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STUDENT REPORT

MASTER THESIS

A Guide for the Integration of Material Efficiency into the Faroese Building Sector

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Abstract

The building sector is a significant contributor to climate change and environmental degradation, as well as being among the top consumers of natural resources. A situation that is expected to escalate in coming years. Presenting a problem, as the planets resources are finite and the current consumption already unsustainable.

Approximately 75% of a building's total emissions, measured over its life cycle, are embodied in the materials used in the construction of a building. Resulting in the building already having a significant negative impact before it is taken into use. Reducing this impact is therefore crucial for a sustainable transition of the sector, whereto the circular economic model presents a systems framework for addressing the inefficient use of resources. By keeping materials in circulation, minimizing waste and resource extraction.

This thesis presents an approach for integration of parameters material efficiency into the Faroese building sector, based on the circular economic principles of narrowing and slowing material flows. These parameters are accompanied by a life cycle based decision-making framework, collectively designed to reduce embodied emissions in public building projects and increase their cost-efficiency.

Clarification of Terms

Building Sector

Normally, referring to the construction sector includes the building sector, defining all construction projects, such as buildings, roads, tunnels, bridges etc. But in this thesis, they are separated. Here, the term "building sector" exclusively refers to the construction and demolition of buildings. Being housing, public building, office space, institutions etc.

Building Developer

This thesis defines the term "building developer" as an organization or individual who procures building projects, which can be done by both the public- and private sector. Thus "public building developer" refers to the public sector and "private building developer" refers to the private sector.

Building Project

As with the concept for the term "building sector", the term "building project" solely refers to the design, planning, and construction of a buildings. Being housing, public building, office space, institutions etc.

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1.0 Background

Globally, an estimated 30% of all extracted materials, 40% of waste generation, and 33% of CO^2-emissions are contributed to the sector (Eberhardt, et al., 2021). Estimations that are predicted to significantly increase in the near future, with the output of the building sector (GCP & Oxford Economics, 2015). Unfortunately, this is a problem, as the planets resources are finite and human activity is consuming them as if there is a never-ending abundance, where the current demand for natural resources is consuming almost two planets worth of natural resources (The World Counts, 2021). By 2050, it is estimated that society will consume three planets worth (European Commission, 2020a). This predicament is due to the fact that the world's economy is currently dominated by a linear economic model, based upon a ”take, make and dispose” development model, requiring large amounts of cheap and accessible materials. Meaning that raw materials are extracted, manufactured to products, sold, and then discarded as waste, illustrated in figure 1.

Figure 1: Linear Economy (Paper Round, 2017)

Though the model has generated a never-before seen level of economic growth (Ellen MacArthur Foundation, 2015), it has also created the forementioned unsustainable consumption pattern (Climate-KIC, 2019). A consumption pattern which contributes to externalities such as increasing carbon emissions, pressures on landfills, and widespread pollution of ecosystems (Arup, 2016). Largely stemming from resource extraction and manufacturing, causing 50% of total greenhouse gas (GHG) emissions and over 90% of biodiversity loss (European Commission, 2020a). Besides from the environmental impact, there also exists a possibility of resource scarcity, presenting the risk of price volatility, supply chain disruptions, and growing pressures on resources with socio-economic consequences (Mancini, et al., 2013). For example, in Denmark, it is expected that Region Sjælland will empty its natural deposits of sand and gravel within a few decades (BygTek.dk, 2022).

Governments and companies have started to worry about their access to material resources. This is based on the historic trend of price volatility of certain raw materials, coupled with the intensification of competition for resources, since China, a major supplier of many critical materials (Ecorys, 2012), has started consuming more and restricting exports. However, whether resource scarcity presents a threat is still debated in the scientific community. Being that there are many uncertainties in assessing the availability of resources. One perspective is concerned about future resource availability, referring to the unprecedented demand for raw materials, due to the globally growing middle class (Mancini, et al., 2013), which has more than tripled in the past 10 years and will most likely continue to grow considerably going forward (Shorrocks, et al., 2021). Because of this, the European Commission expects that the global consumption of natural resources will double within the next 40 years (European Commission, 2020a). The optimistic view is that "technological and socio-economic innovation, markets' adjustments, recycling and international trade" will prevent scarcity of materials. But this would require better management of materials, emphasizing reusing, recycling, and recovering materials at their end-of-life stage, overall creating a circular economy (Mancini, et al., 2013).

1.1 Circular Economy

The circular economic model has had significant traction since its emergence in the 1970's (Ellen MacArthur Foundation, 2015), as it today has gained widespread recognition. Specially, with the release of the European Green Deal, wherein the EU put the circular economic model into practice in their strategy "A new Circular Economy Action Plan", which targets the building sector, addressing the sustainability performance of building materials and influencing building design, promoting durability and a life cycle perspective[1] (European Commission, 2020b). The circular economic model is a systems solution framework that addresses the inefficient consumption of the linear economy model by rethinking material use. The aim is to disconnect economic activity from the extraction of finite materials through managing material flows, keeping materials in circulation at their highest possible value, thereby minimizing waste generation as well as the need for resource extraction.

[1] A life cycle perspective assesses environmental aspects of a products, service, or in this case, a buildings, from extraction of raw materials all the way to disposal.

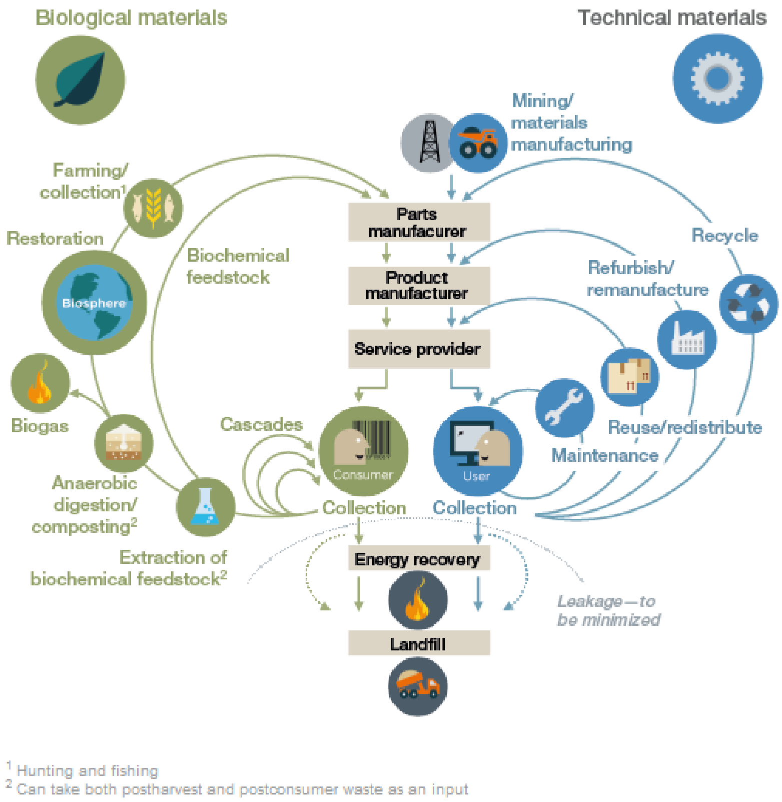

Figure 2: Circular Economy System "Butterfly" Diagram (Ellen MacArthur Foundation, 2015)

The circular economic system, illustrated above in figure 2, presents two types of material flow systems: biological and technical. The biological system refers to the material flow of renewable materials, which are regenerative and can safely cycle through extraction from- and decomposition back into the biosphere (Ellen MacArthur Foundation, 2015). For example, bio-based building materials such as wood, straw, and hemp. Whereas the technical system refers to material flows that cannot re-enter the biosphere due to their synthetic or contaminated state, such as for example plastics, metals, and chemicals (Ellen MacArthur Foundation, 2017). So, as not to be landfilled, materials within the technical system must be kept in circulation through maintenance, reuse, refurbishment/remanufacturing, and recycling (Ellen MacArthur Foundation, 2015). Where recycling should be perceived as the last resort. This is because recycling causes a product to lose all value other than the material value, losing both manufacturing- and marketing value (Goddin, 2021).

In a building sector perspective, the circular economic system resembles figure 3 (below)

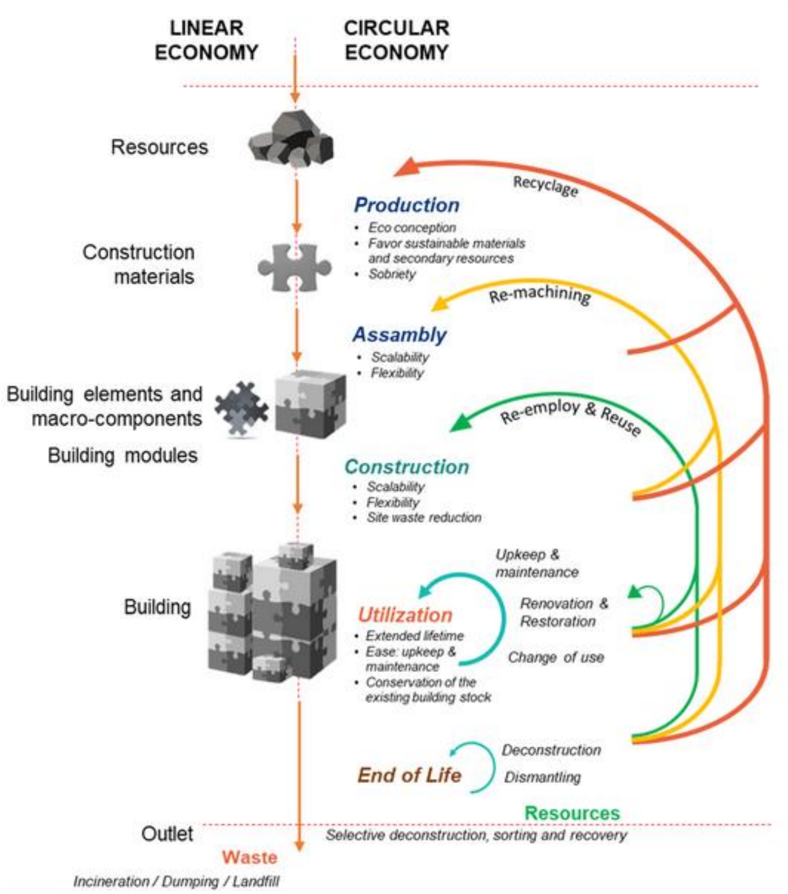

Figure 3: Levels of resource valuation for the building sector. Inspired from the Ellen MacArthur Foundation, Circular economy diagram (Tirado, et al., 2022).

As the "butterfly" diagram (figure 2) illustrates, the circular economic model is a design driven system where waste generation is treated as a design flaw. Therefore, it is crucial that the design of products incorporates the potential of materials being circulated within the economy (Ellen MacArthur Foundation, 2015).

In summary there are five principles towards a circular economy (figure 4), which can narrow, slow, close, or regenerate material flows, as well as inform about material flows.

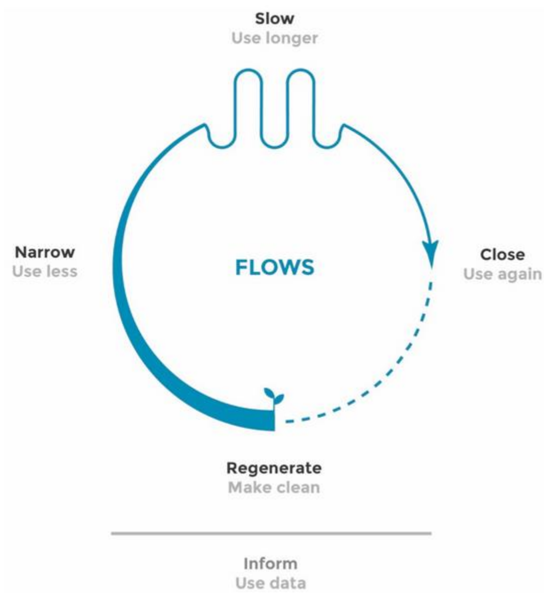

Figure 4: Strategies Towards Circular Economy (Konietzko, et al., 2020)

Narrowing material flows refers to using less impactful materials by designing with “low-impact inputs”, which in a building sector perspective means that the design of a building should aim at using fewer materials and favor the more environmentally friendly type.

Slowing material flows refers to using materials longer by designing for durability, which in a building sector perspective means that the design of a building should aim at using durable materials, where regular maintenance throughout the buildings life cycle will further reinforce durability and help slow material flow (Konietzko, et al., 2020). However, one should keep in mind that durability is not necessarily environmentally friendly, as for example is the case with concrete and metals (Ellen MacArthur Foundation, 2021).

Closing material flow refers to the circulation of materials within the system by designing for recycling, using materials which are best suited for this purpose (Konietzko, et al., 2020). In a building sector perspective, this could for example be designing a building with an emphasize on the reusability and/or recyclability of materials.

