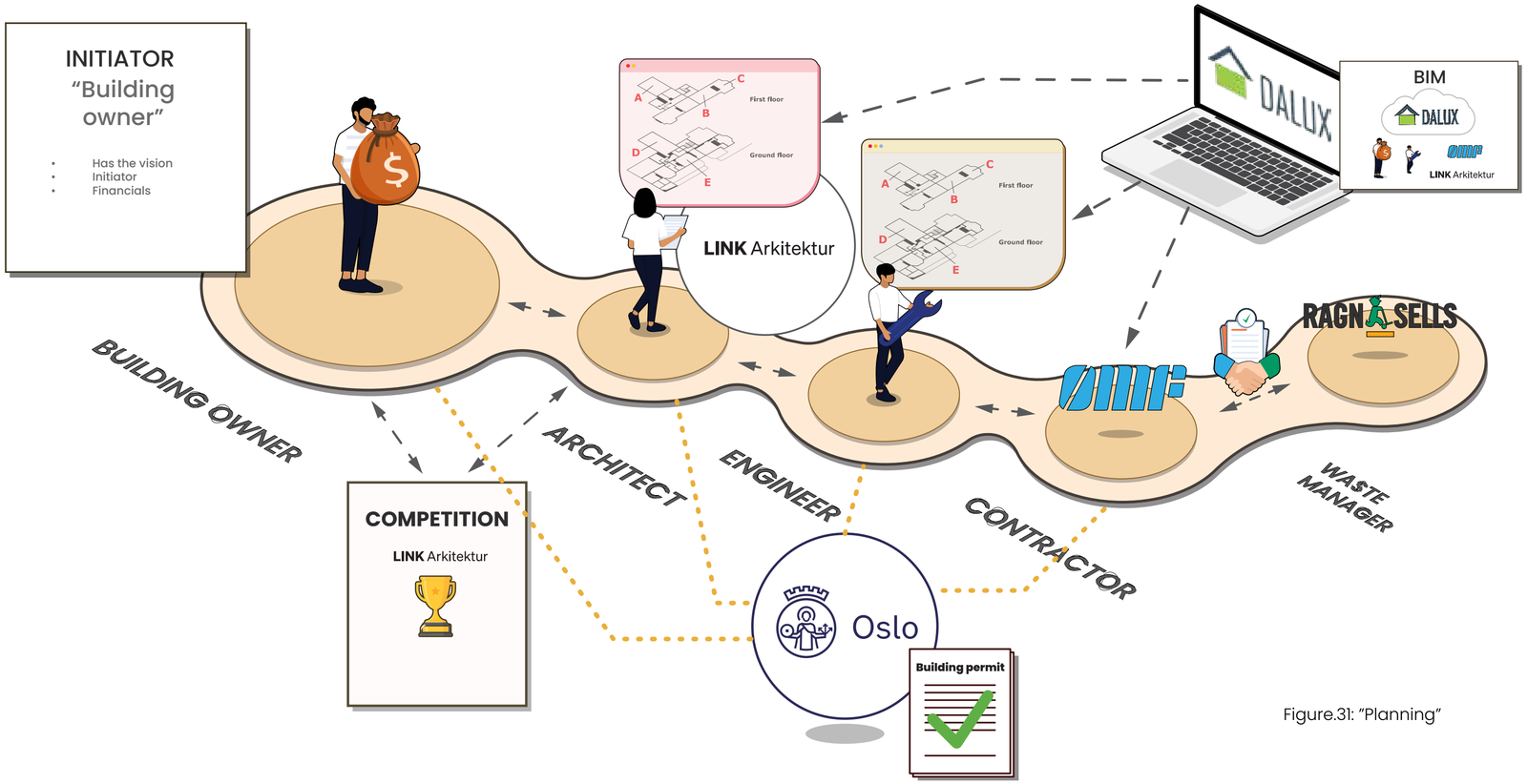


Figure.31: "Planning"

9.4 Construction site

This is the center of the construction process. This is where everything from foundation work to finalizing the building is done. This map chose to focus on the different processes that produce waste and specifically wood waste. The six main stages of a construction project are 1.digging, 2.foundation work, 3.raw construction, 4.outside paneling, 5.inside paneling, 6.interior work. We normally see lumber being used in stage 2-4, and it's also where the waste is produced. We are yet to find anyone who has done an analysis about what stage of construction produces the most amount of wood waste, and this probably changes for each project depending on how they are constructing the building. According to conversations with Ø.M.Fjeld, they assume that a large percentage of the lumber in a construction project is being used in stage 2: foundation work, and mostly used for form work.
The wood waste produced at the construction we have visited during the research of this project is being disposed of in mixed wood containers, and for the projects using impregnated wood, they have a separate container for this (Direktoratet for byggkvalitet, 2018).

We chose to put in the green container which is the container that Omtre uses to collect construction lumber for reuse. This container is currently being tested at a construction site at Kringsjå in Oslo together with contractor Ove Skår. With this container Omtre has a spec sheet that informs the contractor and its workers about what type of construction lumber they want to collect and the minimum length of each piece. These containers and the transportation of them are provided to Omtre by Ragn Sells. Ragn Sells is also the company that provides the contractor with the containers and transportation for all the other fractions of waste as well. The waste collected in the green container is driven from the construction site to Omtre's facilities at Hønefoss, and the rest of the containers (brown and red in this map) are driven to one of Ragn Sells' facilities (Ove Skår, Interview appendix nr. 17, 2023).

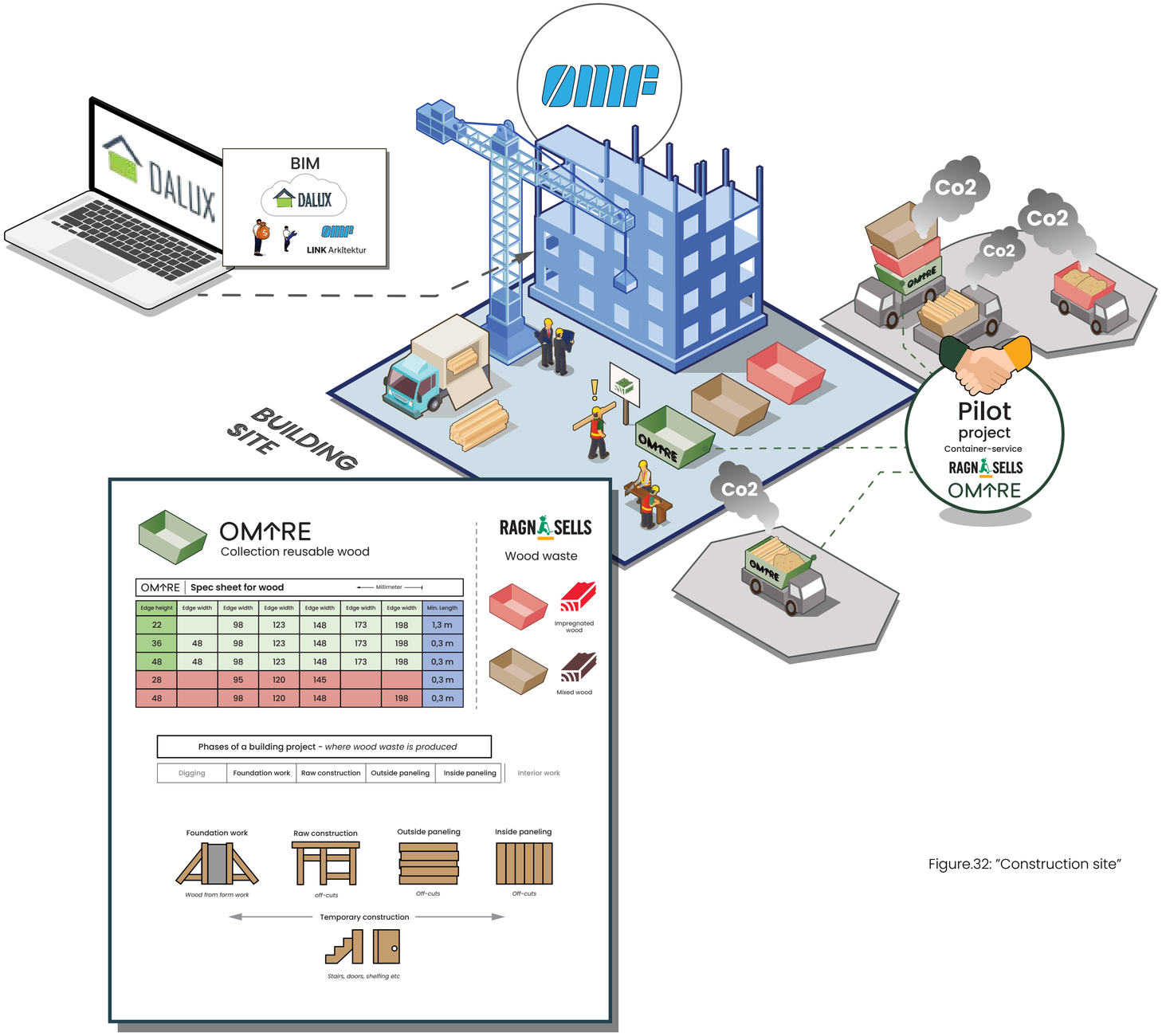


Figure.32: "Construction site"

9.5 Waste Management and reclaiming

This stage of the construction process is where the waste is handled. We have divided it into two different processes. One looks at the process of collecting and refurbishing wood at Omtre, and the other one is how Ragn Sells is managing their wood waste. The focus of this map was to see how they're collecting wood waste and what happens to the wood waste after it's processed. The wood waste containers that are most commonly used is one for mixed wood - which is generally speaking treated wood of different kinds. The other container is for collecting impregnated wood - This is for all the different impregnations that can not be sorted with non-impregnated wood. The last green container is the one that Omtre is testing and developing now, for collecting construction lumber to be reclaimed (Ø.M.Fjeld, Interview appendix nr. 1-2, 2023).

Ragn Sells is a waste management company, the service they're providing is renting out containers to contractors, and collecting them when they're full. They have many different fractions that they collect, and those fractions are dealt with in different ways. The focus for this map is how they deal with wood waste. According to Ragn Sells around 75% of their wood waste is granulated into wood fiber and burnt, to produce energy. The other 25% is used in production of fiber boards. The amount that goes to fiberboard or energy recycling seems to be depending on energy prices among other things. There is money to be made on either process - energy or fiberboards, but more expensive energy can make the burning more profitable (Ragn Sells, Interview appendix nr. 11, 2023).

Omtre's process is similar to Ragn Sells in terms of the collection, but different in the way they treat the waste. Omtre has a container at the construction site for collecting construction lumber for reuse, and this is then transported to their facilities in Hønefoss. This is where the construction lumber is being refurbished. As showcased on the map they have a process for refurbishing the wood, and what they're doing is e.g. removing nails, cleaning the lumber and removing unusable pieces. The unusable lumber and waste produced from the refurbishing is redistributed to Treklyngen - where Omtre is also a part of, which is a collection of companies where some of them are looking for wood waste into new products. One example is a company making bio-coal, from wood waste. During this process they are doing visual inspection to sort out and re-certify the wood into different classifications. To be able to use the short pieces of wood they accept to receive based on the spec sheet, they are doing development of different products and exploring different production methods to use the pieces as efficiently as possible. Their goal is primarily to sell products to businesses and that might be to insure larger sales and reuse on a larger scale compared to e.g. selling individual pieces to private customers. One example of using Omtre's materials is a company called Norsk Massivtre. They have done a few projects where they've bought reclaimed construction lumber, and made their own building elements for different projects. They used a mix of new and reclaimed planks in order to be sure about the strength of their building elements (Omtre, Interview appendix, nr. 9 ,2023; Treklyngen, n.d.)

