Value capture from low embodied emissions of buildings - A business model innovation perspective

Tellnes, L. G.F.; Koch, C.; Torgersen, M.; Kjøniksen, A. L.

Published in:
IOP Conference Series: Earth and Environmental Science

DOI (link to publication from Publisher):
10.1088/1755-1315/1196/1/012096

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Tellnes, L. G. F., Koch, C., Torgersen, M., & Kjøniksen, A. L. (2023). Value capture from low embodied emissions of buildings - A business model innovation perspective. *IOP Conference Series: Earth and Environmental Science*, *1196*(1), Article 012096. https://doi.org/10.1088/1755-1315/1196/1/012096

IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Value capture from low embodied emissions of buildings - a business model innovation perspective

To cite this article: L G F Tellnes *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1196** 012096

View the article online for updates and enhancements.

IOP Conf. Series: Earth and Environmental Science 1196 (2023) 012096 doi:10.1088/1755-1315/1196/1/012096

Value capture from low embodied emissions of buildings - a business model innovation perspective

L G F Tellnes[1,2], C Koch[3,4,5], M Torgersen[1,3], A-L Kjøniksen[1]

[1] Department of Engineering, Østfold University College, Norway
[2] Department of Mechanical, Materials and Manufacturing Engineering. Technical University of Cartagena, Spain
[3] Department of Business and Social Science Aarhus University, Denmark
[4] Department of Entrepreneurship, Innovation and Sustainability, University of Halmstad, Sweden
[5] Department of the Build Environment, Aalborg University, Denmark

Corresponding author's e-mail: lars.g.tellnes@hiof.no

Abstract. The transition to a society with low emissions has led to several intensives for decreasing operational energy and the environmental impact of buildings. The embodied impacts from manufacturing materials have been shown to increase in relative importance as the operational energy efficiency has increased. Several case studies have shown various technical solutions which can reduce embodied carbon emissions. But is this reduction good for business? There are several building projects that have achieved low embodied emissions, but these are often in segments of premium private clients or green public procurement where additional motivation such as reputation and long-term viability is in place. However, with the transition to a low emission society, there is a need to include all types of building markets. This study aims to find business model innovation opportunities with reduced embodied emissions in building projects where the clients have low motivation beyond reducing costs. The approach is through action research with a Norwegian contractor seeking new opportunities while keeping the main competitive advantage. The research starts with a case that could reduce overall greenhouse gas emissions, and includes the potential savings from green loans to find potentials to capture value from reducing emissions. The results show that criteria exist for green loans based on reducing operational and embodied emissions. Future studies are however need to make an integrated assessment on the potential value captured from these green loans.

1. Introduction

In order to reach the climate emission reduction goals, building retrofitting has been seen as one of the most cost-effective solutions [1]. There has been a high focus on new energy requirements and technologies. However, a large share of emissions is related to embodied emissions from manufacturing of materials. Hence, upgrading buildings with reuse of load-bearing structure could give much better climate change mitigation benefits than a new building [2].

There are several ways in which policy can promote a shift to green buildings. These can be regulative and financial, in addition to through information, networks, and certifications. Among policies in Norway, financial means are available as subsidies for energy efficiency, inexpensive building loans, public procurement, and research and development funding [3]. From a business perspective, an energy upgrade is an investment in reducing future energy costs. Hence, in a life cycle cost perspective, the initial higher costs of an energy efficient building could be regained after a certain number of years by annual energy cost savings [4]. There is a challenge in financing the long-term benefits which has a considerable upfront cost. This upfront cost has been met by various kinds of financial instruments [5]. There are also other benefits from upgrading, such as better indoor climate and a larger market for reselling the building. These benefits can be seen as value capture potentials. In addition, it has been shown that certifications create a price premium [6]. In order to achieve a willingness to pay for these additional values of buildings, there have been many standards and ratings developed. Several of these are aimed towards public procurement and larger commercial buildings such as offices. In a number of countries, it is also possible to get montages with lower interest rates to energy upgrade buildings. However, there seems to be a lack of systems that will give value to low embodied emissions from building materials [7].