Regenerating material flow refers to material flows that use renewable and non-toxic materials, in-line with the biological cycle (figure 2), which in a building sector perspective means the design of a building should use bio-based building materials such as wood (Konietzko, et al., 2020). However, buildings are constructed with many different materials and components that are sourced from both the biological- and technical system, thus a building can only be part regenerative.

Informing refers to using information technology to support circular initiatives and should be relied upon as means to an end. For example, to collect data for assessments of externalities and for identifying the best possible solutions. For you can’t improve what you don’t measure (Goddin, 2021). In a building sector perspective, this could be in the form of life cycle assessment (LCA)[2], for which documentation is a key component. It could also be informing about maintenance and repair needs, benefitting in the slowing of material flows (Konietzko, et al., 2020).

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[2] Life Cycle Assessment (LCA) is an international standardized methodology which function is to quantify the environmental impact of products and processes through their entire life cycle.

1.2 Material Efficiency in Buildings

Approximately 11% of the 33% CO2-emission linked to the building sector are a result of building materials (IEA & UN Environment Programme, 2019), of which 8% stems from concrete (CORDIS, 2019). Emissions that are embodied in the materials which are used to construct a building. Embodied emissions refer to the emissions that constitute the carbon footprint of a building material, stemming from the extraction of raw materials, manufacturing process, and transportation to a building site (Rock, et al., 2020). So, before a building is taken into use, it already has significantly impact, which continues to increase throughout its life cycle (Birgisdóttir & Madsen, 2017). Material use being responsible for 75% of a buildings total emissions, presenting great potential for significantly reducing the building sectors overall climate- and environmental impact. For, so far, regulations have, with great effect, primarily focused on optimizing buildings energy-efficiency (Eberhardt, et al., 2021).

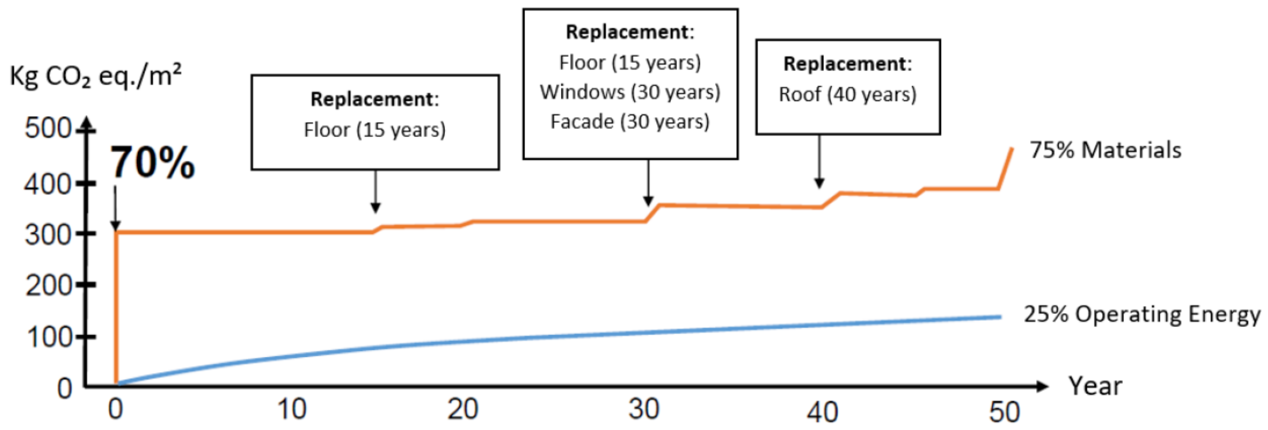

Figure 5: Climate impact from the lifecycle of buildings (Birgisdóttir & Madsen, 2017)

A buildings life cycle, typically measured over 50 years, is comprised of four stages and sixteen modules, illustrated below by table 1, which all optimally should be included when measuring a buildings climate- and environmental impact. The last stage, beyond life cycle and its three modules are representative of keeping materials in circulation within the economy after the building has reached its end-of-life stage.

Materials			Construction		Operation							End of life				Beyond life cycle		
Raw Materials	Transport to Manufacturers	Manufacturing	Transport to construction site	Construction of building	Use	Maintenance	Repairs	Replacements	Refurbishing	Energy Consumption	Water Consumption	Demolition/deconstruction	Transport to disposal	Waste Management	Landfill	Reuse	Recovery	Recycling

Table 1: Stages and modules of a building's life cycle defined in the European standard (EN 15978:2011)

Improving a buildings material efficiency is in-line with the circular economic principles of narrowing and/or slowing the material flow, depending on the design choices (1.1). Here, knowledge about building materials composition is crucial, as a life cycle perspective is needed for identifying opportunities for optimization (Eberhardt, et al., 2021). However, as the impact from building materials is only associated with the materials stage and certain modules of the operation stage, such initiatives will only have a direct effect on these. But if the aim is to close the material flow and thus take advantage of the beyond life cycle stage, the waste generated, when building materials are replaced or when a building is demolished, need to be kept in circulation within the economy (1.1). Research shows that the building sector is currently not mature enough to optimally address the beyond life cycle stage, thus close material flows. In part, due to a building being a complex combination of materials, components, and technical installations (Larsen, et al., 2022), involving many stakeholders, suppliers, and processes. Though there are methods with which this can be done, such as designing for disassembly and selective demolition, these are difficult and complicated tasks, that require the involvement of actors- and systems outside the building sector itself. Such as public initiation, involving both supporting policies and a waste management system suited for the purpose. Actors with the ability to conduct selective demolition, which is rigorous process that requires upstream preparation of materials before reuse and building practices and material choices to be adapted. As well as secondary resource market with economic viability (Tirado, et al., 2022). However, this challenge can be made easier by the design of a building, as the potential for future reuse, remanufacturing, and recycling of building materials, is predicated on this stage of the building process (1.1).

1.3 The Faroe Islands and its Building Sector

The information in this chapter is based upon the preliminary research report "A Development Pathway Towards Better Material Efficiency in the Faroese Building Sector", associated with the 3rd semester of M.Sc. in Sustainable Cities at Aalborg University.

The purpose of the research report was to find a development pathway for the integration of better material efficiency. In this process, geographical- and climate political circumstances where investigated and influential dynamics in the building sector, that can push or prohibit sustainable development, where identified (Jakobsen, 2022).

1.3.1 Geographical- and Climate Political Circumstances

The Faroe Islands is a small country located in the north Atlantic Sea, between England, Island, and Norway. Due to a lack of local resources, the country is heavily reliant on import, thus also making it reliant on international markets as well as receptable to the effects of global trends. Governmentally, the country is formally under Danish rule, but has extensive self-governance, administrated by Landstýrið (the Faroese Parliament) and its ministries. As such the Faroe Islands is not obligated by Danish building regulations, nor climate commitments. Neither is the country a member of the EU. However, the Faroe Islands signed the Paris-Agreement in 2016 and is a member of the Nordic co-operation[3], which both do require the country to mitigate climate change and support sustainable development. Of which, the Nordic co-operation's Action Plan targets the climate- and environmental impact of consumption, requiring member countries to promote resource efficiency and transition towards a circular and bio-based economy (Jakobsen, 2022). Moreover, applying circular economic strategies for reducing the consumption of building materials, especially cement, aluminium, steel, and plastic, and prolonging buildings life cycle can significantly contribute to the goals set by the Paris-Agreement (Woolven, 2021).

Currently, the Faroe Islands is staggering behind in its commitments, with no climate strategy nor national policies that support climate mitigation. The country is currently solely focused on reducing energy consumption through technical solutions. This can be due to fact that emissions from the Faroe Islands are added to Denmark's total emissions, where it is only required that the consumption of fossil fuels, waste incineration, and F-gasses are measured and submitted. As such, a policy for improving material efficiency has no existing foundation wherefrom initiatives can be implemented, but rather needs to be introduced into the public procurement process for building projects as a new component. Nevertheless, some municipalities have introduced CSR (Corporate Social Responsibility) into their procurement process for

[3] The Nordic co-operation is a political organization which includes Denmark, Finland, Island, Norway, Sweden, Faroe Islands, Greenland and Åland

goods, evaluating by emissions from production to transport, so there exists an understanding of the concept behind improving material efficiency and the purpose of a life cycle perspective.

However, in more recent developments (Maj 6, 2022), a new architectural policy "Karmar um lív" (Framework around life), was released. The architectural policy presents a common ideal for the Faroese building sector, putting a big emphasis on sustainable development, stating that "Sustainability is to be a self-evident part of public building projects". Herein, the public building developers commit to adopting a holistic approach to public building projects, aiming for the highest possible economic efficiency, while requiring sensible consumption of resources and that an environmental assessment be conducted for every project. Herein, public building developers are responsible for creating the guidelines for sustainable construction, where public building projects are to serve as an example. Relying on expert assessments before any implementation and with this, catalogue data concerning, sustainability and functionality for every public building (Landsverk, 2022). Though, as this is a brand-new policy, a framework for implementation is in this time unspecified. But the ambition itself, is compatible with the circular economic philosophy (1.1).

Additionally, there is also a proposal for new national waste management legislation, aiming for a more circular waste sector (Løgtingið, 2022), specifically improving the reuse and recycling rate of industrial waste (Minstry of Environment, Industry and Trade, 2022). At the same time, Torshavn Municipality has delegated 7 million kroner towards establishing a material bank, for excess building materials from construction sites. But apart from the location of the material bank, further details about this project are currently unspecified (Dam, 2022).

1.3.2 Influential Dynamics in the Faroese Building Sector

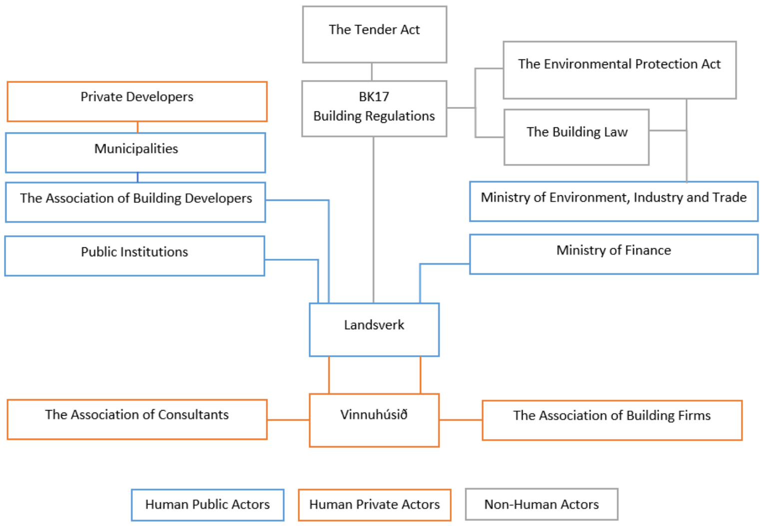

Figure 6: Actor Network Diagram of the Faroese Building Sector (Jakobsen, 2022)

In the Faroe Islands, the public building developers were collectively responsible for 64% of all building projects in 2020. Divided between municipalities and Landsverk, giving them much influence on the sectors practices. Landsverk is a public organization under the Ministry of Finance, responsible for all public infrastructure and public buildings, with administrative authority over the building regulations (BK17). As well as the chairman organization for the Association of Building Developers (Byggiharrasamtakið). Among Landsverk's responsibilities, is the acquisition- and administration of public building projects, thus giving Landsverk authority over the tender process. While municipalities associate with private building developers as well as citizens, and as such do not always have authority over the tender process for building projects. However, both are public institutions and as such are accountable to citizens and politicians, which have influence on their workings (Jakobsen, 2022).

Changes in practices, policies and regulation concerning the building sector are typically made based on negotiations between the Association of Building Developers, led by Landsverk, Association of Consultants (Ráðgevarafelagið) and Association of Building Firms (Føroyar Handverksmeistarafelag). The latter two both members of Vinnuhúsið – The House of Industry, a private organization that promotes Faroese business interests. Luckily, the public building developers have a willingness towards sustainable development and the local private actors have a willingness to provide the required services. However, there is an issue concerning the Faroese Tender Act.

In the Faroe Islands, the public procurement of buildings is legislated by the Tender Act. The Faroese Tender Act, introduced in 1984, is only intended for the "collection of bids concerning work and supply within the construction/building sector". It is a nine-paragraph legal document, that determines the procedure and rules for a tender process for building projects, allowing for both a public- and selective tender process, wherein the latter process the public building developer is obligated to accept the "lowest bid". Unless a subclause is included in the invitation to tender preventing this (Ministry of Envrionment, Industry and Trade, 1984). The issue is that due to a lack of life cycle perspective, building projects are assessed based on lowest acquisition cost, primarily associated with the monetary cost of labor and materials. Resulting in sustainability being disadvantageous in the bid for a building project, as it is known, true or not, to increase acquisition cost. However, the tender act itself does not specify such a circumstance, so there legally is nothing prohibiting the inclusion of requirements for a life cycle perspective nor sustainability (Ministry of Envrionment, Industry and Trade, 1984). The private actors within the Faroese building sector are very content with the current tender act, as it is believed that allowing for other determining factors is problematic and can lead to companies not being able to compete on the market (Jakobsen, 2022). The consensus among private actors in the building sector is such, that for them to introduce sustainability considerations into their business models, there must be a demand for them. Majorly from the public building developers, as they represent their biggest clients.