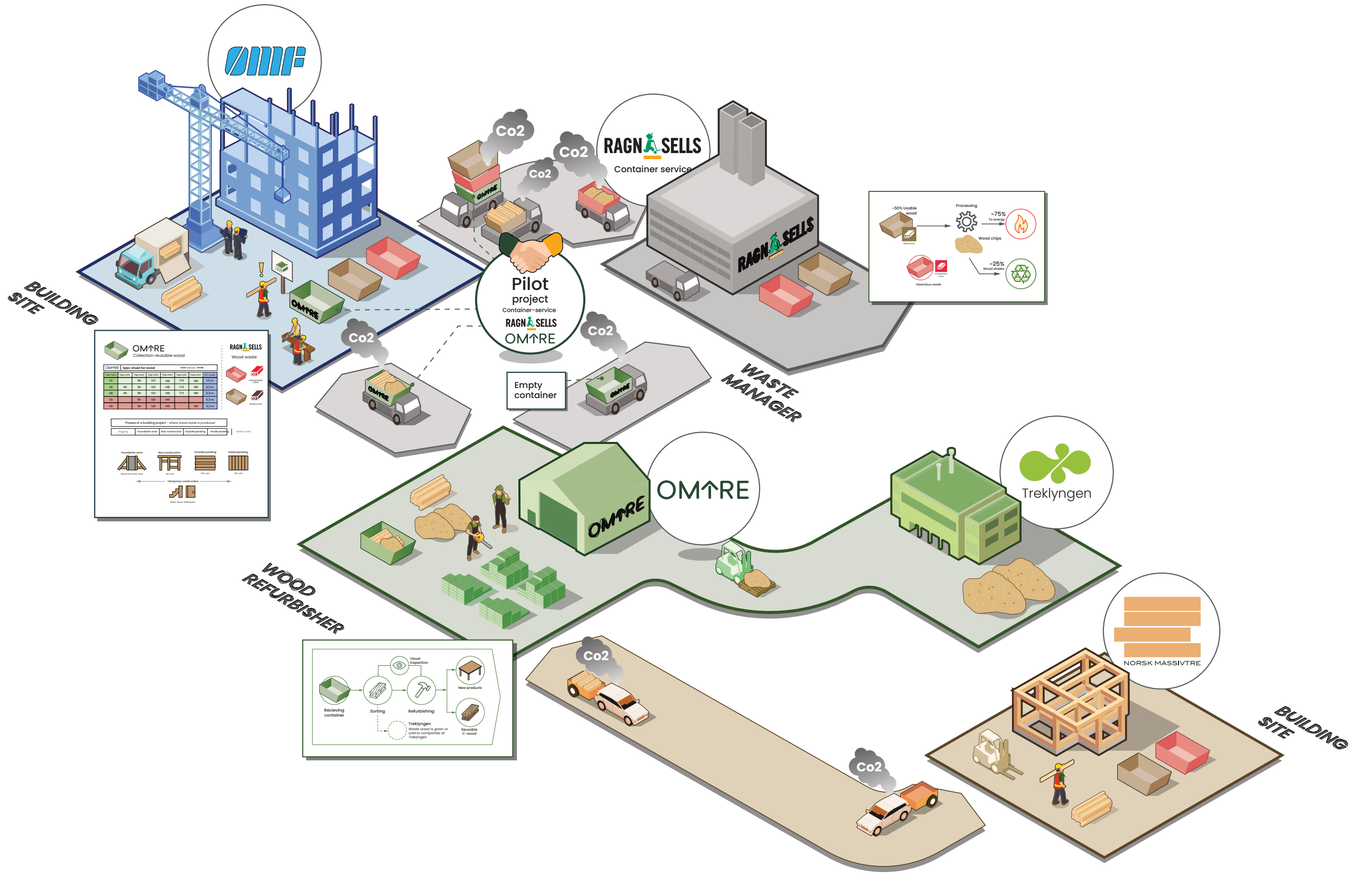
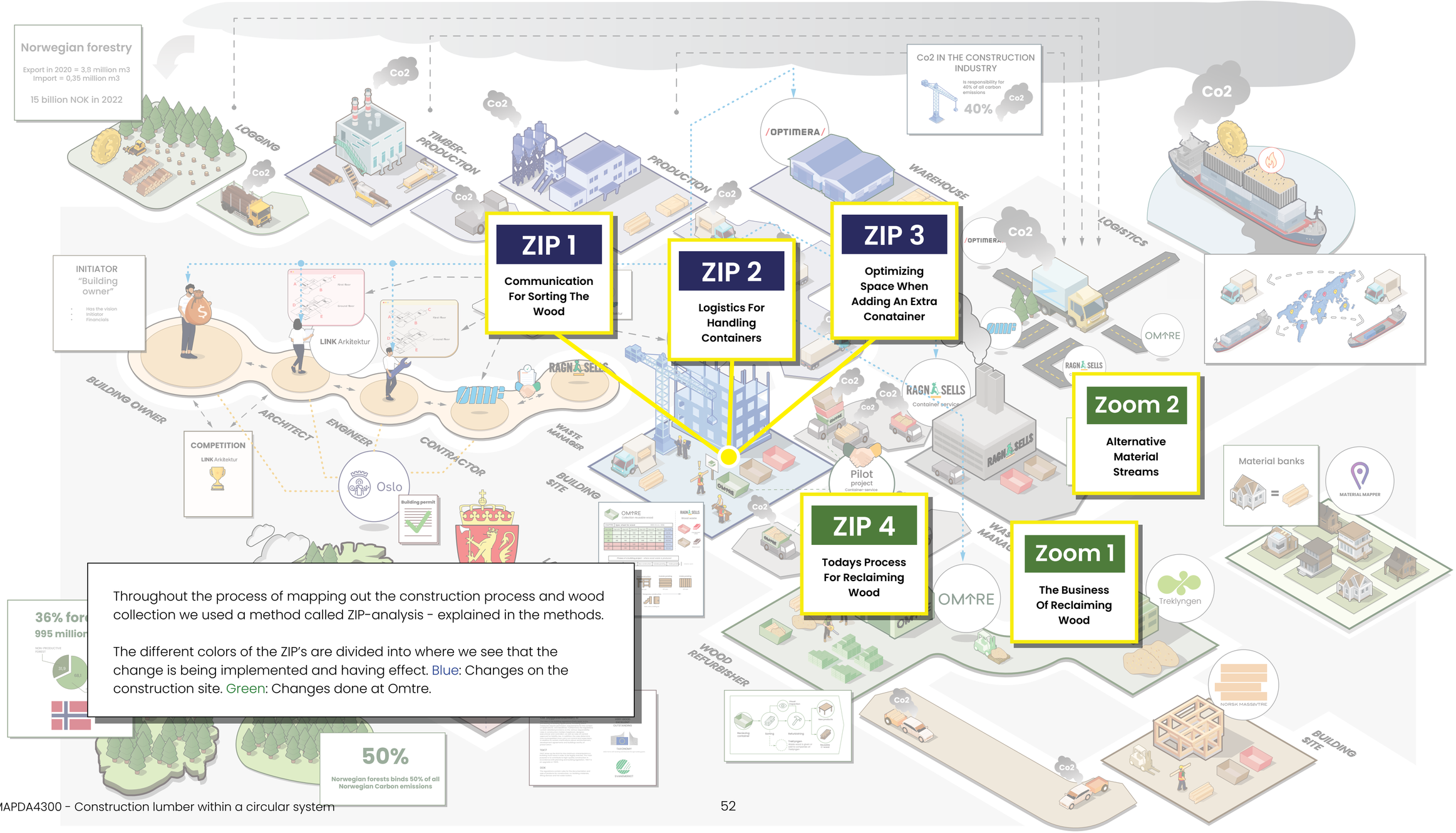


Figure.33: "Waste management and reclaiming"

9.6 ZIP-analyzis



Throughout the process of mapping out the construction process and wood collection we used a method called ZIP-analysis - explained in the methods.

The different colors of the ZIP's are divided into where we see that the change is being implemented and having effect. Blue: Changes on the construction site. Green: Changes done at Omtre.

ZIP 1 Communication for sorting the wood

Figure.34: "ZIP 1"

ZOOM-IN

How is the sorting fraction being communicated today?

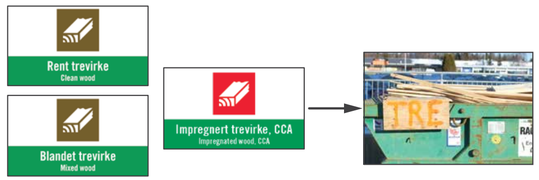
OMTRE

OMTRE | Spec sheet for wood ⟵ Millimeter ⟶							
Edge height	Edge width	Edge width	Edge width	Edge width	Edge width	Edge width	Min. Length
22		98	123	148	173	198	1,3 m
36	48	98	123	148	173	198	0,3 m
48	48	98	123	148	173	198	0,3 m
28		95	120	145			0,3 m
48		98	120	148		198	0,3 m

Omtre's table for what wood they want to be collected

Wood waste

RAGN SELLS

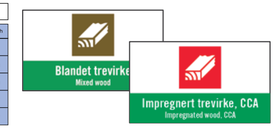


Ragn Sells has divided the different fractions of waste with icons and text, in Norwegian and English. One construction site we observed made their own signs. The picture above of "Tre", is used for a mixed wood container.

POTENTIAL PROBLEM

Bad communication might lead to decreased quality of sorting.

OMTRE | Spec sheet for wood ⟵ Millimeter ⟶							
Edge height	Edge width	Edge width	Edge width	Edge width	Edge width	Edge width	Min. Length
22		98	123	148	173	198	1,3 m
36	48	98	123	148	173	198	0,3 m
48	48	98	123	148	173	198	0,3 m
28		95	120	145			0,3 m
48		98	120	148		198	0,3 m



Omtre's spec sheet is a more detailed description of what goes in the containers with different dimensions and lengths compared to e.g. Ragn Sells.

The spec sheet exists in order to have a controlled material flow into Omtre, and to the products / materials they want to sell.

Normally there will still be a need for at least one other wood container - mixed wood, for all the other wood waste that is not suited for reuse yet. On the construction site, decisions will have to be made whether the wood should be sorted as waste or reusable wood.

How can the sorting for reusable wood be communicated in order for an efficient and correct sorting at the construction site?

INTERVENTION

Clear communication might insure a better material flow and efficient process

OMTRE | Spec sheet for wood ⟵ Millimeter ⟶							
Edge height	Edge width	Edge width	Edge width	Edge width	Edge width	Edge width	Min. Length
22		98	123	148	173	198	1,3 m
36	48	98	123	148	173	198	0,3 m
48	48	98	123	148	173	198	0,3 m
28		95	120	145			0,3 m
48		98	120	148		198	0,3 m

How can this be translated into a visual sign that is easier to follow for a construction workers?

Visual over written communication

According to research done on this topic, there are often workers from different countries at the same construction site. This means that they might not all talk the same language. Having a type of visual explanation might lead to less misunderstanding surrounding sorting.

9.6.1 ZIP 1 - Communication for sorting the wood

This ZIP is a look at what type of material Omtre is looking for and how other wood containers are communicating the type of wood that is to be sorted in their respective containers. The wood spec sheet seen in the ZIP is all the different types of dimensions Omtre is looking for. These dimensions are correlating to most of the different construction lumber typically used at the construction site today. This is normally spruce and pine wood. The red segment of the table is CU-impregnated wood, and Omtre wants to collect everything in one container (Omtre, Interview appendix nr. 18, 2023).

Current wood sorting is normally divided into two different fractions at a construction site. Mixed wood and impregnated wood. There is also one clean wood fraction, but we have yet to see it being used at the construction sites we have visited. These fractions do not have any set dimensions and especially the mixed wood meets a wider range of wood waste compared to omtre. For mixed wood it is: Clean wood, pallets, fruit crates, painted wood, CLT, parquet flooring and particle boards (Ragn Sells, n.d.). Generally speaking this is most type of wooden materials - Excluding impregnated wood, which has its own container.

Omtre is in the beginning phase of starting their business and their communication is yet to be fully tested and adjusted for. Their spec sheet for sorting wood for reuse is currently being tested at a construction site with Ove Skår as contractor. After talking to a manager at Ove Skår we heard that they requested some signage to be put up by Omtre for the containers, and that this is currently under development. An example of signage was shown by the manager for some new safety procedures (not related to this), and what they had to do was to use visual elements together with a written message in different languages. The different languages has to be used, because they have - similar to other construction sites, people from different countries - in their case eastern europe (Ove Skår, Interview appendix nr. 17, 2023).