The objective of this study is to assess the potential to make new business models that could support energy upgrading of commercial buildings that also support low embodied carbon from materials.

1.1. Business models and green buildings - Value capture from low emissions

The role of business models within low emission buildings has been the focus of this study due to the cost challenge. Even if there are several available technical solutions for reducing the environmental impacts of buildings, they are too seldom implemented in practice due to a perception that they represent higher costs [8]. While some argue that it is other aspects that are driving cost than green building certification and low carbon footprint. However, from a business model innovation perspective it could be possible to find new ways to capture value to complement these costs, to reduce environmental impacts, and capture new value. According to previous studies on the benefits of green business models in the construction sector, there are three types of benefits [9]:

1. Credibility / reputation
2. Long term viability
3. Financial benefits

For financial benefits, some studies has shown that energy renovation gives a positive impact on the value of specific projects [10]. However, other studies have found it challenging to find a general value increase of buildings with low energy demand [11]. Different sustainability impacts of retrofitting single-dwelling houses have been assessed, focusing on effects that include both operational energy and embodied emissions, but also benefits to the health of the users [12]. When it comes to lowering embodied emissions, reuse of materials can have a large benefit. New business models are coming with the supply of reused materials with lower embodied carbon. There are however few studies on such cases [13].

In order to have green business models in the finance sector, there has been a development of green bonds. These bonds are arguably designed to support projects with environmental benefits and are part of the movement in responsible investments. Green bonds have had a large increase in both Norway and Sweden, as well as in other western countries. It has been shown that the largest sector of green bonds in Norway and Sweden is through financial institutions to support green buildings [14].

In Sweden, there has been an investigation into whether the use of green bonds and loans actually support green buildings. One study finds that green loans are clearly linked with green building certifications. However, the analysis of the relationships of green finance with key figures such as energy use, carbon dioxide emissions and water consumption was found to be weak [15]. On the other hand, another study suggested that there is a relationship at the national level between green finance and the overall carbon emissions in Sweden. This effect was found to be much stronger in Sweden than in other major countries within green finance [16]. Unfortunately, this study did not mention the effect on buildings compared to other sectors. Hence, there is a need for further investigation into how green loans can make actual changes in the environmental performance of buildings.

1.2. Carbon footprint and life cycle assessment of buildings

Life cycle assessment (LCA) is a standardized method for assessing the environmental impacts of products, and has been extensively applied to buildings and building materials. LCA can be used on a number of different environmental impacts, of which climate change is the most studied impact. It is also possible to include social and economic aspects into life cycle sustainability assessment (LCSA). Purely economic assessment with Life cycle costing (LCC) is especially relevant for buildings with a long lifetime and a balance between investments and long-term operational costs. There are several standards and metrics applied for LCA and LCSA. Among the many studies on LCA of buildings, few of them focus on reuse of buildings and building components [17].

Based on the international standards for LCA of buildings, there are national standards, specifications and practices developed in Norway. For building materials, the standard EN 15804 for environmental product declarations (EPD) is applied for documenting the LCA of building materials. In Norway, about 2000 EPD are available, most of which are related to building materials [18]. For LCA of buildings, the European standard EN 15978 is made on the same framework as EPD. In Norway, this standard has been further specified for carbon footprint of buildings in NS 3720. These standards can also be applied to assess buildings with focus on reuse of materials. This would provide large benefits compared to new buildings from the product phase (A1-A3). Design for reuse and potential emission reductions in the future could also be assessed in module D. The module D is defined outside of the system boundaries to avoid double counting, but is included as it would show valuable information about options at end-of-life. However, this indicator provides less clear interpretations [19].