As for legislation, there is no requirement for sustainability beyond the regulations for a building's energy efficiency in the Faroese building regulations (BK17). Where the Environmental Protection Act does not deal with pollution or waste generation from the building sector. BK17 is an adaptation of the Danish building regulations (BR10) from 2010 and was first introduced in the Faroe Islands in 2017. Before this point there were no building regulations. In term of materials, the only concern is regarding indoor climate, with no regulations nor guidelines pertaining to the disposal of building material waste. This is the responsibility of the municipalities, resulting in two waste incineration plants in the Faroe Islands. They both receive mixed/unsorted building waste, which one plant measures in weight and the other in cubic meters, burning everything besides metals, which get sold for recycling. Fortunately, both waste incineration plants have ambitions relating to circular economy, and as they are owned by municipalities, there is good opportunity for system synergy between the building sector and the city's waste management system, optimizing the potential for reuse and recycling of building materials. However, currently the circumstances are not so that a secondary resource market can be economically viable enough to support itself (1.2) (Jakobsen, 2022).

1.3.3 The Development Pathway

Based on the findings of the preliminary research report, the most optimal pathway for integrating better material efficiency into the Faroese building sector (figure 7), is through a public procurement policy with a life cycle perspective.

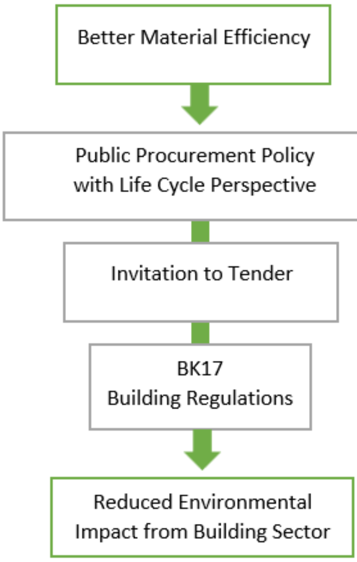

Figure 7: Development Pathway for the Integration of Better Material Efficiency into the Faroese Building Sector (own design) (Jakobsen, 2022)

Public procurement policies are seen as a crucial tool for a sustainable transition, as they can be designed to endorse specific goods and services, thus influencing sector practices. Here, the public procurement policy should set requirements for building material efficiency, which the design- and planning of a building would then have to comply with. For this to be effective, the requirements must have verifiable criteria for the assessment of material efficiency, demanding a greater degree of communication between actors as well as documentation. Furthermore, as the public building developers are financed by taxpayers' money, the public procurement policy must also be economically efficient. Introducing a monetary criteria into the assessment of material efficiency (Jakobsen, 2022).

A benefit of this development pathway is that it allows for experimentation before implementation. Meaning that a public procurement policy allows for modification, more easily than laws and regulations. Moreover, as the demand for sustainability rises, it's likely that private sector investments into sustainability services will increase, developing and improving their capabilities over time, thereby also increasing efficiency (Jakobsen, 2022).

2.0 Research Question

The building sector contains a significant potential for mitigating global emissions by optimizing material efficiency (1.2). Where the circular economic model presents a systemic framework which addresses inefficient consumption by managing material flows (1.1). For which there are five strategies. But as a secondary resource market with economic viability is currently not viable in the Faroe Islands (1.3.2), this thesis will focus on the circular principles of narrowing and slowing material flows (1.1) for the purpose of optimizing material efficiency in public building projects. These strategies should be integrated into the tender process (1.3.2), being the public procurement process for building projects. But for this to be effective, a life cycle perspective must be adopted, and verifiable criteria be defined (1.3.3).

Though, the current situation for the Faroese building sector can be classified as business as usual, recent developments show a willingness for sustainability and a drive for action. Where both Landsverk and municipalities are pushing the transition towards a more sustainable building sector. However, as the tender process is different for the public building developers (1.3.2), with different degree of influence, and due to the circumstances surrounding the writing of this thesis, the focus will be on Landsverk's tender process.

Leading to the following research question and sub-questions:

How can Landsverk optimize the material efficiency of public building projects, by integrating the circular economic principles of narrowing and slowing into their tender process?

- How can life cycle based decision-making be integrated into the assessment of building projects?

- How can the circular strategies of narrowing and slowing be operationalized to the building sector and what is the future perspective for building materials?

- What is Landsverk's current tender process and how can requirements for material efficiency and life cycle based decision-making be integrated?

3.0 Methods

This chapter elaborates on the methods used in this thesis for collection data. The data is qualitative, collected with the methods semi-structured expert interview, participant observation, document analysis and literature review.

3.1 Semi-Structured Expert Interview

The semi-structured interview method is a qualitative approach to collecting data. It much resembles an organized conversation with an informant, who has information concerning a particular field of study, providing the researcher with a better understanding of a given subject or circumstance.
Though the method is structured, it is also both flexible and versatile, as it requires open-ended interview questions to be prepared beforehand, while also allowing for the possibility for improvised follow-up questions, if necessary. This allows the flow of the interview to be dependent on the informant's responses, which in turn presents the possibility for more in-depth knowledge to be obtained, which was not sought after by the prepared questions. Being the reason for the utilization of this interview method. However, the researcher should be aware of not collecting unnecessary and extraneous information.

When utilizing the semi-structured interview method, the researcher should be suited with a neutral perspective, avoiding pre-assumptions that can color the overall outcome of the interview data. Additionally, should the researcher be aware of individual informant biases, that can influence their perspective of a given situation and therefore also the answer to a given question (Magaldi & Berler, 2020).

Semi-structured interviews have been conducted with the following experts:

- Palli Petersen, Civil Engineer, "Verkætlanardeildin", Landsverk
- Bárður Dam í Baianstovu, Architect, "Verkætlanardeildin", Landsverk

The informants are in the same organization but have different professinal backgrounds and work with different aspects of the tender process. The interview guides are similar for both informants, but while conducting the interviews, some questions where either left out or reformulated due to previously learned knowledge or the informants role in the tender process.
The Interview guides are included as appendix.
The interviews were recorded and conducted in the Faroese language.

3.2 Participant Observation

During the writing of this thesis, the researcher had an office space at Landsverk (1.3.2), resulting in socialization with personnel, access to project- and policy documents, as well as the possibility to play the role of a fly on the wall. Leading to the use of the method participant observation.

Participatory observation is about collecting data by objectively observing and participating in natural unfolding events. Here, gathering knowledge through casual conversations with actors within the organization plays a big part, where it is important that the researcher has an emphasis on listening and following the lead of the informants (Musante & DeWalt, 2010). In this case, the goal was getting insight into Landsverk's narrative and circumstances.

During this time, the researcher attended two conferences; "Karmar um lív" (Framework around life), which introduced the new architectural policy and "Fígging av íløgum í Føroyska undirstøðukervið" (Financing investments in Faroese Infrastructure). As well as one internal orientation meeting concerning the planning and construction of the building Glasir, which among other things experienced design errors, heavy delays, and legal strife between actors. Additionally, the researcher sought out- and had informal conversations with Landsverk personnel.

3.2.1 Informal Conversations with Landsverk Personnel

Bogi Vinther, Head of Building Maintenance, "Verkætlanardeildin", Landsverk

- The researcher had an informal conversation with Bogi Vinther about practices and procedures associated with Landsverk's tender process. Concerning general circumstances for the maintenance of buildings. Referenced as (Vinther, 3.2.1).

Ólavur J. Hansen, Construction- and tender Lawyer, "Skipan og Menningardeildin", Landsverk

- The researcher had an informal conversation with Ólavur J. Hansen about the legislation surrounding the tender process and the current circumstances for including requirements for sustainability into the process. Referenced as (Hansen, 3.2.1).

Róaldur Jákupsson, Head of Finance, "Fíggjardeildin", Landsverk

- The researcher had an informal conversation with Róaldur Jákupsson about the availability of finance for maintenance and the interest in a long-term investment perspective for building projects. Referenced as (Jákupsson, 3.2.1).

Sigurd Lamhauge, Managing Director, Landsverk

- The researcher had an informal conversation with Sigurd Lamhauge about the influence of- and collaboration with authorities and other external actors. Referenced as (Lamhauge, 3.2.1)

3.3 Document Analysis

Document analysis has been conducted during the writing of this thesis, introducing different principles, concepts, and strategies concerning the building sectors transition towards sustainability. This includes documents published by the Ellen MacArthur Foundation, BUILD – the Danish Building Research Institute, the European Commission, and the Faroese Government. As well as other more independent sources. Documents from these organizations have been selected as they are very credible and the documents themselves representative, providing valuable insight into circumstances surrounding the field of study. Where documents from the Ellen MacArthur Foundation have defined the understanding of circular economy. BUILD has been relied upon for scientific research concerning circular design- and construction. The European Commission for their circular initiatives and strategies, which present developments that can influence the European market. And Faroese governmental policies, especially the Faroese Tender Act, as it presents the legal framework for the public tender process. As well as Landsverk's "Verkætlanar Handbók", which specifies all stages and procedures of Landsverk's tender process.

3.4 Literature Review

The method literature review refers to the gathering and review of existing knowledge about the field of study. The gathered information should not simply be reproduced, but rather both analyzed and synthesized in a critical mindset (Bryman, 2012). This method has been implemented throughout the thesis, contributing significantly. The knowledge primarily consisting of academic articles and scientific reports, mainly concerning sustainable development within the building sector, including circular construction and life cycle assessment.

Also, a significant part of the background chapter and overall understanding of the Faroese building sector is from the preliminary research report "A Development Pathway Towards Better Material Efficiency in the Faroese Building Sector", written by the author of this thesis in the 3rd semester of M.Sc. in Sustainable Cities at Aalborg University.

4.0 Research Design

This chapter illustrates the thesis research approach. It follows a deductive approach, starting with the background chapter that narrows the field of study and forms the research question and sub-questions. By answering the sub-questions and discussing the collective findings, a conclusion is reached, which provides an answer to the research question itself.

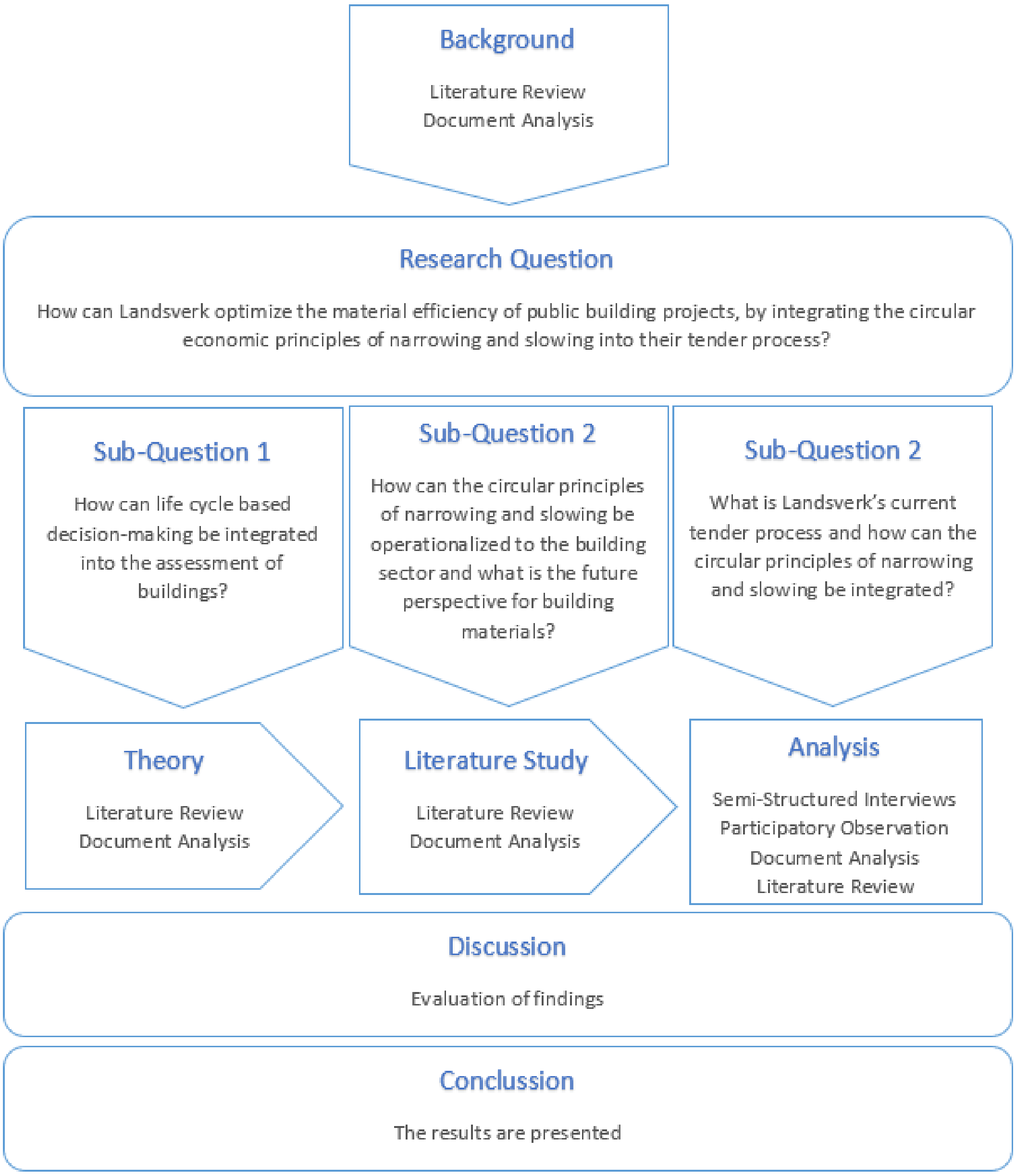

Figure 8: Research Design (own design)

5.0 Theory

This chapter introduces the theoretical framework for life cycle based decision-making and proposes a decision-making framework for the assessment of public building projects in the Faroe Islands.