Without knowing how the signage that is under development looks like, it's apparent that visual communication together with different languages is important to make sure that all the workers understand the message. To effectivize the communication it might be better to have more visual elements to reduce the amount of text having to be written / read on the signs (Ove Skår, Interview appendix nr. 17, 2023).

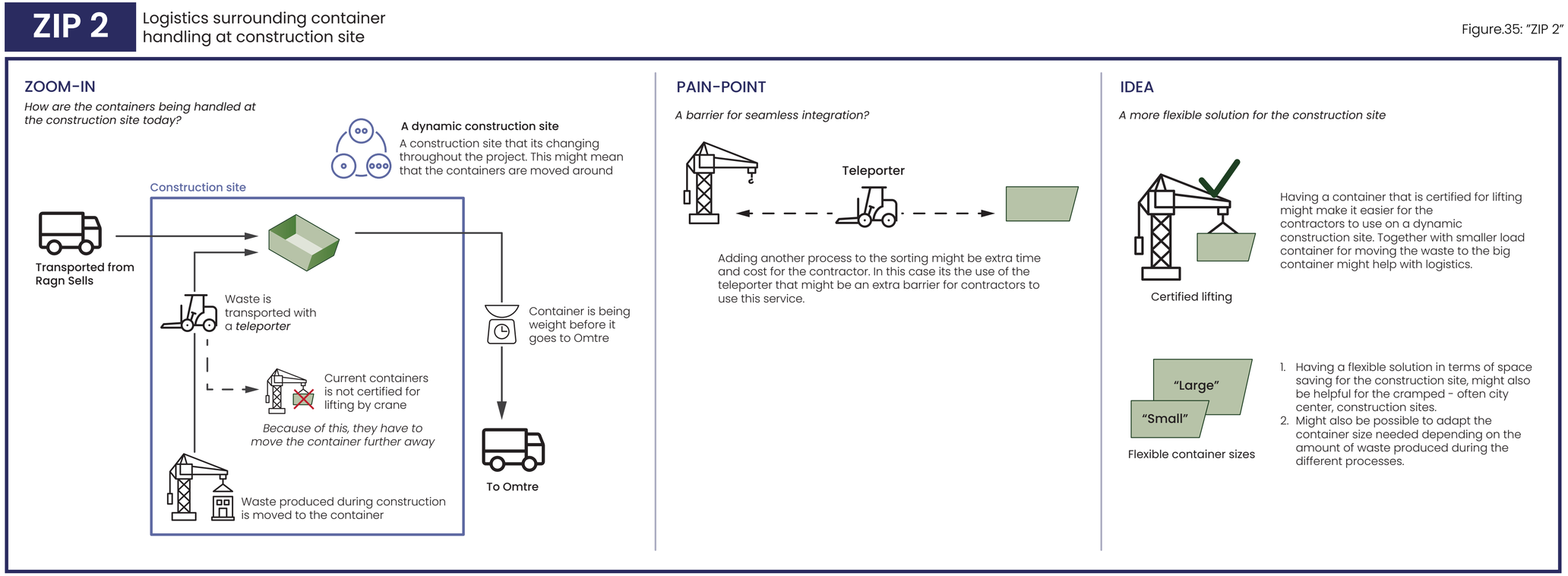


Figure.35: "ZIP 2"

9.6.2 ZIP 2 - Logistics surrounding container handling at construciton site

This is a ZIP that looks at how the container logistics is being done at the construction site. This zoom-in chose specifically to look at the container wood to reuse. After talking to Ove Skår, who is doing the first pilot project with omtre, they talked about their construction site as being dynamic, and that there is generally a need for flexible solutions. The current container that Ragn Sells supplies for Omtre is not certified to be lifted by a crane, but only a specific container truck when Ragn Sells is at the construction site. This means that because of the construction site moving around, they had to put the container further away since it's not being moved until they get a new one. This also means that the container is outside of the reach for the crane. That led to Ove Skår needing a teleporter - which is a big forklift, to move the trash from where it is produced to the container for reusable wood (Ove Skår, Interview appendix nr. 17, 2023).

Ove Skår has looked at a solution where they can have smaller containers that can be lifted by the crane and use that to move the wood from where its produced to the main (green) container. At the construction site at Kringsjå - where the pilot project is done, they have an open container with a saw, and that is where most of the clean wood waste is produced. If the main container is still not movable by the contractor the waste will still have to be moved by the teleporter (Trinity Hire, n.d.; Ove Skår, Interview appendix nr. 17, 2023).

Because of the dynamic construction site, there is a need for flexible container solutions by Omtre and Ragn Sells. According to Ove Skår this means containers that can be lifted by the crane and it might also be helpful for them to have different sizes on the containers for the parts of the construction project where less wood waste is produced. At the end of a project there might also be less space left on the plot that is being built on, and for that reason smaller containers might be better suited (Ove Skår, Interview appendix nr. 17, 2023).

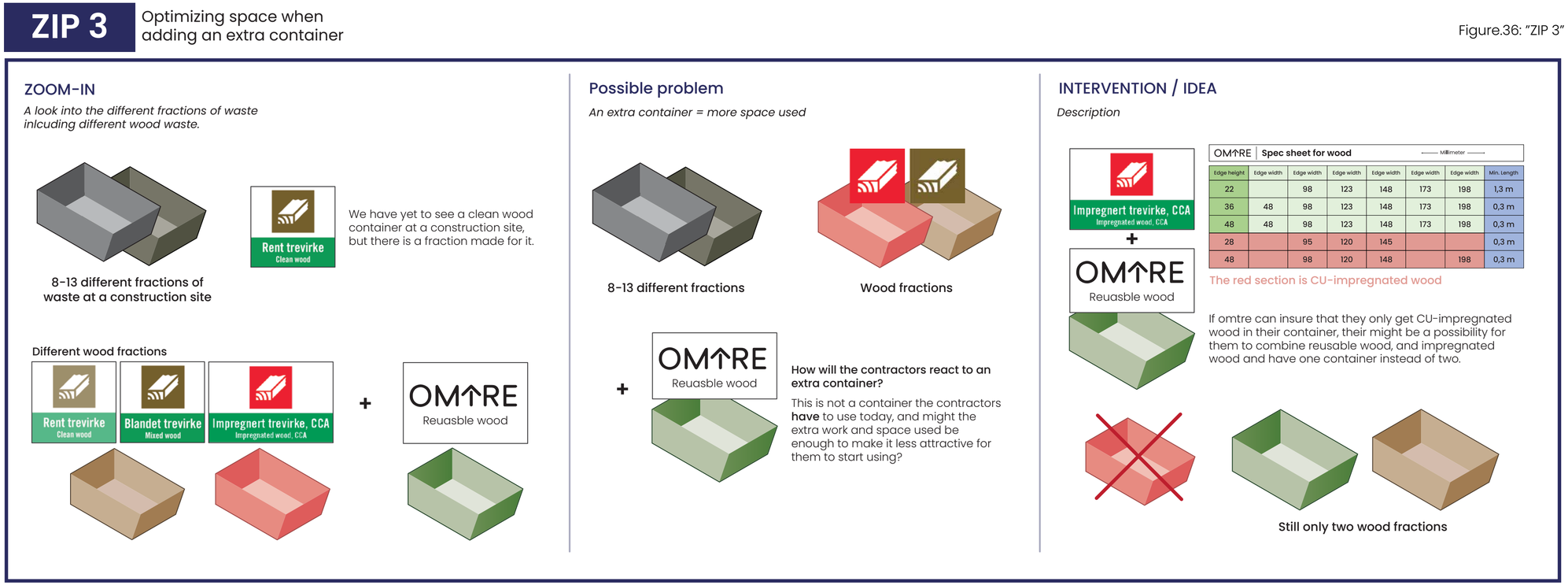


Figure.36: "ZIP 3"

9.6.3 ZIP 3 - Optimizing space when adding an extra container

This zip is a look into how the new container for sorting wood for reuse is implemented on today's construction site. The construction site at Kringsjå with Ove Skår as contractor is doing a pilot project with Omtre to test out this new container. They currently have 13 different waste fractions, and at any given time they might have as many as 8 different containers at the same time. This depends on what part of the construction process they're in. Since Omtre is only collecting regular and cu-impregnated construction lumber, there currently still a need for a mixed wood container for e.g. wood packaging, and other wooden material that is not construction lumber. Because of this, Omtre's container will be an additional container on the construction site (Ove Skår, Interview appendix nr. 17, 2023).

At this current project Ove Skår is not using Impregnated wood, and does not currently need a separate impregnated wood container for this. Ø.M.Fjeld's construction site visited earlier in the project did use impregnated wood in their project, and had a separate container for this. The reason to have a separate container for this is that non-impregnated and impregnated wood should not be mixed together, because the old type of impregnation (CCA) produces toxic fumes when burnt. While the new CU-impregnation is safe and can technically be sorted with non-impregnated wood, it is practically impossible to differentiate CU from CCA-impregnation, and because of the dangerous fumes from CCA, it is all considered hazardous waste. CCA is not being sold anymore, and is not allowed to be used in new buildings, so it might not be likely that it will end up in omtre's container as long as its only waste produced from new materials.

The questions for this intervention is how the contractor reacts to another container at the construction site - Especially at construction sites with less space, and whether Omtre's container can replace the existing container for impregnated wood to counteract this change.
Since Omtre is collecting CU-impregnated construction lumber together with non-impregnated lumber it is technically possible for them to replace the impregnated wood container. For this to work they need to be hundred percent certain that they only get CA-impregnated wood if anything ends up being burnt later. We don't know if there could be CCA-lumber found in rehabilitation project's where part of a building might be demolished to be refurbished, but this might have to be looked at on a case to case basis (Norsk Gjenvinning, n.d.).

9.6.4 ZIP 4: Todays process of reclaiming wood

This is a zip that looks into the current process of reclaiming the wood at Omtre. The way that they reclaim the wood today is that everything is done by hand. They get wood waste in - either construction lumber or e.g. wood from old log cabins. Depending on how the wood looks like they do different processes that might involve removing screws, cleaning the wood and cutting off broken pieces. There is one person working in their facility part time, and is normally the one doing this work. This process seems to be working today with the scale that Omtre is collecting the wood at today, but for the future - when the business is scaled up, new processes might have to be implemented to effectivize the process (Omtre, Interview appendix nr. 18, 2023).

The potential for this ZIP is look into current and future solutions for reclaiming wood on an industrial scale. One company that is working with machines that are doing the same processes that Omtre is doing by hand today. Their machines is cleaning the wood and removing the screws with 3d scanning to locate the screws and arms that are pulling out debris like screws and nails. Their machines could either be placed at Omtre's facility or be placed locally on the construction site to reclaim the wood locally. (Urban Machines, n.d.)

During the research of this project we got a presentation from a professor at a university in Sweden where they looked at using CT scanners to simulate the strength of the wood and locate debris in the wood. While their use case was also for use manufacturing of the planks to streamline the process of sorting the planks, they also suggested using this for reclaiming wood. For Omtre to be more sure about the wood they collect and the strength of it, can make it safer to re-certify the wood into the certifications c14,c18 etc (Johannes Huber, Interview appendix nr. 12, 2023).