In a Norwegian context, BREEAM-NOR is a buildings classification system that has been driving documentation of materials for new buildings´ sustainability performance. BREEAM-NOR gives credit for many sustainability areas such as energy use, health, and materials. Through BREEAM-NOR, EPD has been demanded in building projects and has been an important driver in Norway for the availability of EPD [20]. The use of LCA on whole buildings level has been less common, but simplified building level LCA has become mandatory in the last versions of BREEAM-NOR. LCA and carbon footprint of buildings have also been important for public procurement, and there is a development of guidelines for making benchmark values for Norwegian buildings [21]. Another driver for carbon footprint of buildings has been FutureBuilt, which is a lighthouse program for public procurement of buildings in Oslo and the surrounding municipalities. FutureBuilt has requirements for low carbon footprint, and has been applied for more than 50 projects since 2010. The methods for calculating carbon emissions reduction have recently been updated to FutureBuilt zero. The new approach aims to assess the buildings if they comply with the set targets for emission reductions and includes several aspects often left out. These includes dynamic characterisation factors, biogenic carbon and future changes in technology for maintenance, energy supply and end-of-life of building [22].

In European Union, the method Level(S) is used to assess LCA of buildings. It is based on EN 15978 and therefore has several similarities with NS 3720. However, several aspects are specified differently, and therefore the results might not be the same [23]. For asset management, there are several methods proposed to include value capture in a life cycle perspective. A hybrid methodology has been proposed for Life Cycle Valuation of capital goods. This method is based on life cycle costing and life cycle assessment [24]. Another method is the integrated Life Cycle Investment Assessment Method [25]. Overall, there are is a large selection of LCA adaptions to buildings available.

1.3. The problem with low value commercial buildings

This article is focusing how the construction industry can make energy upgrading with low impact materials profitable. Energy upgrading itself is a growing market, but how can the reduction of materials embodied emissions be a profitable market for actors who would like to choose the lowest cost? The objective of the study is to assess the life cycle impacts of a building utilizing a combined carbon footprint and value capture perspective. There are three questions that we seek to highlight:

1. What are the criteria for green finance in the Norwegian building sector
2. What are the main cost drivers in low-cost commercial steel buildings in Norway?
3. How can embodied carbon emission be reduced when energy upgrading commercial steel buildings in Norway?

Although we need to focus on a national context to understand the business aspect properly, the concepts should be internationally usable if context specifics are considered.

2. Methods

The case study is part of Greenbizz research project that aims to helping startup and small and medium-sized companies with energy reductions and energy conversion in a life cycle perspective to reducing carbon footprints. The project uses tools such as life cycle assessment (LCA), energy measurement, and green business model analysis and innovation [26]. This project applies action research, which is a method for collaboration between academia and industry [27].

The study involves a case company, Norbygg, that is a contractor for steel buildings in Norway. This company have visions of sustainable solutions with energy efficiency and reuse. However, the challenge for the construction company is that their customers have low willingness to pay for good reputation and long-term viability. In order to find value creation and value capture with low embodied emissions, the staff of the case company is interested in potential financing of green building projects. Hence, the focus of this study is mapping of financial benefits and the performance of the case study on climate change mitigation. In order to enable a price and cost estimation, a particular building is used as an example. The methods applied in this study are threefold. First, potentials for providing green loans to green buildings was screened. Secondly, the case study was described with activities for erection and costs. Finally, a carbon footprint study of the building case study with standard LCA was conducted.

2.1. Screening of criteria for relevant green loans

The criteria for achieving green loans were screened through the websites of major Norwegian lending institutions. The list of financial institutions mapped is shown in Table 1.

Table 1. Financial institutions in the screening study

Acronym	Full name	Description
DNB	DNB Bank ASA	Largest Norwegian bank. 55 Billion NOK Turnover
Nordea	Nordea Bank Abp	Large Nordic bank 96 Billion NOK turnover
Danske Bank	Danske Bank A/S	Denmark largest bank.
KBN	Kommunalbanken Norway	State owned bank for municipalities
KLP	Kommunal Landspensjonskasse Gjensidig Forsikringsselskap	Mutual insurance company managing pensions of municipal employees
Eiendomskreditt	Eiendomskreditt AS	Financial institution aimed for real estate to SME.
SB1 Hallingdal Valdres	Sparebank 1 Hallingdal Valdres	Local bank with focus on two municipalities

IOP Conf. Series: Earth and Environmental Science 1196 (2023) 012096 doi:10.1088/1755-1315/1196/1/012096