5.1 Life Cycle Based Decision-Making

Due to the purpose of this thesis and the area of implementation (2.0), there is an environmental aspect, concerning the reduction of embodied emissions in buildings (1.2), as well as an economic aspect, concerning the requirement of cost-efficiency (1.3.3). Where both aspects stand to gain from a life cycle perspective.

Life cycle based decision-making is considered vital for the transition towards sustainability and is increasing in popularity. Specially in Europe, as the European Union (EU) has a habit of integrating requirements for life cycle assessment in their policies (Sala, et al., 2021), with the goal of supporting an economy that is focused on resource efficiency and environmentally friendly materials (Grzyl & Siemaszko, 2018). However, having a life cycle perspective is not just crucial in efforts to reduce the environmental impact of a product, service or in this case a building (Arler, et al., 2015), but is also very beneficial in the assessment of economic investments (Estevan & Schaefer, 2017). This has resulted in life cycle assessment methods becoming well-recognized and standardized (Arler, et al., 2015). The most prominent standards for assessing the environmental performance of buildings being ISO 14040/14044 and EN 15978, the latter being the most commonly used in Europe (Rock, et al., 2020). Where the most prominent standards for assessing economic performance are the European standard EN 16627 and the international standard ISO 15686 (Larsen, et al., 2022).

Research utilizing LCA and LCC shows that the basis for making long-term investment decisions is greatly improved. Where lowering building quality in the effort to lower initial construction costs, results in higher operation costs, whereas increasing the building quality lowers operational cost and reduces emissions. Which does not necessarily require a much higher acquisition cost to increases the property value (Grzyl & Siemaszko, 2018). However, research also shows there currently is inconsistency in how life cycle assessments are conducted (Rasmussen, et al., 2018), due to the existence of many different providers of data reflecting a various range of sources of life cycle inventory (LCI), that don’t necessarily work with the same principles and assumptions. So, even with similar assessment scopes, results have shown to be significantly dependent on the practitioner’s data sources and methodological choices as well as idiosyncrasies. There are also aspects of influence such as the location of a building, which determents the building requirements, climatic circumstances, and social norms. Choice of heating and cooling systems, as well as energy- water consumption patterns (Rock, et al., 2020). Furthermore, life cycle assessments also present challenges concerning the availability of data, where the lack of a harmonized standards for providing life cycle data from manufacturers can make assessments incomparable and increases uncertainty (Estevan & Schaefer, 2017). Despite this, life cycle assessments remain valuable tools for evaluating the environmental- and economic performance of buildings and for creating public policies for life cycle performance of buildings (Rock, et al., 2020). As well as supporting the building sectors transition to a circular economy (Larsen, et al., 2022). As such, there is a call for harmonizing methods for life cycle assessment within both the EU (Schreiber, et al., 2021) and the scientific community, where the previously mentioned standards are seen as a viable option for this purpose. Also, an increasing number of building material manufacturers are publishing life cycle data for their products, in accordance with the formats of these two standards (Rock, et al., 2020), increasing their availability and reliability of data.

Typically, LCA and LCC are utilized independently of each other, but due to similarities between the two assessment methods, their collective integration is not uncommon (Meynerts, et al., 2017). However, there also exists a third dimension with influence over the decision-making process, being the functional and technical performance (Pecas, et al., 2012).

5.1.1 Functional- and Technical Performance

The LCA and LCC are influenced by the circumstances surrounding the functional- and technical performance of a building. The functional performance is determined by the necessity of the building, being it office, institutional or residential. It is the use-specific purpose of the building users which the design of the building is based upon. While the technical performance, being influence by the functional performance, concerns the structural and physical characteristics of the building, as well as the technical installations. Such as requirements for insulation, fire resistance, etc. (Lutzkendorf, et al., 2005). Where, in the Faroese context, the requirements for technical performance are legislated by the building regulations (BK17) (1.3.2).

5.2 Decision-Making Framework

The integration of a life cycle perspective into a decision-making framework is motivated by the aim of optimizing material efficiency in the Faroese building sector, in a cost-efficient manner. Here, the framework for integration is built upon the concept of eco-efficiency, where the scope of the assessments are defined by the aim.

As illustrated by figure 9, this framework is categorized as the first step, from business as usual, in the process of transitioning the built environment to having a net positive impact, where eco-efficiency is about gradually reducing the negative impact from buildings (Sustainia, 2012).

This requires re-evaluating the way buildings are perceived and a willingness to adopt new solutions. Also, it is important to discard the belief that sustainably is an expensive endeavor, as this typically is not true, when assessing a building with a life cycle perspective. Where the ability to influence a building project is most optimal pre-construction, whereafter this ability decreases over time, while the cost of changing aspects increases (Sustainia, 2012).

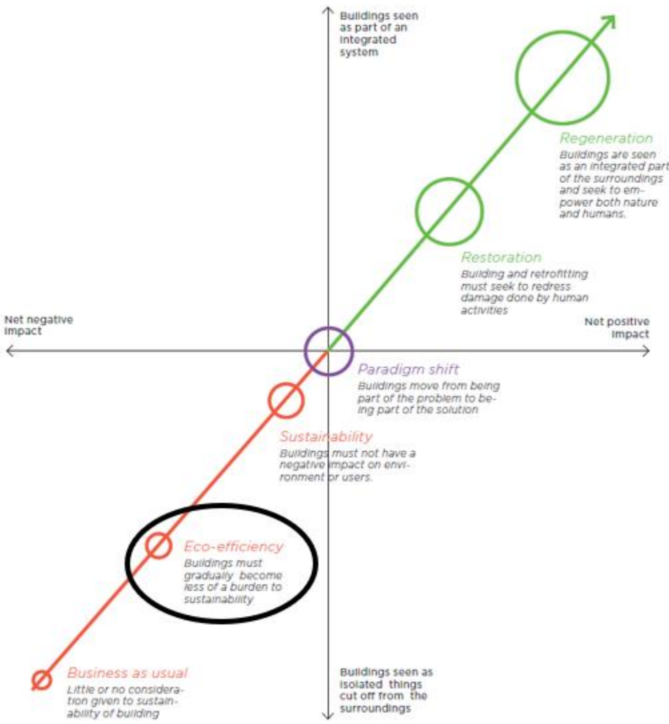

Figure 9: Towards net positive impact buildings (Sustainia, 2012)

5.2.1 Eco-Efficiency

The concept of eco-efficiency was published by The World Business Council for Sustainable Development (WBCSD) in 1992 and is now typically associated with global business strategies for sustainable development. The WBCSD defines eco-efficiency as “being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth’s estimated carrying capacity” (Ehrenfeld, 2005). Meaning its function is to maximize cost-efficiency while minimizing material consumption and environmental impacts (Pecas, et al., 2019). Including the economic and ecological (environmental) performance aspect of sustainability in a life cycle perspective but excluding the social aspect (Ehrenfeld, 2005). It is a concept of doing more with less, improving products and services while using less resources, generating less waste and creating less pollution (Cucek, et al., 2015). A philosophy compatible with the circular economic model (1.1).

Even though eco-efficiency is commonly known as a business strategy, it can also be used as an indicator for performance (Cucek, et al., 2015). Where the economic and ecological profiles are calculated and together constitute the eco-efficiency profile of a product or service (Pecas, et al., 2019). But for the eco-efficiency profile to be of use, the scope of the economic and ecological profiles must be defined and coupled with some form of measurement tool (Ehrenfeld, 2005). However, eco-efficiency is a concept which lacks study and has no commonly agreed upon definition nor universal framework for measurement (Pecas, et al., 2019). Though, fundamentally, it is a ratio of data concerning the efficiency of the two performance indicators/profiles (Ehrenfeld, 2005), that collectively support decision-making regarding design alternatives (Pecas, et al., 2019). With the goal of "increasing product or service value, optimizing the usage of resources, and reducing the environmental impacts" (Cucek, et al., 2015).

The concept of eco-efficiency as a decision-making framework for the design of a building is fitting with the purpose of this thesis. As the thesis has a circular philosophy, focused on optimizing material efficiency in terms of embodied emissions (1.2) and requires an economic perspective, as it pertains to public procurement (1.3.3). Thus, neither having a social aspect. Furthermore, as the current circumstance in the Faroese building sector is business as usual (1.3), integrating eco-efficiency measures is an appropriate first step in a transition towards sustainability. Therefore, the term eco-efficiency will be used to define the decision-making framework for assessing the material- and cost-efficiency of building projects with a life cycle perspective, where the parameters for eco-efficiency goals have been redefined to reflect this (table 2).

Traditional Definition	Thesis Definiton
Increasing product or service value	Increasing cost-efficiency of building
Optimizing the usage of resources	Optimizing building material efficiency
Reducing environmental impacts	Reducing embodied emissions

Table 2: Eco-Efficiency Goals Redefined

As eco-efficiency fundamentally is a ratio between ecological and economic factors in a life cycle perspective, and the product in question is a building, the life cycle assessment methods "Life Cycle Assessment" (LCA) and "Life Cycle Costing" (LCC) should be utilized as assessment tools.
The LCA is a method of assessment that quantifies resource use and environmental impacts (Statens

Byggeforskningsinstitut, 2019), assessing the individual activities in a life cycle, that collectively produce the product or service being designed (Arler, et al., 2015). As the LCA does not include economic considerations (Estevan & Schaefer, 2017), the inclusion of LCC is necessary in regard to the requirement for cost-efficiency (1.3.3). With the goal of securing better and more cost-efficient buildings, the LCC can include the entire life cycle of a building, showing the entire life cycle cost or of its individual components, which allows for comparing the cost-efficiency of alternative building design choices, such as choice of materials (Haugbølle, et al., 2017). As such, these are useful tools for a public procurement process to determine the most eco-efficient solutions (Grzyl & Siemaszko, 2018).

Thus, the building material efficiency and embodied emissions should be measured using LCA and will constitute the ecological profile, while the cost-efficiency should be measured using LCC and will constitute the economic profile. Collectively creating the eco-efficiency profile (figure 10).

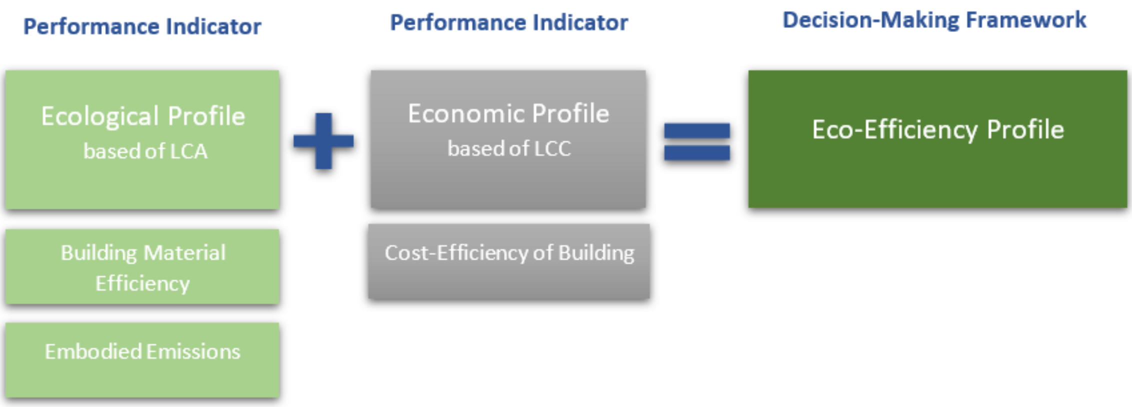

Figure 10: Eco-Efficiency Framework for Building Projects (own design)

The term sustainability is defined as a combination of economic, environmental, and social considerations. Therefore, as eco-efficiency is a balance between environmental and economical sustainability, excluding the social aspect, it cannot be classified as "sustainable design". Though, still being considered a sustainable innovation.