The question about what type of technology makes economic sense to invest in it yet to be answered. Questions about the CT-scanning were raised by Omtre during the presentation, in terms of data being produced and saved during the scanning, and whether the energy needed to scan and store the data counteract the positive climate impact of reclaiming the wood in the first place. The technology from Urban Machines is closer to what Omtre is using today, and might make more sense to invest in for Omtre. The process of scaling the business for reclaiming wood isn't just about having machines for reclaiming the wood, but having well working service - both logistically and economically, will also have to be in place. Shorter term, the priority might be to focus on this, since their refurbishing process could technically be scaled up with more people in their facility to start with (Johannes Huber, Interview appendix nr. 12, 2023)

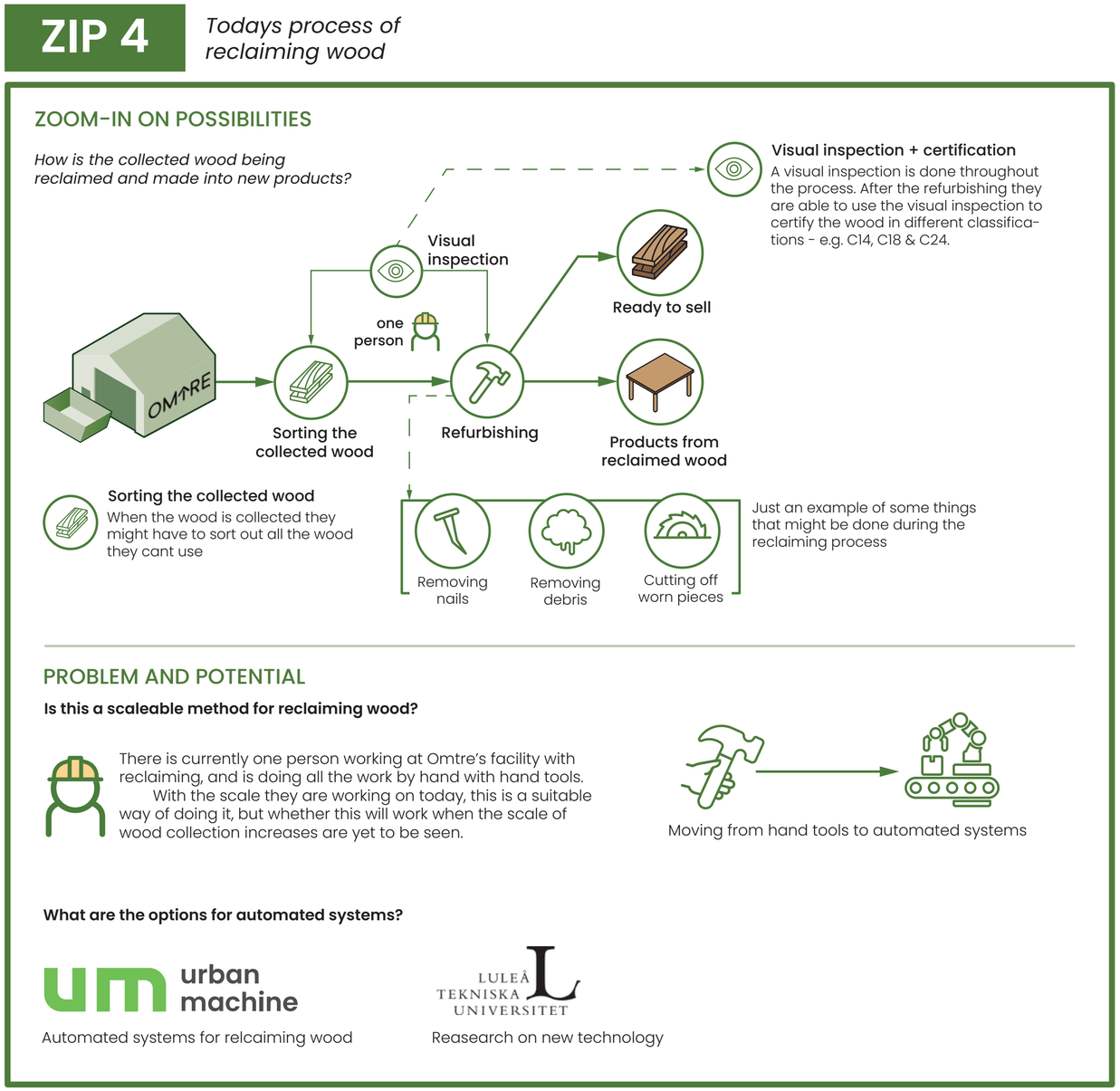


Figure.37: "ZIP 4"

9.6.5 Possibility 1: The business of reclaiming wood

This ZOOM is a speculative look at the business of collecting and reclaiming wood. What has been mapped out is an overview of how Omtre is working right now and where we think the expenses and profits are. Omtre has not been able to share how their business model looks like, so rather than looking at how it is today, we wanted to explore how things might be done in order to find new solutions, and to raise questions about potential challenges.
In order to have a more circular way of using construction lumber on a large scale for the future, one important step is to find a way to make it profitable. Is it possible to make money? Why would the contractor want to pay for another wood waste contractor when it's not currently "needed"? Is there a market for reclaimed wood, and who would want to buy it?

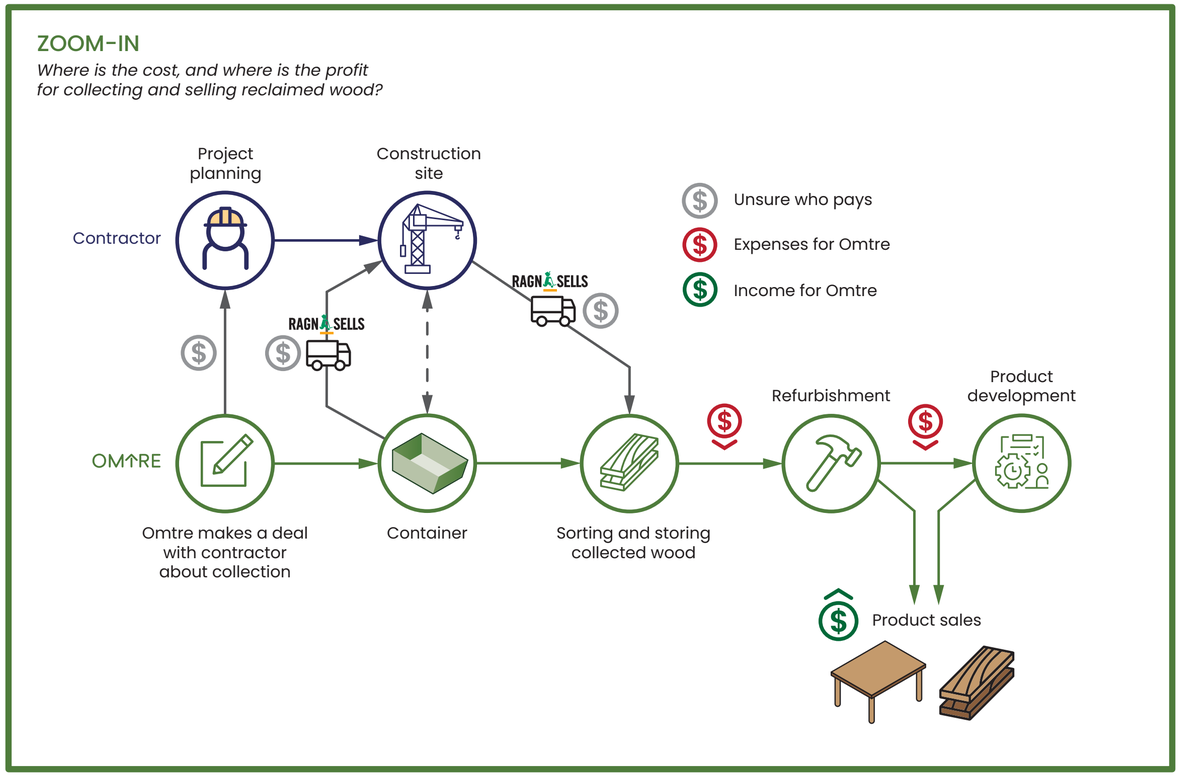
Omtre is still developing their business, and as far as we know, there is only one pilot project currently being done on a larger scale construction site, so there is still more investigation being done on this topic. In this pilot project, Ragn Sells, Omtre and Ove Skår, are investing time, money and resources to find out how the system of collecting wood for reuse is working in the real world. Right now they're not necessarily looking at economics, but rather looking at how viable the current solution is for the stakeholders involved. As far as we know Omtre is only making their money by selling reclaimed construction lumber, either by selling the lumber as it is, or making new products out of it and selling those. We have been told that they don't want to set up their own logistics system, and rather use other companies to provide them with the containers, transportation and everything that comes with that. Today Ragn Sells is the one that provides Omtre with that.

Different perspectives from different stakeholder
Looking at the perspectives from the different stakeholders for this service can help to understand how the economic picture might look like. The contractors are already paying for containers for all of the different fractions they have at their construction site, and they will do that for all of their projects. Omtre is a new actor in the building industry and they need to have contractors interested in having another container at the construction site. If this new container can't replace any of the existing containers, then it will become an extra cost for them - if they're the one paying for it. Ragn Sells is an established actor in the industry and is providing all the containers and surrounding logistics for many construction sites. We have raised questions whether Ragn Sells is making less money on the waste collected when they only charge for the service of collecting and transporting the waste. Today, Ragn Sells collect the mixed and impregnated wood waste and after they process the wood it is sold as fuel for energy recovery or for fiberboard. Would it be interesting for Ragn Sells to continue this partnership if they end up making less money, and if they are, would it still be interesting for them in order to work towards more circularity?

One more question that we have raised is: If Omtre is not directly providing the contractor with waste management service, then who is paying for that service? It might make sense for Omtre to pay for the service, but then we are wondering if they have more expenses during this process compared to what they might get back in sales.

Possibility 1 *The business of reusing wood*

Figure.38: "POSSIBILITY 1"



9.6.6 Possibility 2: Alternative material streams, and different business models

This zoom is a look into the possibility of different material streams for omtre to take advantage of. For the future development of the reclaimed lumber industry it might be beneficial to take advantage of a wider set of material streams and locations. This can meet the need for other industries to also become more circular.
While Omtre is currently looking at solutions for construction sites, we wanted a speculative look at how they could expand their business. This map consists of different materials streams that we saw as relevant to look at. When presenting the different options we chose to look at possible positive and negative outcomes of choosing different material streams. This is more of a discussion than a suggested solution, but this could be the beginning of further development for Omtre and the other stakeholders.

The different material streams

Recycling stations: The recycling station could e.g. be one of Ragn Sells' facilities, and the suggestion here is to have an Omtre container at this location rather than at the construction site. This could mean that the contractor doesn't have to be involved, and could maybe make the integration easier. These recycling stations collect waste from many different areas, and for Omtre it would mean that they can collect waste from a wider area and only have one place where the waste is picked up and driven to Omtre's facility.

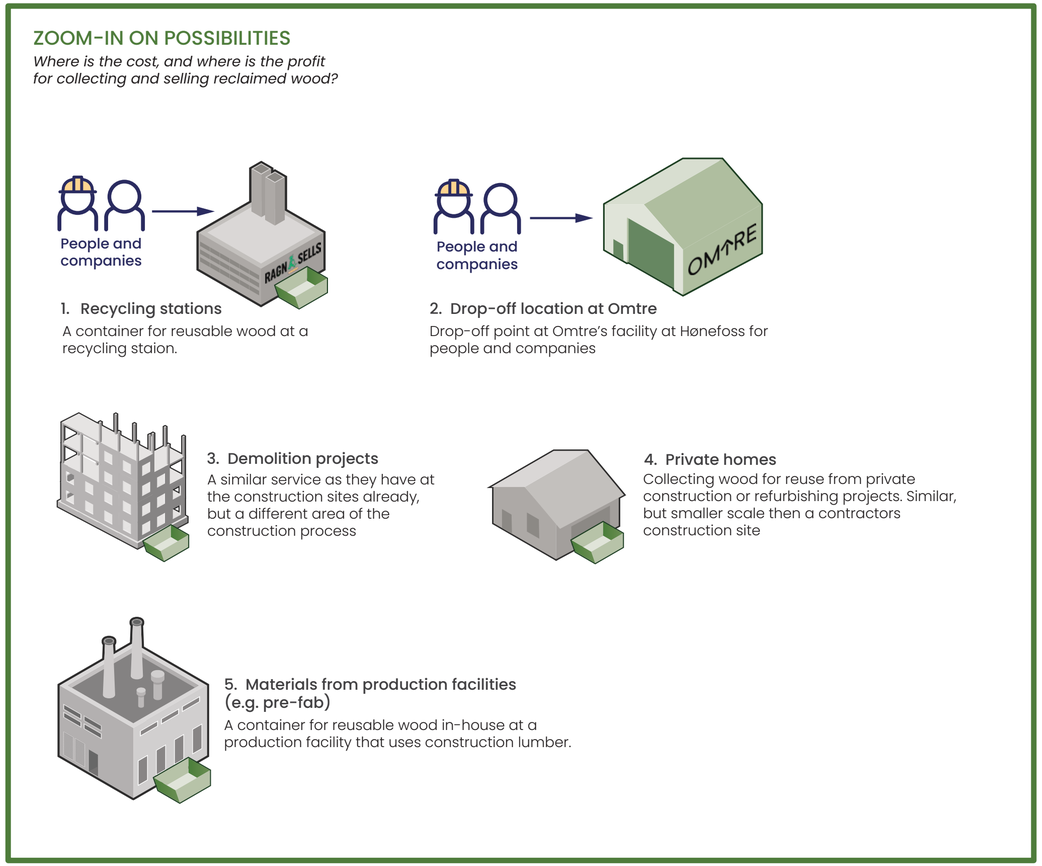
Private homes: There is a lot of waste being produced by households, and during construction and refurbishment, there might be enough waste being produced that it could be useful to have a container there. It could also be the same case for construction of private homes. This is not necessarily a focus on scale, but rather to meet a wider crowd of people.
Another option to try to meet the private customers could be to combine this with having a drop off location at Omtre in hønefoss.