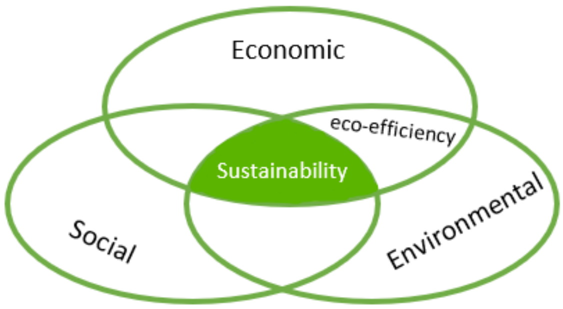

Figure 11: Dimensions of Sustainability (Remmen, et al., 2007) (own design)

5.2.2 Scope of Decision-Making Framework

The scope of the decision-making framework is what defines the measuring parameters for the life cycle assessment methods LCA and LCC. However, LCA and LCC assess different aspects of a building project and thus have different scopes. Though both have a 50-year assessment period.

Scope of Ecological Performance

Since research shows that the results of an LCA is significantly influenced by the practitioner's data provider and assumptions (Rock, et al., 2020), there most must be a common understanding of what is being measured. Therefore, the LCA must be conducted in accordance with the European standard EN 15978 and, as is most common, include the life cycle stages A1-A3, B4, C3 and C4 (Rasmussen, et al., 2022), as illustrated by table 3 below.

Materials			Construction		Operation							End of life			
Raw Materials	Transport to Manufacturers	Manufacturing	Transport to construction site	Construction of building	Use	Maintenance	Repairs	Replacements	Refurbishing	Energy Consumption	Water Consumption	Demolition/deconstruction	Transport to disposal	Waste Management	Landfill
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4

Table 3: Scope of LCA (EN 15978) (own design)

However, the focus on integrating eco-efficiency goals (table 2) into the tender process, influences the scope. The modules A4 and C2 are exclude, as suppliers are unspecified at this stage of a tender process (Statens Byggeforskningsinstitut, 2019). Also, the modules A5, B1, B2, B3, B5, B7, C1 have been excluded from the life cycle scope, as they all present uncertainty scenarios, such as for example climatic factors, maintenance practices, and user behavior. Luckily, research shows that they overall have a relatively little impact (Rasmussen & Birgisdóttir, 2015). Though, maintenance- and repair practices can prolong the buildings life cycle.

According to the EN 15978 standard, LCA assesses based on nine impact indicators (figure 12) (Statens Byggeforskningsinstitut, 2019).

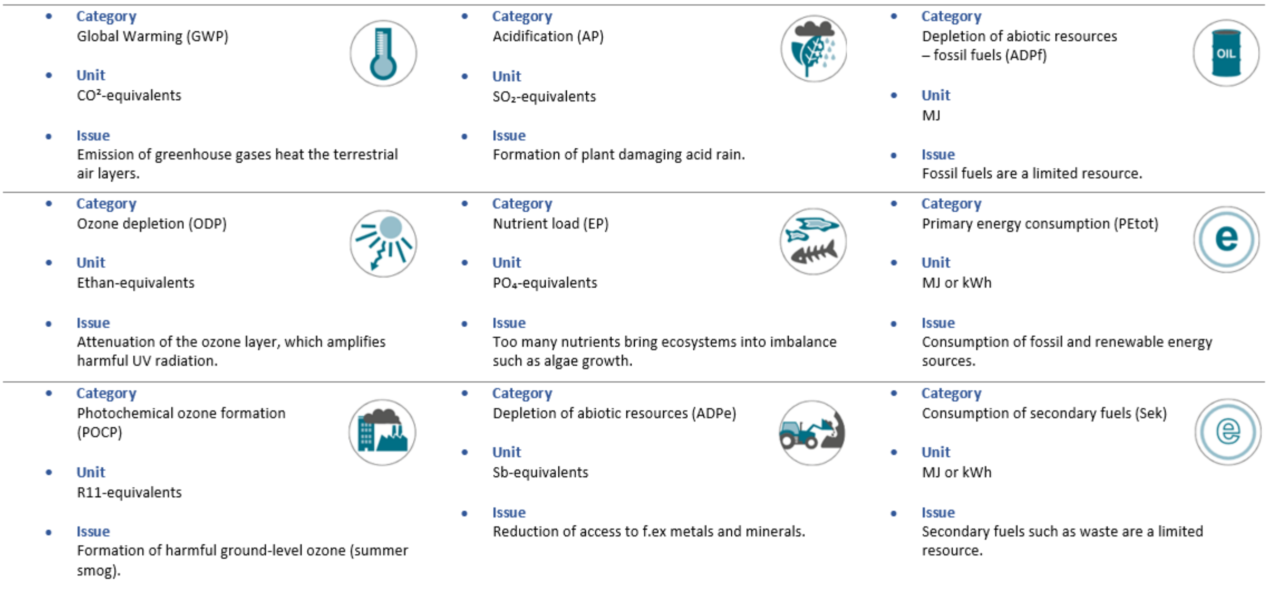

Figure 12: LCA Impact Indicators (Birgisdóttir & Rasmussen, 2015).

Furthermore, all data must be sourced from Ökobaudat.

Ökobaudat - Sustainable Construction Information Portal is a database that collects- and provides LCA data for buildings. Ökobaudat sets requirements for data providers, such as manufacturers of building materials, and subjects the data to strict quality control and screening for conformity before approvel, in accordance with the newest version of the European standard for environmental product declaration for sustainable construction works, EN 15804 (EPD standard) (Ökobaudat, 2022). Which seems fitting, as the Faroese building sector imports the bulk of its materials from European countries. Hereof, over the past five years, mainly from Denmark, Norway, Germany, and Sweden (Joensen, 2022). Ökobaudat provides two types of performance data for the life cycle assessment of buildings; generic data and industry- or product specific environmental declarations (EPD's). Generic data is typically used in the design of a building, pre-construction, when no specific suppliers have been chosen. As such, generic data is primarily meant for guidance, before any final decisions are made (Jørgensen, et al., 2020). Whereas EPD's provide more precise data, where product specific EPD's are most optimal. However, these are currently less available (Birgisdóttir, 2021). Though, it is worth noting that the use of generic data can affect the assessment in both an optimistic and pessimistic manner (Kanafani, et al., 2021) (Rasmussen, et al., 2022).

Scope of Economic Performance

The reliability of data also presents an issue for the mainstream use of LCC, as the lack of a harmonized standard for providing life cycle data from manufacturers can make it incomparable and increases uncertainty (Estevan & Schaefer, 2017). Therefore, the LCC must be conducted in accordance with the European standard EN 16627:2015, which is applicable for new buildings and gives the means for reporting and communicating the results of the assessment. The LCC is applicable for many purposes, but here the LCC should be used for budgeting, estimating both acquisition- and future operational costs (ILNAS, 2015), as its purpose is pre-construction decision-making. Providing an assessment of different building project solutions. Including the life cycle stages A1-A3, representing the cost of materials, and B2, B4, B6, as well as C3 and C4, as illustrated by table 4 below.

Materials			Construction		Operation							End of life			
Raw Materials	Transport to Manufacturers	Manufacturing	Transport to construction site	Construction of building	Use	Maintenance	Repairs	Replacements	Refurbishing	Energy Consumption	Water Consumption	Demolition/deconstruction	Transport to disposal	Waste Management	Landfill
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4

Table 4: Scope of LCC (En 16627) (own design)

The LCC calculates the cash flows over the life cycle of buildings (ILNAS, 2015), meaning that the impact indicator for LCC is monetary units, for example, Danish kroners. Expressed in cost terms and thus requires technical and cost data for products and components, as well as service life data such as inspection frequency, replacement rate, and maintenance.

Currently, technical data related to aspects of economic performance are included under the provision of the forementioned European standard for environmental product declaration for sustainable construction works, EN 15804, to form part of the EPD (ILNAS, 2015).

6.0 Literature Study

The purpose of eco-efficiency is to gradually make buildings less of a burden to sustainability, which this thesis aims to do through the circular economic principles of narrowing and slowing material flows (1.1).

However, as reducing the negative impact of the building sector is a significant part of reaching the goals in the Paris Agreement for net zero emissions (Rock, et al., 2020), more steps need to be taken. Eventually reaching regenerative buildings (figure 9), primarily constructed with bio-based materials, giving them the potential of being re-circulated within the biological system (1.1). Therefore, it would be optimal for public building projects to have a future perspective and already start considering this transition in the design of public buildings. Considerations which have become more relevant, due to recent developments for the Faroese building sector, as well as with the Nordic co-operation's ambition for a bio-based economy (1.3.1)

This chapter is therefore divided into two parts. The first part will examine existing literature pertaining to building design compatible with narrowing and slowing material flows. For the purpose of operationalizing eco-efficiency. The second chapter will research literature to pertain a future perspective concerning building materials, especially focusing on bio-based materials.

6.1 Building Design Principles for Narrowing and Slowing Material Flows

In the Faroe Islands, public building developers represent the majority of the demand for building projects (Jakobsen, 2022). Thus, their requirements and expectations are the driving force for the integration of circular practices (Teknologiske Institut, 2019). But as circular economy is a generic term, representing an overall ambition of decoupling economic growth from negative environmental impacts (1.1), there is a need to operationalize the circular principles of narrowing and slowing material flows. Where the building developer influence on functional performance and the choice of materials are used.

However, as collaboration is an essential part of a successful implementation of circular principles, as well as requires that established practices are changed (Brown, et al., 2019), the building developer must implement these circular principles in a systemic manner (Konietzko, et al., 2020). Thus, requiring a policy that favors, incentivizes, and facilitates them (Acharya, et al., 2018). Where a lack of policies has shown to be a barrier for the implementation of circular economic principles, where it is a key obstacle for the integration of requirements for material efficiency. Therefore, any organization seeking to adopt circular principles, must have a policy that clearly communicates the course of action for fulfilling its requirements (Galvão, et al., 2018).

Narrowing and slowing material flows in term of building design consists of minimizing material consumption and preferably using less impactful materials. As well as prolonging the buildings life cycle by emphasizing durability and maintenance, in an effort to reduce the negative impact from buildings (1.1). Though circular economic principles, such as narrowing and slowing material flows, are gaining popularity within the building sector, the development and implementation of these principles into building design is fragmented. Where a “lack of knowledge about the performance and related benefits of various building design” is identified as an issue. As such, there is currently no uniform method for operationalizing these principles. However, there exist various individually consolidated building design strategies that are representative for these two circular economic principles (Eberhardt, et al., 2022), which can be used to operationalize and thus define the course of action for reaching the eco-efficiency goals (table 2).

6.1.1 Design Strategy for Eco-Efficiency

A building consists of a multitude of components and materials, each with an individual life cycle and characteristics influencing the buildings life cycle. Additionally, buildings are typically long-lived, which intails that the requirements for functional performance may change over time, as users change, causing uncertainty about furture circumstances pertaining to the buildings materials. The functional performance and esthetic design choices of a building, herein choice of materials, thus have a significant influence on the building impact. So, in terms of narrowing and slowing material flows in accordance with the eco-efficiency goals (table 2), the following building design strategies are applicable; “Component and material optimization”, “Material selection/substitution”, and “Adaptability/flexibility” (figure 14) (Eberhardt, et al., 2022). The first two strategies being compatible with narrowing material flows, while the third is compatible with slowing material flows. Where “Cost-efficiency” has been added as a design strategy, to incorporate the economic performance aspect of the eco-efficiency goals (table 2), while also accounting for the life cycle perspective.

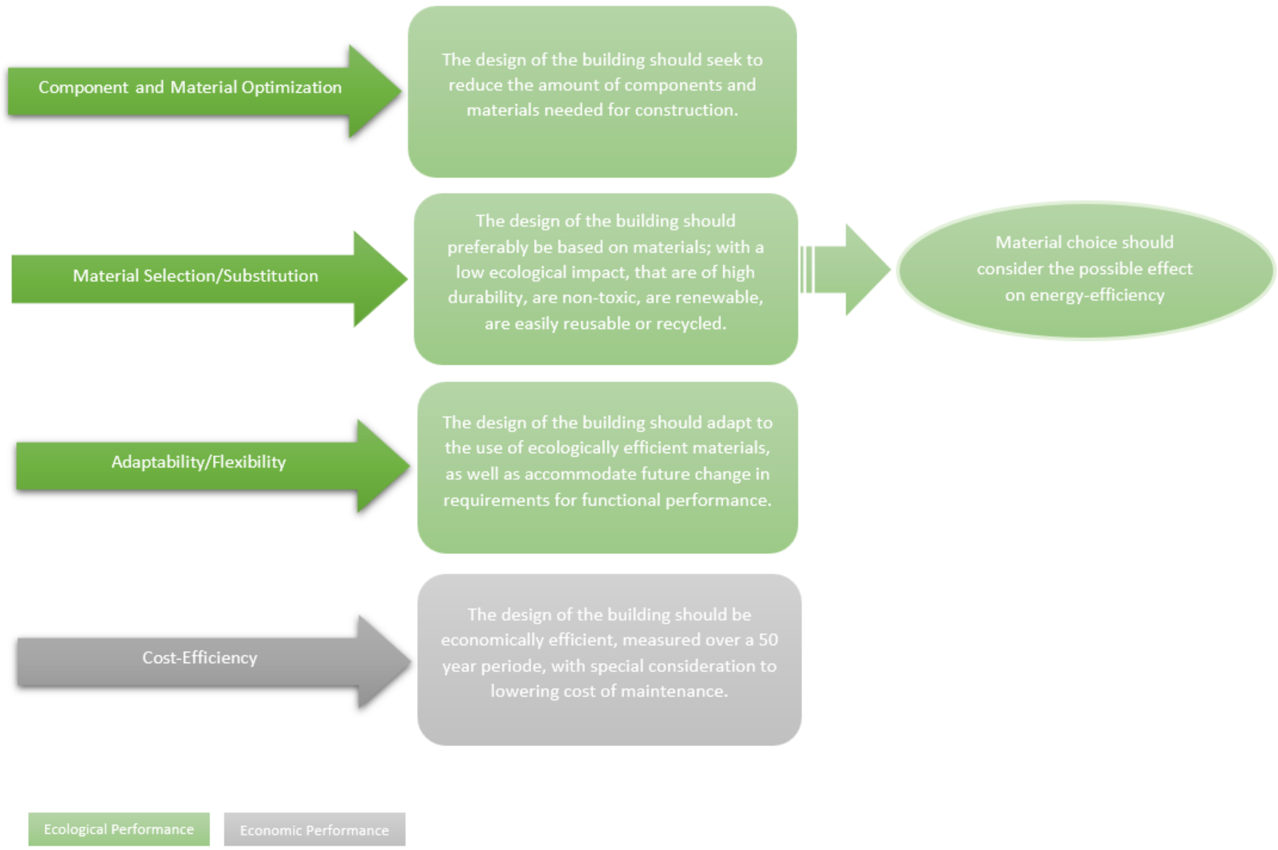

Figure 13: Building Design Strategies for Narrowing and Slowing Material Flows (own design)

Though the three design strategies addressing ecological performance are among the most utilized, there exists a gap between research and practice, as development is occurring independently. Research shows that the performance of the strategies lack scientific data, as the effect of the implemented strategies are seldom assessed. Therefore, using life cycle assessment in association with the design strategies is crucial to ensure the effectiveness of the strategies (Eberhardt, et al., 2022). Additionally, creating a baseline based on traditional building practices could contribute to the assessment. Giving the possibility to compare results and thus monitor and communicate effectiveness (Le Den, et al., 2022).

The consideration of material choice possible effect on energy-efficiency takes account for technical performance (5.1.1), among other things being responsible for the buildings energy-efficiency. Studies show that insulation initiatives typically are environmentally viable, as they offset the impact from material consumption by reducing energy consumption, measured over 50 years. Though the degree of viability depends on the type of insulation material and application. An example of considerations between material- and energy efficiency is the choice of windows. Today, 3-layer and 2-layer windows are most common in Scandinavia, where 3-layer windows are more energy-efficient. However, the environmental impact is also much higher, being approximately 8.000 – 10.000 $kgCO^2eq$ over the additional impact caused by the increased heat demand from 2-layer windows. Research shows that the most viable solution is a combination of the two, where 3-layer windows are installed on the north side of the building and 2-layer windows on the rest (Kanafani, et al., 2021).

6.1.2 Eco-Manager

The consideration of material choice possible effect on energy-efficiency (6.1.1) is just one reason for technical knowledge of building design, as well as an awareness of the local climate, laws and regulations concerning the building sector, is important for optimal implementation of sustainability initiatives. It has long been recognized that the integration of sustainability requires systems thinking, with a multidisciplinary lens of the interconnectivity of environmental, economic, social, and political issues. With which a system's ability of accepting positive change and its vulnerabilities can be identified, and unintended repercussions avoided (Williams, et al., 2017). As such, there must be an understanding of the dynamics between Landsverk and the network of both human and non-human actors with which the organization associates. Where the challenge is "balancing the relative autonomy and self-preserving tendencies of organizations, with recognizing their roles and responsibilities as part of wider systems" (Williams, et al., 2017).

For an organization wanting to integrate circular principles into their projects, their goals must be managed and communicated. As such, a crucial aspect to the successful implementation of circular practices within the building sector is the assignment of an, here termed eco-manager, responsible for the eco-efficiency of building projects. Working on a corporate level, defining environmental terms and procedures as well as communicating with external actors about set requirements (Galvão, et al., 2018). Because it is quite common that ambitions for sustainability fade as the building project takes shape. For the integration of eco-efficiency to succeed, intentions must be maintained throughout the process and be prioritized by all actors involved. Collectively identifying barriers and finding solutions for further development (Værdibyg, 2021).

6.2 Future Perspective: Building Materials

The design of a building should have a future perspective, seeking to reduce building waste and facilitate the waste management process, by using building materials that have high durability and easy reusability and recyclability (European Commission, 2020 c). For it is almost certain, that continued inefficient consumption of non-renewable materials will cause significant depletion of resources (Eberhardt, et al., 2022). Research by the Ellen MacArthur Foundation in collaboration with Material Economics concludes that while transitioning to renewable energy sources will address 55% of global emissions, it is equally crucial to address the remaining 45% stemming from resource consumption. Designing out waste and keeping materials in use can significantly reduce GHG emissions. Just applied to the steel, aluminum, cement, plastic, and the food industry, it has the potential of reducing global emissions by 9.3 billion tons CO^2e in 2050. Which prospectively compares to eliminating all emissions from transportation. However, it is projected that by 2050, the global demand for steel, cement, aluminum, and plastic will have doubled or quadrupled, increasing emissions to approximately 649 billion tons CO^2e by 2100. Exceeding the Paris Agreements 1.5 °C target by 420-580 billion tons (Ellen MacArthur Foundation, 2021).

Luckily, EU's plans for a transition to net-zero GHG emissions will bring profound change to the materials we use (Material Economics, 2021 a). In March of 2022 the European Commission presented a proposal package "to make sustainable products the norm in the EU". The proposal package is to the European Green Deal (European Commission, 2022), a strategy reliant on the circular economic framework that aims to decouple economic growth from resource use and reach net-zero emissions by 2050 (European Commission, 2019). The proposal package includes a revision of the construction products regulations with the purpose of ensuring that the design and manufacturing of building materials is "based on state of the art to make them more durable, repairable, recyclable, and easier to re-manufacture". Additionally, the proposal will enable information requirements, greatly assisting the harmonization of European Standards (European Commission, 2022), like the EN 15978 standard for assessing the environmental performance of buildings, increasing availability of EPD data and thus also the reliability.

Considering the EU's plans, the strategies used by both policymakers and businesses foresee that the reliance on bio-based materials will substantial increase (Material Economics, 2021 a)

6.3.1 Bio-Based Building Materials

Transitioning the built environment towards having a net positive impact, to a point where buildings are regenerative, building materials must fit into the biological system (1.1). Meaning that bio-based materials are the most viable option. Bio-based materials are a core element of circular economy (Ellen MacArthur Foundation, 2021). Bio-based materials refers to materials from biological organisms, being for example land-resources like trees, plants, flax or marine-resources like eelgrass and seaweed. Materials with the capacity to capture and store CO_2 during production, keeping it out of the atmosphere with great benefit to climate change mitigation (Rasmussen, et al., 2022). For, while conventional non-renewable building materials emit emissions throughout the materials stage (1.2) as well as generate waste and pollute the environment, bio-based materials sequester carbon (Ellen MacArthur Foundation, 2021) and are, of course, biodegradable (1.1). Which in an LCA perspective means that the materials stage (A1-A3) counts negative, and the end-of-life stage (C3-C4) counts positive, as here the carbon is released (5.2.2.1) (Rasmussen, et al., 2022).

Bio-based building materials have the potential to largely replace conventional materials such as bricks, concrete, steel, and mineral wool. Doing so would change buildings from being significant emitters of CO_2 to carbon storage depots, storing carbon throughout their life cycle and beyond, if materials are reused or recycled. In a Danish perspective, over-time replacement of conventional building materials to bio-based, is estimated to be able to save the atmosphere from 1,8 million tons CO_2/year by 2032. For comparison, the current consumption of concrete in Denmark is responsible for emitting 1,5 million tons CO_2/year. It is also worth noting, that concrete consumption would decrease in-line with the transition to bio-based building materials, reducing overall emissions even further. As decreased demand would decrease manufacturing. However, if the materials are imported, then this reduction in emissions would be contributed to the manufacturing country (Rasmussen, et al., 2022). This is due to the “production-based (territorial) accounting” in the Intergovernmental Panel on Climate Change (IPCC) guidelines, which state that the manufacturer holds the responsibility for emissions and therefore also the benefit of reductions (IPCC, 2006). As such, emissions from imported building materials are not included in a country’s estimation of total emissions. Which also is the case for the Faroe Islands (Umhvørvisstovan, 2021). Nevertheless, the replacement benefits remain and are globally beneficial.

Policy has already heavily influenced the use of biomass over the last two decades, overseeing an 150% increase in association with the production of bioenergy. However, using biomass as fuel does not represent its highest value. Rather, there is a need to steer the use of biomass towards material manufacturing. This is not only feasible, but also more cost-effective and has the potential to reduce global emissions by approximately 144 million tons CO_2 (Material Economics, 2021 a).

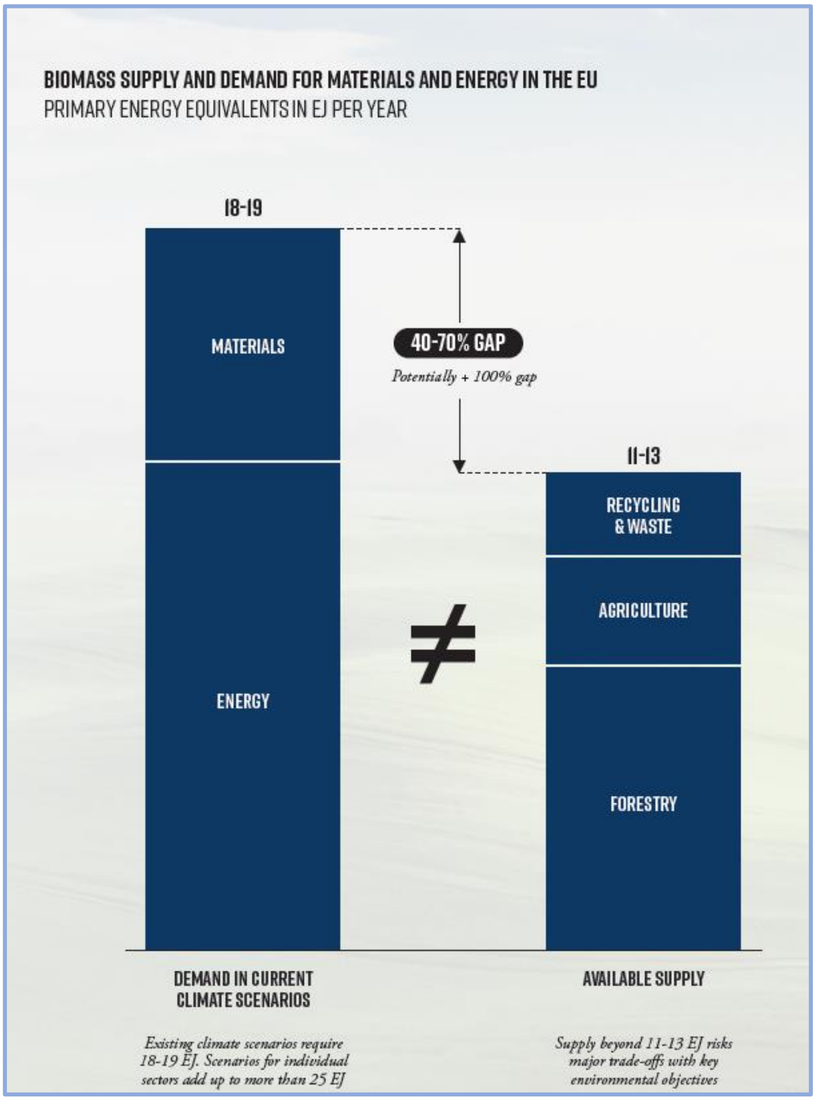

Figure 14: Supply of- and Demand for Biomass (Material Economics, 2021 a)

In step with the increased awareness of the climate crisis, priorities are shifting and the future use for biomass is expected to profoundly change, with demand increasing by 70-80%. Largely due to the multifunctionality of biomass, creating demand from feedstock and food production, energy production, biofuel for aviation and maritime vessels, and of course material production. However, research shows that future biomass use will exceed available supply with 40-70% by 2050 (figure 15). Meaning that ambitions for increased use, far exceed a realistic and sustainable increase in supply (Material Economics, 2021 a). For example, the demand for wood continues to increase. Which has caused concern among experts, who foresee that the supply will be unable to accommodate the sustainable transition of the building sector (Kristensen, 2022). Making reuse and recycling a crucial part of upscaled biomass use. For even though there is a "urgent need to priorities future biomass use", if not sustainably managed, the extraction- and manufacturing of bio-based materials can have a significant effect on natural systems (Material Economics, 2021 a). Furthermore, to ensure optimal utilization of bio-based building materials, there is currently a need for experience in terms of both manufacturing and construction. For, unlike wood, other bio-based building materials are not commonly known in the building sector. As such, new bio-based building materials and their use in the building sector will require documentation of properties and capabilities, until the necessary experience is gained. Which is an economically heavy endeavor (Rasmussen, et al., 2022).