Demolition sites: This is a suggestion for Omtre to have a similar service as they have at the construction sites, but have containers located at demolition sites. According to numbers from SSB demolition projects were responsible for 51 343 tons of waste produced in Norway in 2021. This is not just wood waste but all the waste in total. While this is a smaller percentage than construction and rehabilitation projects, it's still a large amount of waste that could be reduced. We are not sure whether demolition projects in Norway have this detailed sorting with different fractions as we see at construction sites, and if not, that could change in the future. Another challenge could be a more contaminated and random material stream. It might be easier to predict the materials used in a construction of a new building, compared to an old one. If the building is demolished rather than disassembled, and the materials are not separated from each other it might complicate the sorting process.

Materials from production facilities: The exploration of this material stream is something that has been discussed during interviews with contractors. It's mentioned that less waste is produced at the construction site when they get prefabricated building elements, but is there really less waste or is the waste just moved upstream to the production facilities? If they were to do wood waste collection at a production facility you could have closer control over the materials and possibly less contamination, since everything is potentially under the same roof. This possibility can help the factories be more circular and take care of the waste that is not counted as waste on the construction site, but still technically a result of it.

Possibility 2 *Alternative material streams, and different business models*

Figure.39: "POSSIBILITY 2"



9.7 Intervention map

An implementation map - or intervention map, is a model we first made in a previous mapping project we did for BeSafe, and we use it to showcase all the interventions in one map. Some of the interventions are closely connected to existing processes, and some of them are explorations of broader ideas, and larger systemic changes. Our goal with the map is not to solve any problems directly, but rather highlight potential challenges and use this as a map for further development for the stakeholders in the system.

For every ZIP-analysis we have an intervention goal that describes the outcome or result of the change if it were to be implemented. With the map shown here you can see the different ZIP's and they end up in the system. Together with the intervention goals, we are able to perceive the future of the construction process.

Zip 1 intervention goal:
Make the information about sorting wood for reuse more understandable to increase the quality of sorting from the construction site.

Zip 2 intervention goal:
Have solutions for containers that can create a more flexible solution for the contractors to use. This can potentially make the service more attractable for new clients.

Zip 3 intervention goal:
Use the least amount of space when needed when adding an extra container to the construction site. Potentially replacing an existing container with the new container for reusable wood.

Zip 4 intervention goal:
Find solutions for reclaiming the wood that has good potential to be automated and scaled up for the future of reclaiming wood.

Possibility 1 systemic change:
Creating a business model that can help grow the wood refurbishing industry, and have something that can benefit customers on either side of the reclaiming process.

Possibility 2 systemic change:
Have the reclaiming industry meet a broader audience, by taking advantage of a wider set of material streams. This can be good for the business of reclaiming wood, but also help a wider set of industries to be more circular.

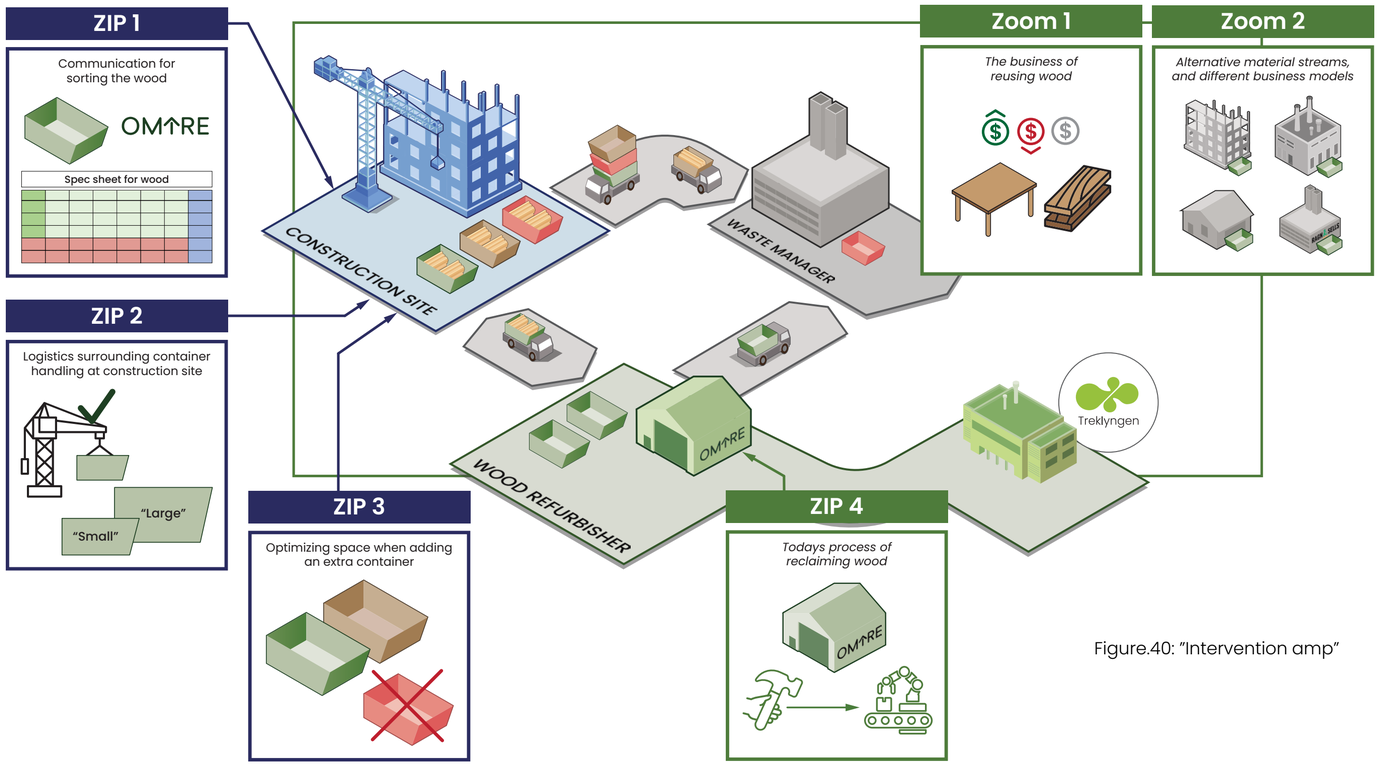


Figure.40: "Intervention amp"

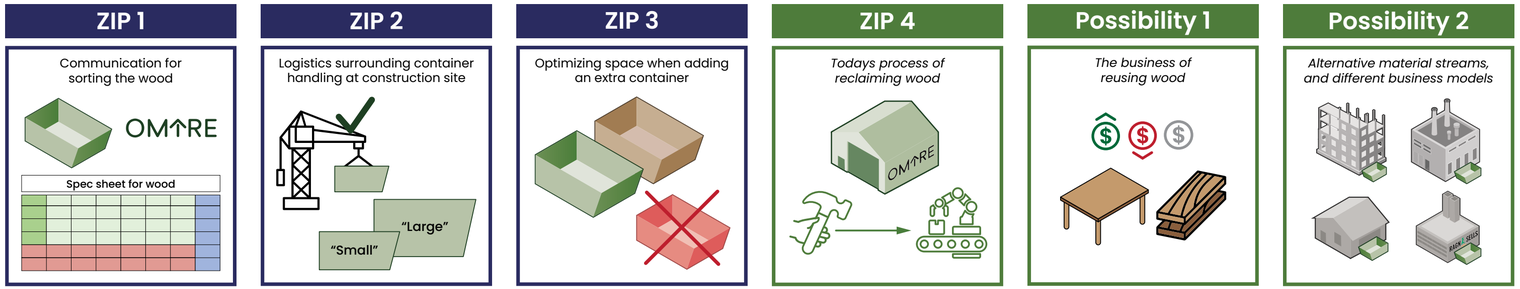
9.8 Leverage Points

This page illustrates the overview of all ZIP-analysis in connection with the leverage points. The next slides will demonstrate which leverage points they targets and the ripple effect they create.

Target

Ripple effect

Figure.42: "Leverage points"



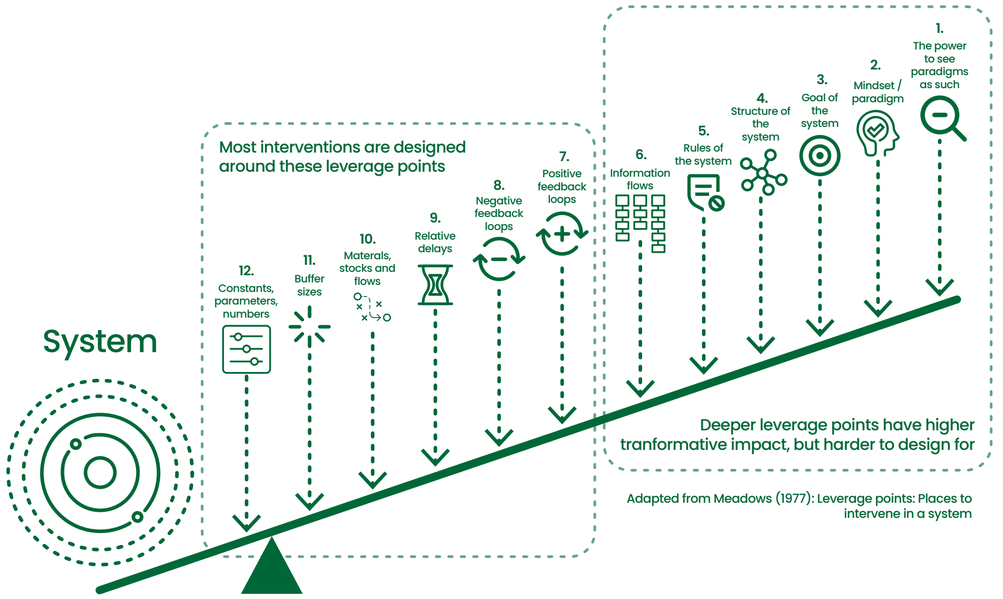


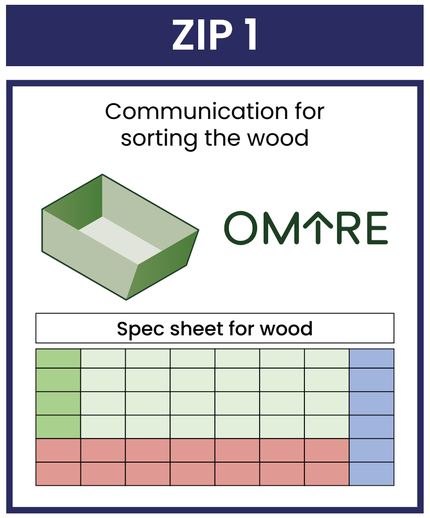
Figure.41: Adapted from Meadows (1977): Leverage points: Places to intervene in a system

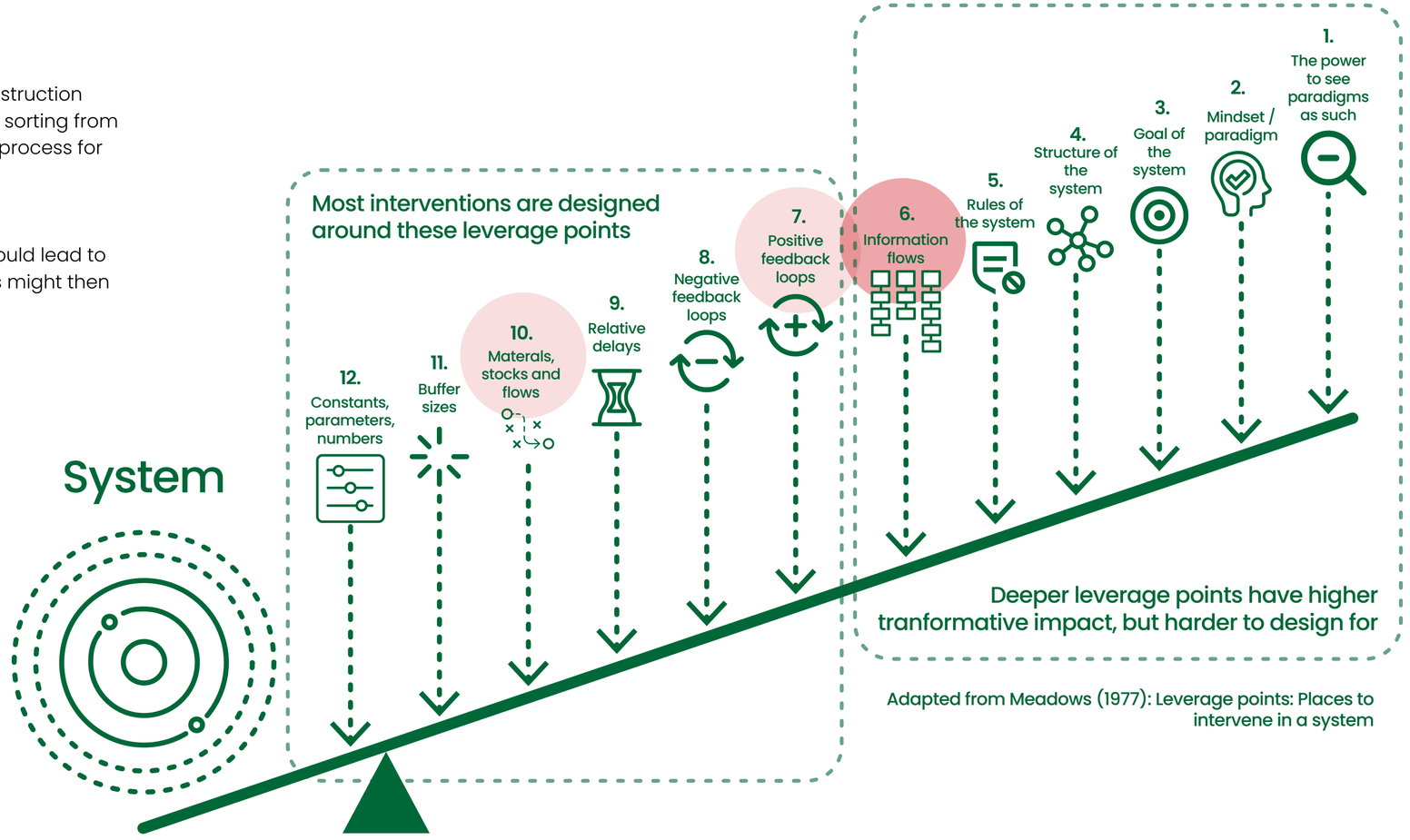
9.8.1 Leverage Points - ZIP 1

Information Flow
By communicating better about the sorting of the wood with well formulated signs, the aim is to improve the information flow between the workers at the construction site and Omtre.

Materials, stocks and flow
By having better communication about the sorting on the construction site, we aim to change the flow of materials to Omtre. Cleaner sorting from the construction site can lead to a more efficient refurbishing process for Omtre with less second hand sorting.

Positive feedback loop
If you increase the in-flow of materials into Omtre, then that could lead to increased use of reused wood in newer construction sites. This might then go back into Omtre again after some time.

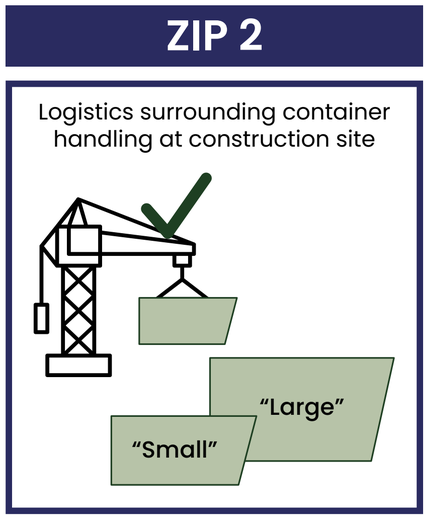


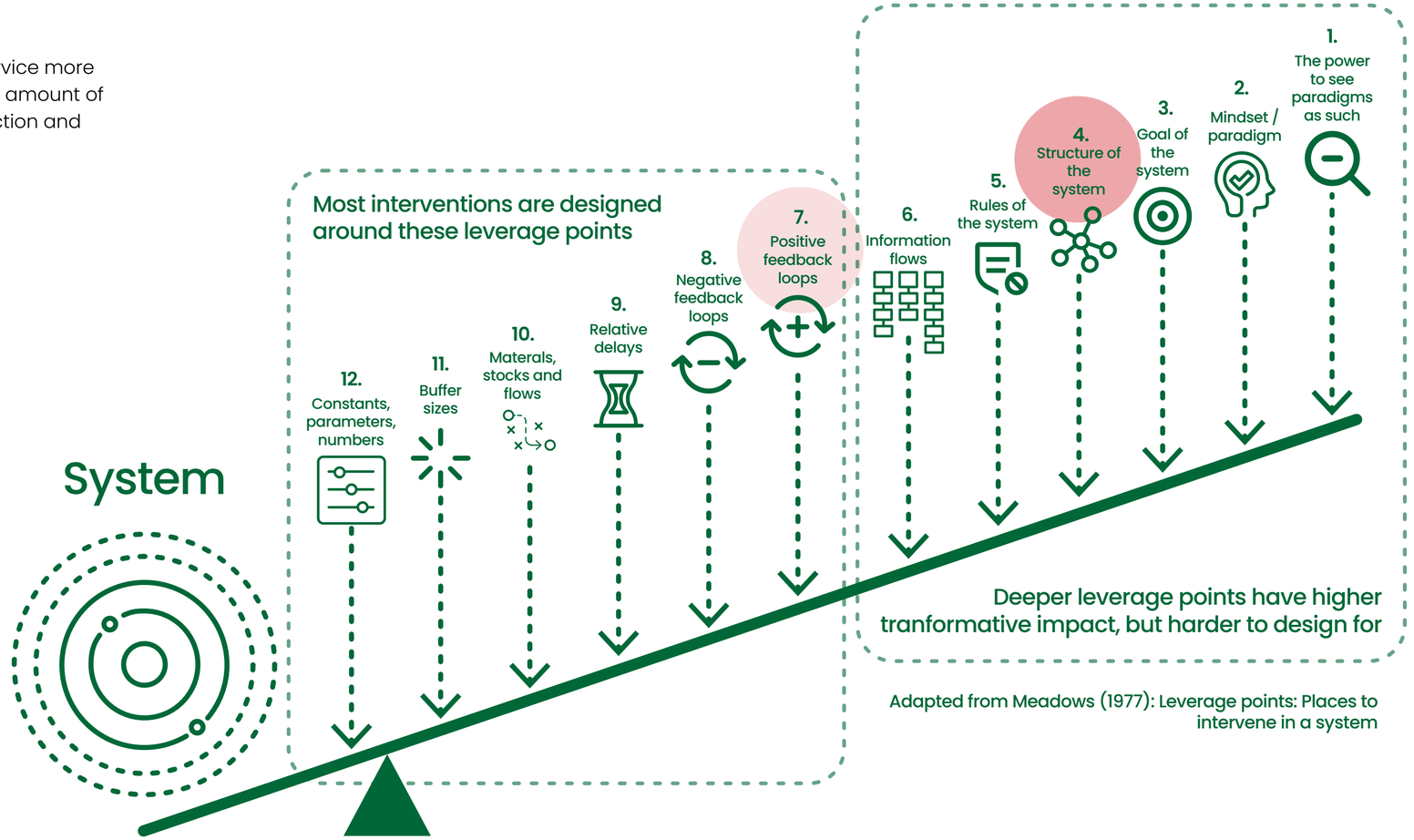


9.8.2 Leverage Points - ZIP 2

Structure of the system
By having a more flexible solution of collecting reusable lumber for the contractor we aim to change the structure of the system from where it is today. The goal is to have a less rigid and easier to use service.

Positive feedback loop
A more attractive solution for the contractor can make the service more attractive for other contractors to use, and might increase the amount of customer, which in-turn will lead to an increased rate of collection and reuse.