7.0 Analysis

Since requirements for eco-efficiency are to be integrated into the Landsverk's tender process for building projects, it is important to understand the dynamics of the current system. Furthermore, the integration of eco-efficiency also represents a change in the market for private actors providing services within the building sector. This chapter introduces and analyses Landsverk's current tender process, pre-construction, and identifies and presents opportunities for integrating requirements for eco-efficiency as well as a transitional perspective.

7.1 Landsverk's Tender Process

Fortunately, Landsverk is determined to add requirements advocating for the consideration of sustainability (Baianstovu, 3.1), which presents a potential framework for the integration of requirements for eco-efficiency. Landsverk's system for procuring public building projects is divided into 12 step process, with 1-7 concerning the preparation of a building project and 8-12 concerning construction, oversight, and maintenance (Landsverk, 2021). Whereof the 6 stages illustrated in figure 16, are associated with the preparation process and define "pre-construction". Wherein the most influence is to be had.

Idea	This stage provides a general description of the reason- and expectations for the building project.
Building Catalogue	This stage provides a summary of the requirements for the building project, based upon the idea stage.
Tender for Consultant	This stage is where an external consultant is appointed through a tender process, wherein proposals for the building project are submitted by interested private actors.
Planning	At this stage the first concept for the building is produced. It includes architectural design, functional performance, general material choice, guiding principles for construction and technical installations. As well as an estimation of construction time and cost.
Building Project Proposal	At this stage final decisions are made in relation to the planning stage. Including a more specific estimation of construction time and cost. This is the last stage, before the project is handed-in to the authorities for approval.
Master Project	In this stage the project is finalized, including a final estimation of construction time and cost, and serves as the basis for the invitation to tender for building firms.

Figure 15: Design Stage for Public Building Project (own design) (Landsverk, 2021)

Landsverk's tender process is usually public, wherein applicants first must register for pre-approval to then be able to make a proposal for the building project, if approved. The purpose of pre-approval is to ensure that the applicants have the necessary resources, economic stability, and experience compatible with the building project requirements. The proposal itself typically includes an overall idea for design and a general estimation of construction time and total cost of building project. Typically, all the applicants partly get financial reimbursed for their proposals, but this amount is not near the total cost of preparing the proposal. Meaning that the applicants that do not get chosen, suffer financial loss. The proposals are evaluated by a committee, consisting of professionals from Landsverk and a user group, based upon 50% considerations of criteria such as functional performance, quality, etc. and 50% consideration of economic costs. However, criteria and consideration percentages vary between projects and often more heavily favor cost (Baianstovu, 3.1). Though not demanded by the authorities (Lamhauge, 3.2.1), Landsverk does include sustainability as a criteria in their tender process, but "it is very unspecified and clearly shows that we (Landsverk) don't fully understand the subject. What is missing, is that we (Landsverk) know how to specify what we demand in terms of sustainability in building projects" (Baianstovu, 3.1). As such, this aspect of the invitation to tender has a tendency to be under-prioritized by applicants (Baianstovu, 3.1) and has resulted in confusion and disputes over criteria being fulfilled (Hansen, 3.2.1).

After the most optimal idea from an applicant is found, the proposal for the building project is planned and finalized, continually vetted in terms of functional performance, choice of materials, maintenance, technical installations, etc. This proposal is then submitted to the authorities for approval and since finalized into a master-project, which functions as the basis for the invitation to tender for the interested building firms (Baianstovu, 3.1).

7.2 The Integration of Eco-Efficiency

"One of the first practical steps towards circular procurement is to consider strategically how it can be integrated into existing procurement practices and systems" (European Commission, 2017).
Well, the 50%-50% consideration criteria in the Tender for Consultant process presents the framework which allows design parameters for eco-efficiency (figure 14) to be integrated. By including the building design strategies for narrowing and slowing as parameters in the Building Catalogue, considerations for reducing embodied emissions and increasing cost-efficiency are a part of the building project from the start. Giving the greatest opportunity for reducing the buildings embodied emissions in the most cost-effective manner.

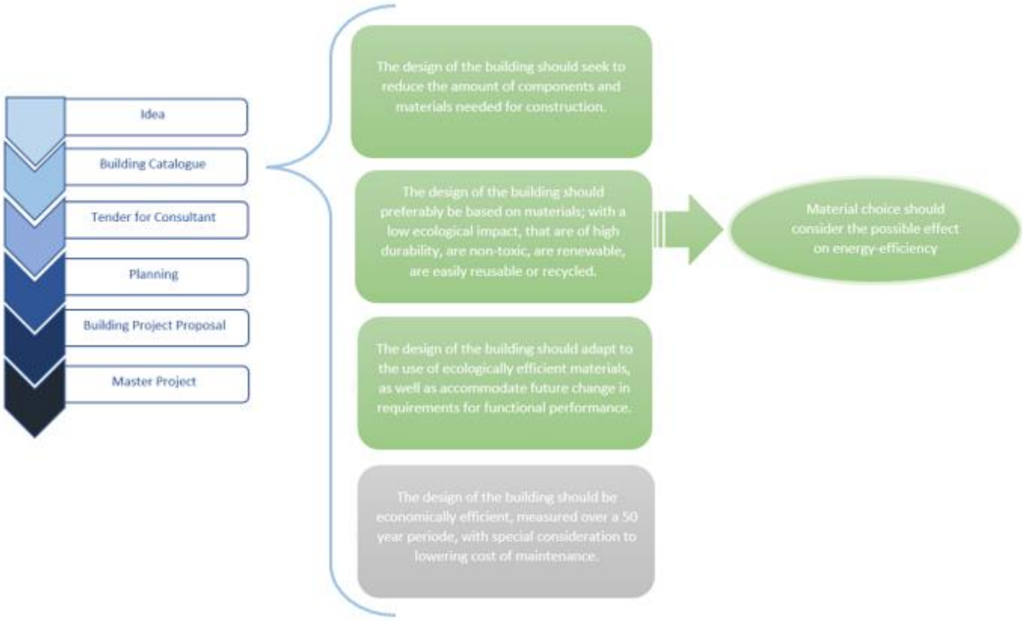

Figure 16: Integration of Eco-Efficiency Design Parameters into Design Stage (own design)

This not only provides Landsverk with concrete parameters which specify their demand for sustainability in building projects, but the parameters are also representative of Landsverk's ambitions in the new architectural policy (1.3.1), as it speaks to the policies goals of sensible consumption of resources and highest possible economic efficiency (Landsverk, 2022). Of course, consideration of cost-efficiency already exists, but not with a life cycle perspective (1.3.2), and not with considerations of maintenance cost (Vinther, 3.2.1). Which is what the new design parameters introduce. Currently, maintenance considerations are included in the evaluation of submitted proposal for building projects, but only in regard to quality, not cost. And not always (Vinther, 3.2.1). Evaluation of maintenance costs first occurs after one-year of use, when the responsibility for building maintenance passes to Landsverk (Vinther, 3.2.1).

The integration of eco-efficiency presents a challenge to the private actors providing services within the Faroese building sector. Because it requires them to re-evaluate their perception of building design and find new solutions (5.2). As reducing material consumption whilst also maintaining structural integrity and functional performance is not a simple endeavor (Eberhardt, et al., 2021). It requires knowledge of building material composition, specifications, availability, alternatives, and design implications (Dodd, et al., 2016). For this same reason it will be difficult for the committee to evaluate a building project proposals degree of eco-efficiency. So to ensure effectiveness and fair competition, quantified and comparable documentation is needed. This is where the assessment methods LCA and LCC come in.

7.2.1 The Addition of the Decision-Making Framework

With the assessment methods, LCA and LCC, the degree of eco-efficiency for each proposal can be assessed and the results illustratively presented, making it possible for the committee to both compare and argue for the best proposal. Again, this is representative for the ambition of the architectural policy, to make environmental assessments a self-evident part of every building project, and to catalogue sustainability data for public buildings (Landsverk, 2022). So, as eco-efficiency must be documented, the applicants in the Tender for Consultant process, must hand-in both an LCA and LCC report. The issue with assessing the life cycle of a building, is that it is data comprehensive, resource-intensive (Arler, et al., 2015) and optimally requires a specialist (Estevan & Schaefer, 2017) (Pecas, et al., 2012). Approximately taking 50-60 hours and costing around 58.000-66.000 DKK, depending on projects scope, data availability, and purpose (Butera, et al., 2021). As the Faroese building sector does not currently have any professionals with life cycle assessment competences, this aspect of the proposal will in the beginning have to be out-sourced and thus be an extra expenditure. However, the extra expenditure is not a deal-breaker, according to Landsverk, who consider it small in relation to the typical cost of a building project (Baianstovu, 3.1)(Lamhauge, 3.2.1)(Hansen, 3.2.1). For comparability, it is important that the applicants have the same assessment framework (5.1) and know what to request from their supplier of LCA and LCC documentation. Therefore, every applicant should hand-in documentation in accordance with the same assessment methodology and scope. As those specified in the Scope for the Decision-Making Framework (5.2.2).

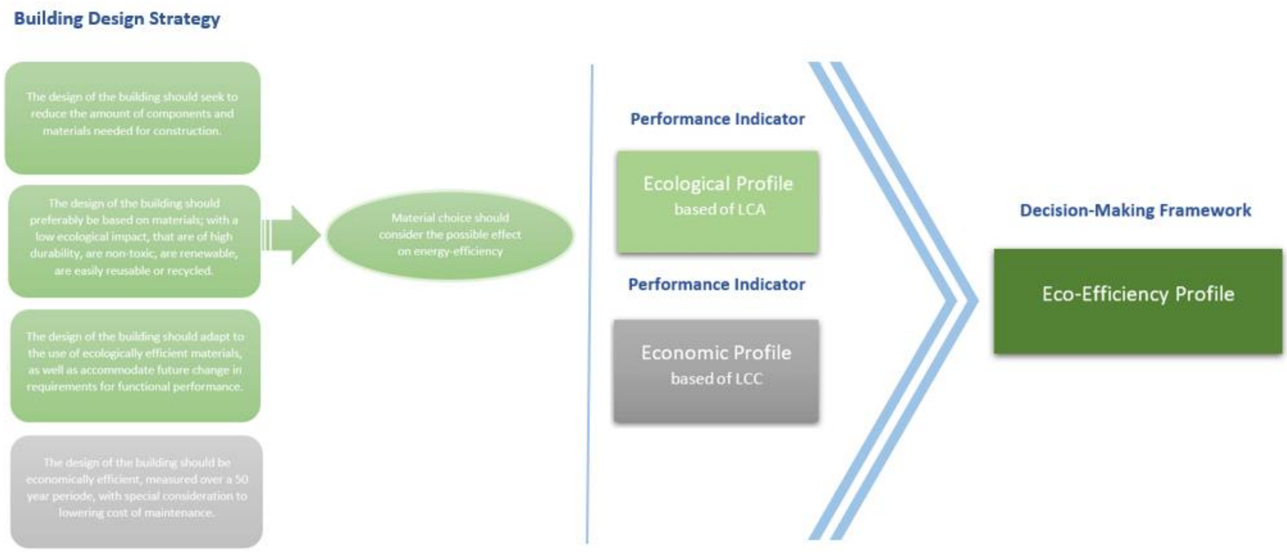

Figure 17: Framework for Eco-Efficiency (own design)

However, even though research shows that there are economic benefits from utilizing LCC (5.1), unfortunately, it is very common that public building developers are prohibited to include the buildings operation cost by a construction budget, that is too modest to allow for the inclusion of additional costs. In such cases, it is not in the interest of the suppliers to consider a long-term investment perspective in their proposals for a building project (Haugbølle, 2021). Also, communications between Landsverk and the authorities, who provide financing, is at times unproductive, where Landsverk has difficulty in convincing them of the importance of consistent maintenance (Landsverk, 2019). Currently, Landsverk maintenance budget provides 90-100 kroner pr. square meter, but an estimation of what maintenance is required suggests that 180-200 kroner pr. square meter is needed (Vinther, 3.2.1)(Jákupsson, 3.2.1). But hopefully, the life cycle perspective combined with the methods for assessing eco-efficiency can communicate the benefits of a long-term investment perspective. For public buildings should be perceived as long-term investments and worthy of quality, especially as they typically remain in the ownership of the public and service many generations of citizens.