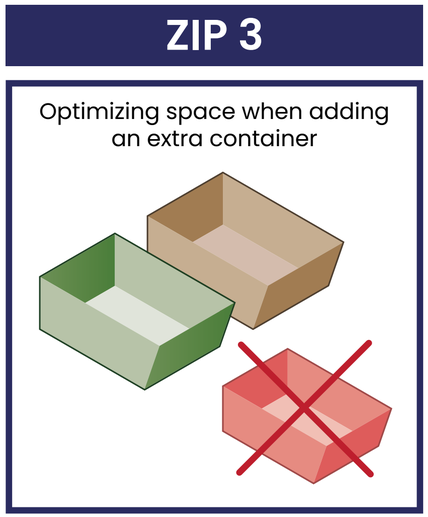


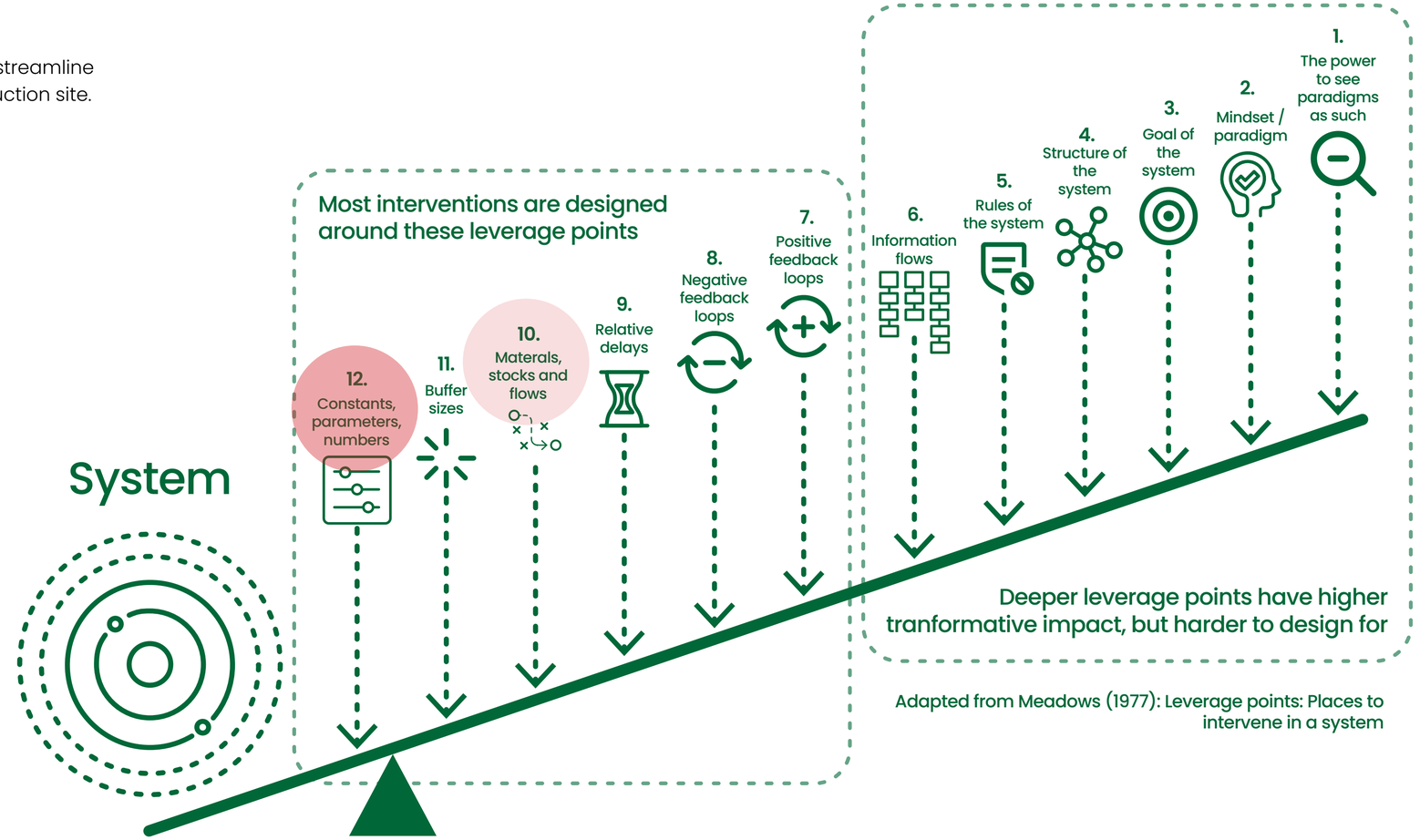


9.8.3 Leverage Points - ZIP 3

Eksempel
By having a more flexible solution of collecting reusable lumber for the contractor we aim to change the structure of the system from where it is today. The goal is to have a less rigid and easier to use service.

Materials stocks and flows
We think that by reducing the amount of containers, it might streamline the sorting and the flow of containers to and from the construction site.



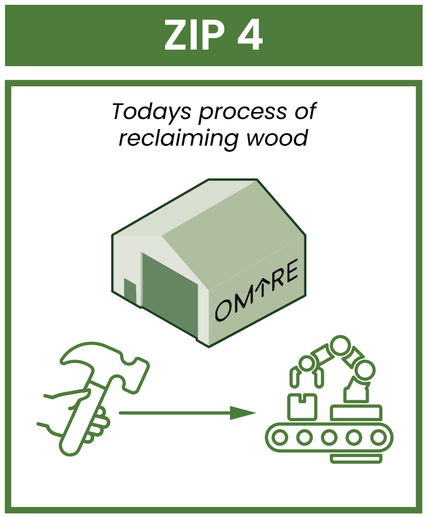


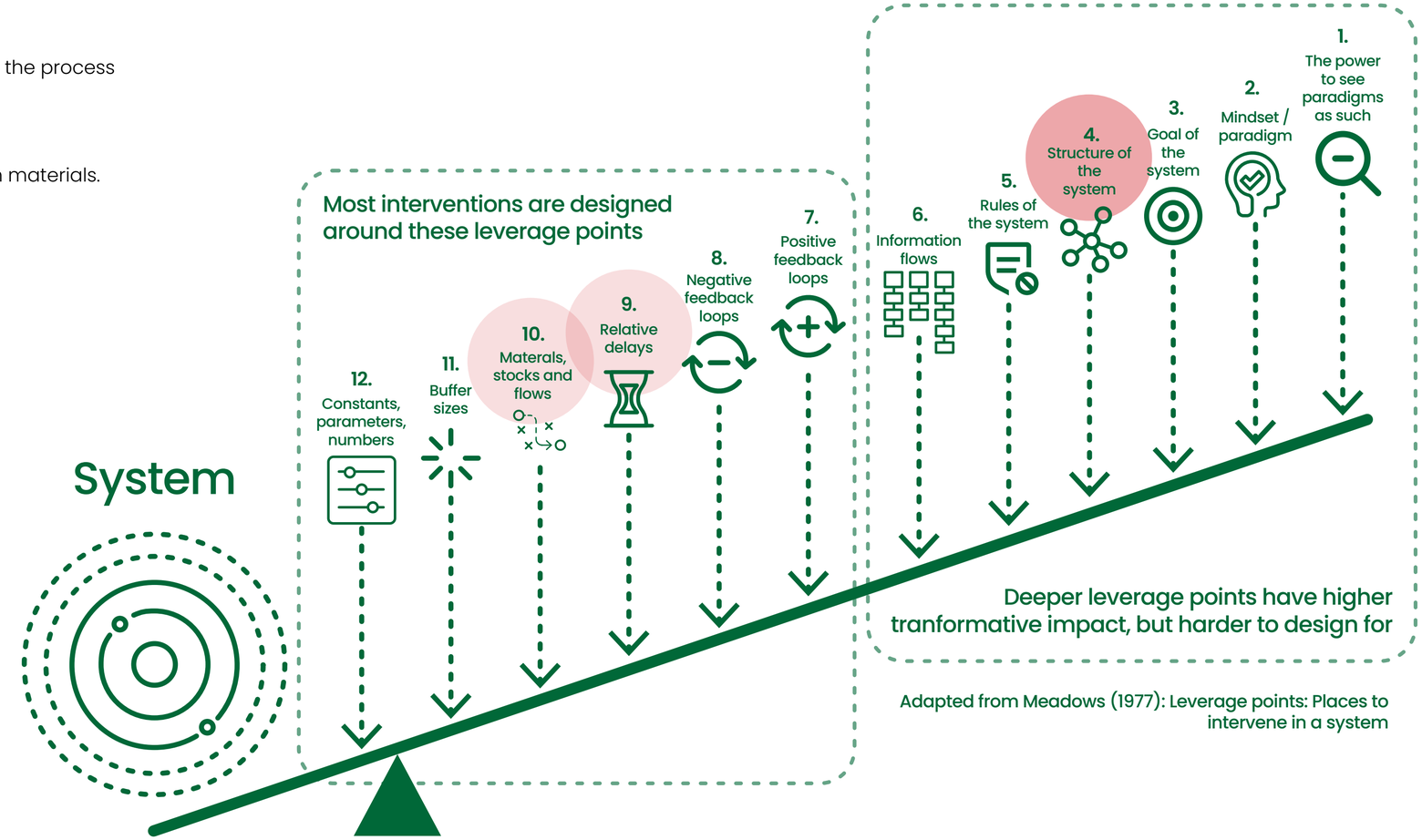
9.8.4 Leverage Points - ZIP 4

Structure of the system
By having a more flexible solution of collecting reusable lumber for the contractor we aim to change the structure of the system from where it is today. The goal is to have a less rigid and easier to use service.

Relative delays
By automating the process we can reduce delays by making the process more efficient.

Materials, stocks and flows
More efficient refurbishing can lead to a faster turnaround on materials.





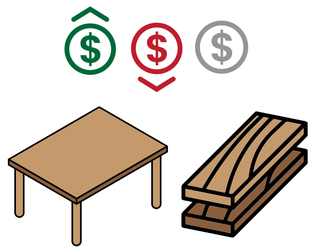
9.8.5 Leverage Points - POSSIBILITY 1

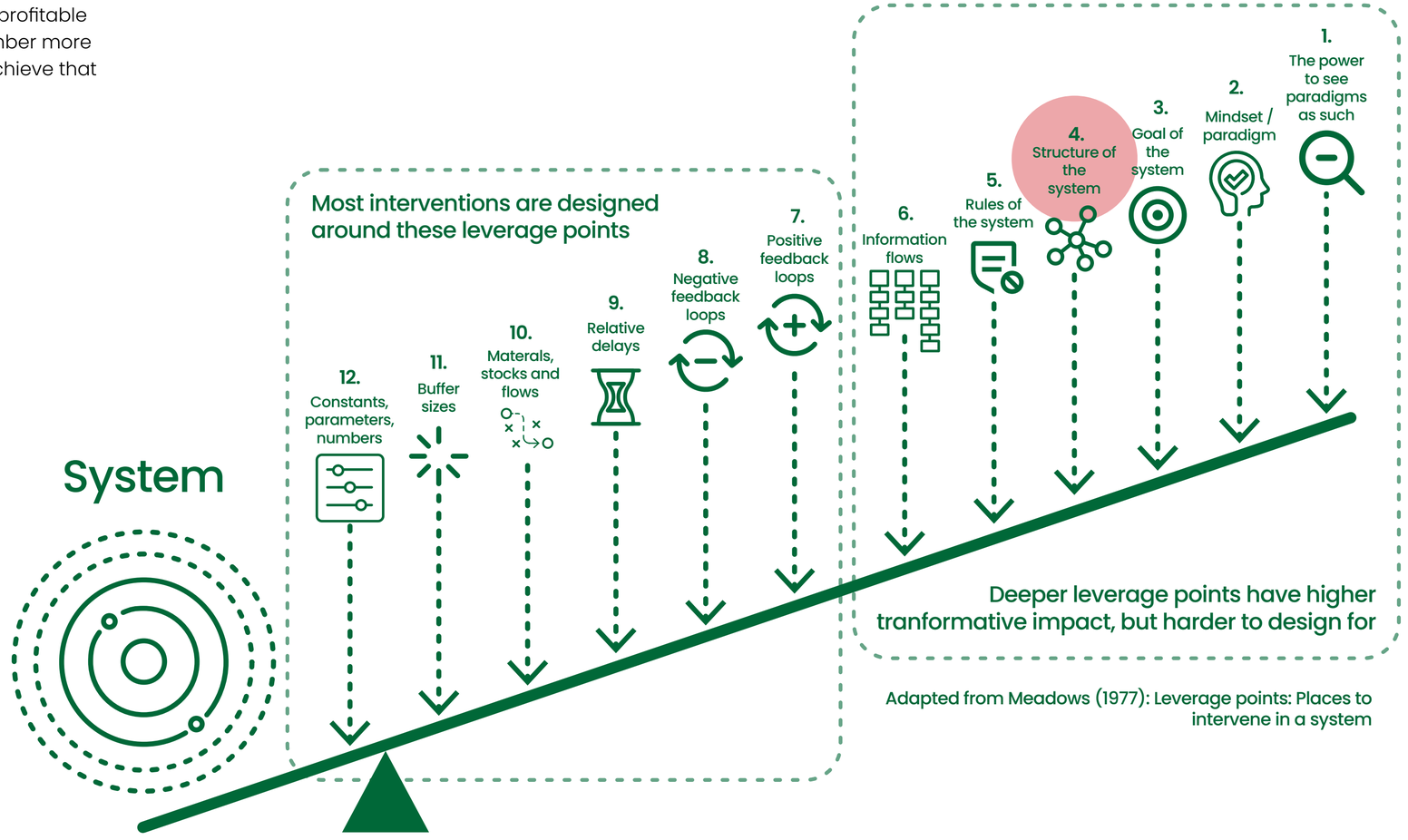
Structure of the system

As far as we know, the business model for Omtre is still under development, and they are yet to figure out how to make the service they provide and the products they sell as profitable as possible. There might be a need to change the structure of the system in order to focus on more profitable solutions. While their goal is to find out how to make use of lumber more circularly, we think that a profitable company is essential to achieve that goal.

Possibility 1

The business of reusing wood





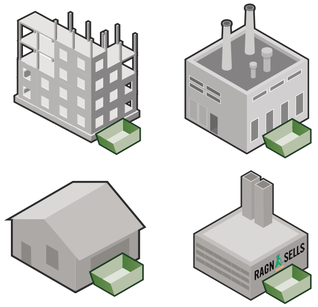
9.8.6 Leverage Points - POSSIBILITY 2

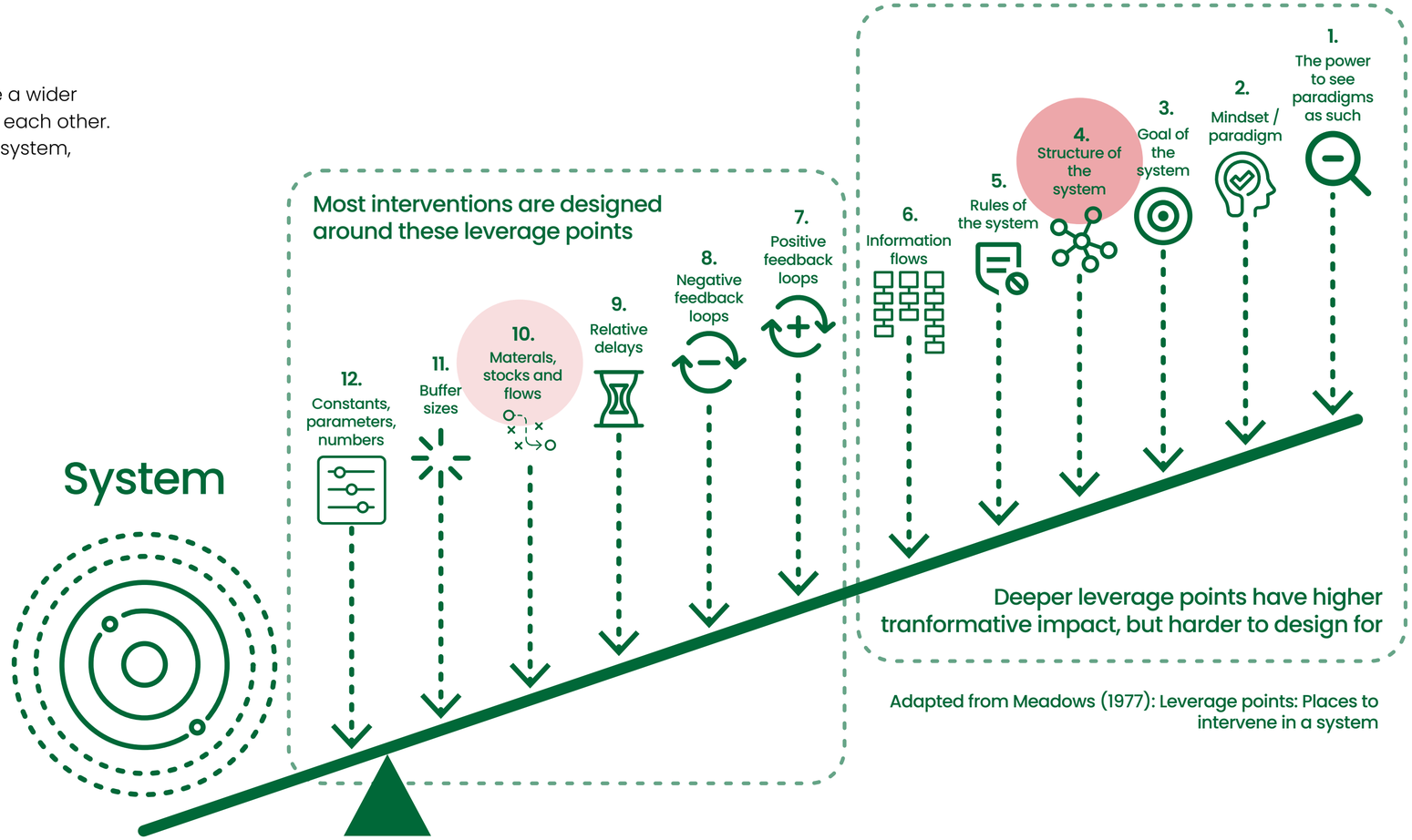
Structure of the system
These explorations of different material streams are connected to changes in the overall structure of the system. Expanding to a wider set of material streams means a change in business models and how they collect the materials.

Materials, stocks and flows
For an increased reuse of construction lumber Omtre will have a wider set of material streams, that are not necessarily connected to each other. If one stream reduces it waste output, it wont delay the whole system, because they get materials from different areas.

Possibility 2

Alternative material streams, and different business models





Adapted from Meadows (1977): Leverage points: Places to intervene in a system

10 Discussion

Economics
The building and construction industry alongside the reclaiming industry must make money to survive in our current economic system. This gives incentives to make decisions based on economic profit and leaves environmental concerns in second place. Investment in technology/machines, workers, transportation and a time demanding refurbishing process makes reclaiming wood waste a business with high expenses. This combined with the relatively low prices of new and reclaimed construction lumber makes it hard to earn back the initial investment.

It seems to us that the reclaiming industry would benefit from laws and regulations aimed at actors in the building and construction industry. These laws could for example make documentation needs for reused materials simpler and impose CO2 limits on new buildings in TEK, causing reused wood to be more desirable (Grønn Byggallianse, n.d.). The trend towards burning wood waste is seen as a barrier because it competes with companies wanting to reuse the material. Economic incentives towards reuse could make wood waste more accessible for the reclaiming industry. There are laws under development that seek to make reclaimed construction lumber as easy to use as virgin construction lumber. The effect of this remains to be seen, but we are hopeful that laws and regulations like this could make reclaiming wood more profitable in the future (Byggeindustrien, 2022).

Documentation on reclaimed wood
Certifications for reclaimed planks - how is this a challenge?
Certification and material-documentation are certainly large barriers for OMTRE and the work towards creating a circular industry in general. Documenting the material's quality and performance are crucial for making sure that the materials on the market are safe to use. Especially for load-bearing construction. It is not easy to imagine integrating reused wood into the same system, especially with the ones with load-bearing performances. In the near future, it can maybe be more fruitful to look towards other areas of use with lower documentation requirements, such as cladding, or even other industries

Scaling up and centralizing the lumber refurbishing facility
For the business of reclaiming wood to evolve to a large-scale industry in Norway, work has to be done in many parts of the process. Finding efficient ways of collecting the lumber from different material sources, having efficient ways of reclaiming the wood, and finding use-cases and a market for the reclaimed wood. Some of which we have highlighted in the results. One topic that came up in a discussion with Norsk Massivtre, is that when Omtre has the refurbishing facility centralized in Hønefoss, you have to transport all the waste from all the different constructions site to Omtre, and the other way around when the material is sold. This might introduce more transportation to the lumbers life-time and increase pollution because of that. While you still might end up reusing all the wood, it's likely better to have the least amount of transportation possible. As said in Cradle to Cradle: "all sustainability is local", and this should be said about refurbishing wood also. The more locally used the construction lumber is, the less pollution you might add the process. (McDonough & Braungart, 2009, p.123-126)

The challenge of increased transportation is yet to be solved, but the solution presented by Urban Machines has the possibility for a moveable machine / conveyor belt that can refurbish the lumber locally at the construction sites,
if there is a need for a more comprehensive processing of the material like finger joining or similar in order to create products from the wood, then this might end up being more difficult to do locally. (Urban Machines, n.d.)

In terms of cost savings for the company refurbishing the wood it might be important to have a quick turnaround for the materials at the facilities where it's refurbished. This could involve totally or partially automating the process. This is where e.g. Urban Machines come in. Today at Omtre everything is done by hand and that is possibly because of saving cost and the small scale they're working on today. In order to scale up their refurbishing they either have to hire more people or facilitate for a more automated process and additionally invest in machines. Which might be a large up-front cost. We are not sure where this money will come from, and if other parts of the business have to be in place before they invest in possibly expensive machines.

Materials and sustainability - Can wood replace concrete and steel?
There are many different factors concerning sustainable buildings, both embodied CO2 and operational CO2. Cement-based materials have high performance structural abilities compared to wood, which enables the building with a tall and narrow design, and a lower areal footprint. Secondly it is well known that concrete has a long lifespan, which is essential for the building to make up for the embodied carbon footprint. The building also has to be able to transform to numerous other areas of use over its lifespan to prevent demolition and end of life when the property gets reregulated.
With that said, we know that wood, especially construction lumber (in isolation) is a way more sustainable material option, but does not hold as many constructional properties as concrete, which results in architectural limitations to height and the building's lifespan. To increase the materials lifespan through a circular system could therefore be a gamechanger for the industry becoming more sustainable.

Who owns this wicked problem?
During our research phase, we discovered one important thing. Nobody actually "owns" the problems we investigate in this thesis. All actors share the responsibility, and no one actually has a clear vision of who actually sits with the main responsibility. The result of this is that many businesses are pointing fingers at each other, and are more or less waiting for others to take initiative.

It is interesting to take part in the rapidly moving landscape towards the green shift. We see a change in paradigms where central actors view the circular economy as something inevitable and have the choice to swim or sink in the rising tide.

11 Conclusion

In the conclusion, we will give a short summary of the project. Next we will go through the intervention points and summarize their aims. Followed by the research we think is needed to increase the knowledge base related to this issue. Finally we will share our thoughts on how it was to work on this topic, from a designers perspective. For the readers ease, we will repeat our research question:

"How can system oriented design be a tool for creating a circular system for reusing construction lumber in the Norwegian building and construction industry?"

Short summary of our project
In this project we have done research, analysis and design using System Oriented Design as our main approach. Through this methodology we have gained a general understanding of the environmental issues we face and to what extent the global and Norwegian building industry contribute to these issues. We have discussed wood's abilities as a carbon absorber, building material and whether it could be favored compared to more frequently used building materials.The Norwegian forests have great potential for timber extraction. It consists of a large number of old trees, which do not have as good absorption abilities of CO_2 compared to younger trees, but are still great wood for construction materials. Even though we have a large number of raw materials available in Norway, there are barriers concerning circularity in the building industry today and there are challenges for reusing wood in the same industry. Nevertheless, there are some actors using reclaimed lumber in their products, although this is still being done on a relatively small scale.

We see that reusing construction lumber on an industrial scale is possible, but there is more work to be done in different areas of the construction process and within different stakeholders. Our mapping and ZIP-analysis is a way to inform and guide the stakeholders into making the necessary changes. All in all we think that to increase the circularity of construction lumber, all the stakeholders have to work together. The government, building owners, architects, contractors and the waste managers.

Interventions
Through the intervention points, we hope to highlight areas we think could contribute to a more circular use of reclaimed lumber. We want to achieve this by:

1. Highlighting the need for clear communication between Omtre, the contractors and the construction workers, so that all of them understands Omtres spec sheet, with the result of achieving correct wood sorting.
2. Emphasize the importance of flexible container solutions.
3. Possibly reducing the amount of containers needed on an already tight-spaced construction site.
4. Investigating technological solutions that can make industrial upscaling possible and step away from ineffective manual processing. All of these interventions could have the desired effect of reducing, in this case ØMFs, waste generated per m2 of finished building.

Further research
Our project has looked at a system with a specific set of actors and in a specific time period. We have aimed at getting a "snapshot" of the current system, but understand that systems naturally change over time and look different with the introduction of for instance new laws and regulations. Readers should know that continuous updating is needed to have a clear understanding of the system. To increase the knowledge base on this area, we propose that further research can be done on the following topics:

1 Reclaimed wood products - What types of products can be made from reclaimed lumber?
2. Markets - What markets are willing to purchase reclaimed wooden products?
3. Economics - How can collaboration between contractors, refurbishers and waste managers be profitable for all the involved partners?
4. Material sourcing - What other material streams could a refurbisher tap into in order to utilize reclaimed wood in new products?

Designer's thoughts
We are trained in design thinking and are used to having a user centered approach to design. With the Gigamapping method we have looked at materials- and information flows, relations between stakeholders and not so much the people handling materials, conveying information or working within the companies. If we had more time and developed our interventions further it would be more relevant to talk to specific people and design with their needs as our primary interest.

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Torstein Kjenne
Sebastian Larsson

Master Thesis In Product Design /
Design For Complexity

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Interview appendix

The interviews and observations have their own number in the appendix and the text in the report refers to this number.

List of figures