Since the LCA and LCC assessments are conducted based of information in the Tender for Consultants process, and there most likely will be changes to the design and material list before the building project reaches the Master Project process (Vinther, 3.2.1)(Baianstovu, 3.1), it would be relevant for Landsverk to acquire or develop in-house competences that are capable of accounting for the changes and re-calibrating the LCA and LCC assessment.

7.2.2 A Gradual Transition

“The transition to a circular economy will require the application of systems thinking and new approaches to the way we design, operate and maintain built environment assets” (Acharya, et al., 2018). A re-evaluation of how buildings are perceived and the adoption of new solutions (5.2). Furthermore, the integration of circular design practices into the building sector can currently be considered a niche innovation (6.1), thus requiring acceptance from the system as a whole to be successful (Loorbach, et al., 2017). Such change can only succeed in collaboration with the private sector. For, the requirements and expectations from building developers create a market for architects/consultants and building firms to adhere to, where proposals most suited to the requirements and expectations win the public building projects (Teknologiske Institut, 2019). Which in-turn creates new requirements for manufacturers of building materials, as illustrated by figure 19 below.

Figure 18: The Chain of Demand (own design) (Haugbølle, 2021)

Fortunately, the introduction of the niche innovation (eco-efficiency) into the current system comes from a dominant organization within the Faroese building sector, Landsverk (1.3.2). Directly effecting the existing system, forcing a reactionary shift by putting pressure on the system to incorporate the innovation and making it advantages for actors to adjust. Nevertheless, it will take time before the elements of eco-efficiency become stabilized within the system, making it an integral part of the design of public building projects (Loorbach, et al., 2017). Time for the market to adjust to the new demand. Time to develop necessary knowledge and capabilities.

Therefore, the eco-manager (6.1.2) should work to assist the transition in collaboration with actors within the building sector. Firstly, the Association of Consultants and Association of Building Firms (1.3.2) should be informed about the new demand (eco-efficiency), as they represent the private sector interests. A good idea would be for the eco-manager to conduct a preliminary market consultation (PMC). As a PMC in association with the integration of eco-efficiency can help ensure a smooth tender- and construction process. The purpose of the PMC is to engage with suppliers to gather information about the capabilities on the market and price developments, thus informing tender-preperation and allowing for refinement of requirements to current possibilities. This is specially relevant in more complicated matters, when there may be a need to assess if the planned procurement is technically, financially or operationally feasible. Or if there is a sufficiant number of suppliers on the market to ensure effective competition (Campagno, 2018).

Additionally, changes do occur from when a building project proposal is approved to it is a Master Project and used as an invitation to tender for building firms. Each of the processes (figure 16) in the pre-construction tender stage is composed of 6 to 21 tasks (Landsverk, 2021), whereof some have influence on the integration of eco-efficiency. Therefore, to ensure more effective integration, an eco-manager should be appointed with the responsibility of representing eco-efficiency during the tender process, as well as communicating with external actors about the subject. In association with the processes, the eco-manager should have the following responsibilities (table 5):

Idea	The eco-manager should function as a consultant for the building users in their considerations for the building project, if they so wish.
Building Catalogue	The eco-manager is responsible for the integration of eco-efficiency into the Building Catalogue and evaluating the effect of eco-efficiency on the building project.
Tender for Consultant	The eco-manager is responsible for communication with applicants about eco-efficiency requirements and evaluating the degree of eco-efficiency of the submitted proposals.
Planning	The eco-manager is responsible for working with the hired consultant with matters relating to eco-efficiency of the building project.
Building Project Proposal	The eco-manager is responsible for collaborating over general recommendations for material choice with the consultant and interpreting the conditions for the building projects eco-efficiency.
Master Project	The eco-manager is responsible for examining the finalized building project for any changes with an effect on eco-efficiency.

Table 5: Responsibilities of Eco-Manager (own design) (Landsverk, 2021) (Sustainia, 2012)

8.0 Discussion

This chapter addresses the existing obstacles for the integration of eco-efficiency into Landsverk's tender process. Additionally, the chapter examines the possibility for further development of sustainability within the Faroese building sector.

8.1 Obstacles for the Integration of Eco-Efficiency

Even though circular economy is increasingly being identified as viable framework to address the challenges causing climate change and the unprecedented demand for natural resources, it is still not widespread within the building sector, though it is gaining traction (Acharya, et al., 2018). In part due to a lack of governmental policies (Galvão, et al., 2018). As such, the proposed approach for integrating eco-efficiency presented in this thesis, is not a tried-and-true approach. However, the life cycle based decision-making framework and the chosen building design strategies are individual verified. As well as representative of circular principles and the ambitions of the new architectural policy. Nevertheless, the system in which eco-efficiency is to be integrated, presents some obstacles.

8.1.1 Lacking Capabilities

Unfortunately, there is currently a lack of capabilities and understanding of sustainability within the Faroese building sector. Presenting an obstacle for the effective integration of eco-efficiency. Because, for Landsverk to effectively integrate eco-efficiency into their tender process, there must be someone responsible for managing the innovation, as the trend is, that such ambitions otherwise fade. Such is Landsverk's current situation, where a lack of necessary capabilities results in the requirements for sustainability being neglected.

As this is the situation for Landsverk, it would be wise to firstly conduct a PMC (Preliminary Market Consultation) focused on uncovering the existing capabilities on the market. For the worry is, that the local private actors also lack the necessary capabilities and thus a steadily increasing degree of eco-efficiency requirements will be unavoidable. Something to consider, since pushing the market beyond its capabilities has no benefits. Then rather it must be a gradual and collaborative process.

8.1.2 Documentation

To ensure effectiveness, fair competition and for communication purposes the ecological- and economic performance must be documented. Where the assessment methods LCA and LCC are recommended for their legitimacy and associated data benefits. However, this responsibility will likely have to be out-sourced.

Though applicants for public building project tenders receive some compensation for their proposal, it is only a fraction of the total cost for the applicant. So, for private actors, the requirement for documentation represents additional costs, which likely would not be fully reimbursed. Increasing the financial loss to the applicant if the proposal is not chosen. As such, the introduction of requirements for conducting LCA and LCC assessments, each costing approximately 58.000-66.000 kroner, will most likely not be met with open arms.

Additionally, it is very common that public building developers are prohibited to include the buildings operation cost by a too modest construction budget. Forgoing the life cycle perspective and the necessity of conducting an LCC. Thereby weakening the decision-making framework. The challenge here is to convince the authorities, that the budget for public building projects should not solely be based upon estimated acquisition cost, but also include the cost of ownership. This would particularly be of benefit for Landsverk, as they also have the responsibility of maintaining public buildings and are significantly challenged in doing so, by a lack of funding. Whereas the LCC presents the possibility to account for maintenance costs and thus the opportunity to reduce them.

Luckily, a digital variant of both LCA and LCC methods have been developed specifically for buildings by the Danish Building Research Institute (BUILD), called LCAbyg and LCCbyg (Danish Building Research Institute, 2022). Both in accordance with the European standards.
These digital variants present the possibility for actors within the Faroese building sector to conduct assessments inhouse. Likely, resulting in a feeling of ownership over projects (Dodd, et al., 2016). Of course, it is assumed that the user has technical knowledge of building design, as well as is aware of the local laws and regulations concerning construction (Jørgensen, et al., 2020). But such is the case for the Faroese building sector. Therefore, training inhouse practitioners' could prove to be a worthy initiative, as it could foster sustainability capabilities, like for example help architects with assessing the effect of their design- and material choices, steadily improving their understanding and capabilities.

Besides from the digital tools being user friendly, the developers, BUILD, have made user-manuals and technical documents that illustratively explain the tools different functions and include example constructions which, among other things, can be used as a starting point (Jørgensen, et al., 2020). There also exist dedicated YouTube channels with learning-tutorials, as well as there being offered webinars and Q&A sessions for practitioners (BUILD, 2022a). Moreover, there is a built-in notification function that alerts the user to data issues concerning a project, helping the user throughout the process (Jørgensen, et al., 2020). So overall, it should not be overly difficult for a professional with technical construction knowledge to become familiar with the digital assessment tools.

8.2 Further Development

"Today's global economy has developed interconnected, interdependent, and complex supply chains. Businesses increasingly source their materials and components from across the globe" (Ellen MacArthur Foundation, 2021) So, even though the Faroe Island is not a member of the EU, the fact that the country's building sector is reliant on import for its building materials, primarily supplied from European member countries, means that also is reliant on international markets as well as receptable to the effects of global trend developments. Developments which indicate a future increased use of bio-based building materials.

A way of integrating a higher use of bio-based building materials could be to steadily increase the percentage required by the invitation to tender. However, this must be done with caution, since demand is foreseen to become higher than sustainable supply allows. Making the re-circulation of materials, through reuse and recycling, an unavoidable necessity for a sustainable building sector.
Fortunately, it light of new developments, closing material flows may become more viable option in the near future.

Moreover, the fact that bio-based building materials can be manufactured with marine-resources like seaweed, presents a local commercial opportunity. For the Faroe Islands has an abundance of seaweed, where businesses already have started harvesting- and utilizing it for industrial- and commercial purposes. Thus, started developing the infrastructure and capabilities eventual needed.

9.0 Conclusion

This thesis presents a possible first step for the Faroese building sector in a gradual transition towards net positive impact buildings, based on the circular economic principles of narrowing and slowing material flows. Accompanied by a life cycle based decision-making framework, collectively designed to reduce embodied emissions in public building projects and increase cost-efficiency. Going from business as usual to eco-efficiency.

Overall, eco-efficiency is systemically simple to integrated, as Landsverk already is including requirements for sustainability in their tender process, creating the framework. However, eco-efficiency is a niche innovation, which will be introduced into the system by a dominant organization and thus has the potential to be disruptive and create reluctance, if not implemented correctly. And the findings throughout this report indicate that this is something that should be done gently.

Even though the circular economic principles of narrowing and slowing material flows are not yet a consolidated practice within the building sector, individual consolidated building design strategies which are compatible with the philosophy of these principles exist. The chosen building design strategies provide clearly communicated course of actions for public building project proposals to follow. Which is essential for a successful integration, and it is what Landsverk is currently lacking. However, the development and implementation of these strategies is fragmented, resulting in a gap between research and practice. Additionally, the building design strategies formulate parameters for building projects that are outside the Faroese building sectors traditional practices. Requiring an overall understanding of sustainability and specifically knowledge of material composition, alternatives, as well as material choice possible effect on a building's energy-efficiency. Which likely will present a transitional challenge.

A crucial aspect for both monitoring effectiveness of the building design strategies and assessing the eco-efficiency of building project proposals, are LCA and LCC. But these assessment methods are typically resource intensive and optimally require a specialist, increasing the cost of the tender process. Which the private sector, who already are using significant resources to prepare proposals for public building projects, probably will object to. However, a compromise could possibly be found with the digital variants of the assessment methods, LCAbyg and LCCbyg, that allow for conducting assessments inhouse and are developed to be user-friendly. Where the positive side-effect of this is its potential to generate a better understanding of material efficiency and foster sustainability capabilities.

As for further development towards net positive buildings, literature study revealed that bio-based building materials are expected to become more widely used, as they have the potential to largely replace conventional building materials. Where the demand is expected to exceed a realistic sustainable supply. However, besides from wood, the use of bio-based materials in the building sector does not currently have the necessary grounding and therefore will require resource intensive and expensive documentation of properties and capabilities, until enough experience is gained. The scarcity of legislation would make the Faroe Islands an optimal laboratory for such innovation, but the lack of local resources and the costly demand for documentation will likely prevent this. Nevertheless, it is recommended to follow the development and steadily increase the percentage of bio-based materials required by the tender.

To summaries, the biggest obstacle for the integration of eco-efficiency into Landsverk tender process and therein the Faroese building sector, is seemingly the lack of necessary knowledge and capabilities. Especially an issue, as the effective integration of eco-efficiency will require a person responsible for managing and representing eco-efficiency through the tender process. It is unknown if the local market can service this deficiency, but it is unlikely, as the Faroe Islands has not put much value on sustainability until recently. Therefore, it is recommended that the first step in the process of integrating eco-efficiency should be to conduct a preliminary market consultation. Because it is highly probable that it will take time and a collaborative process before knowledge and capabilities are at a level where eco-efficiency can become an integral and effective part of Landsverk's tender process. Fortunately, both the public and private sector show a willingness for a sustainable transition.

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