2.2. *Case study*

Norbygg, a steel construction contractor, has been erecting commercial steel buildings in the Østfold region in Norway since 1979. These buildings are typically made of steel frames and envelope, while sandwich elements have been common in later years. Typical uses are storage (including cold storage) as part of a logistic set up, retail, car workshops, and offices. There is a belief that several of these buildings would benefit from energy retrofitting. However, the customers often have a short time horizon for their investments, and do not seem interested in investing in sustainability for a good reputation. Accordingly, there is a need for tools that can give direct economic benefits from energy upgrading. Alternatives to energy upgrading would be to leave buildings as is, but also to erect new buildings instead of rehabilitation. The first step to such a comparative assessment was to make a carbon footprint of a new building. The company has selected a concept building design as representing a simplified typical building that they are delivering. The building is 30 m wide and 60 m long with a mezzanine type second floor 30 m wide and 12 m long for offices. The drawing of the building is shown in Figure 1.

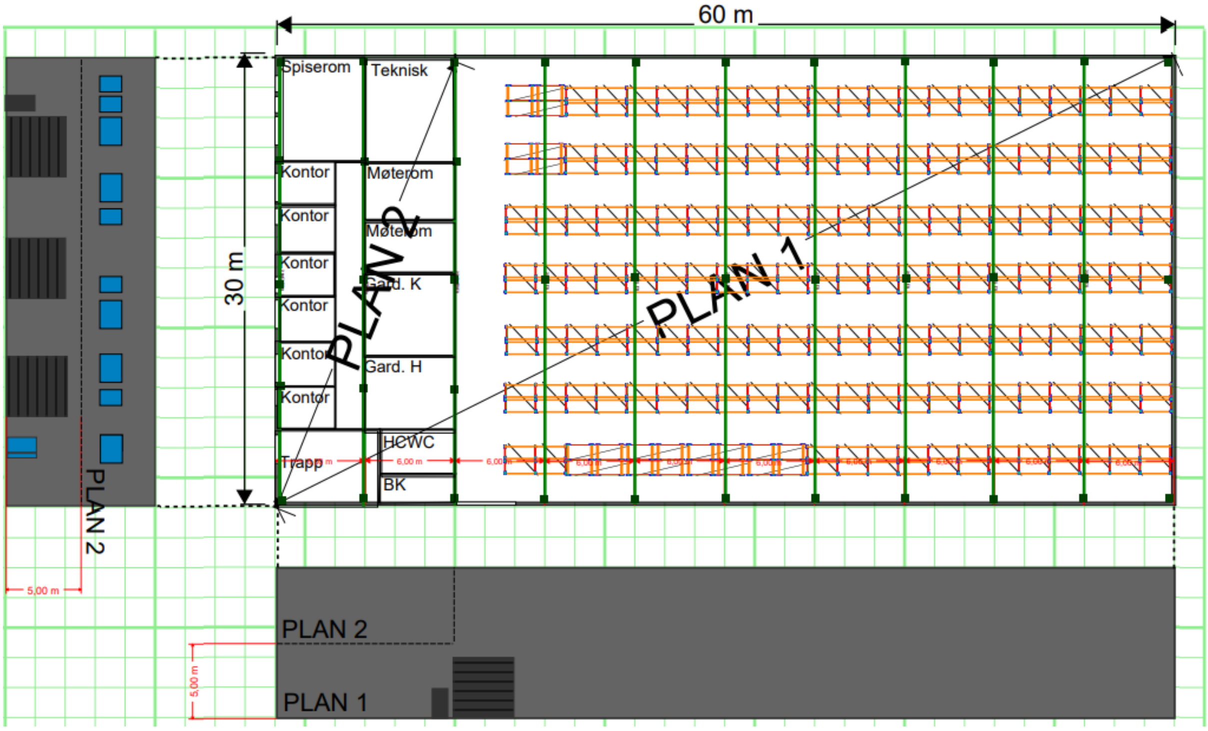

Figure 1. Technical drawing of the concept storage building used in the study.

The building is made of a concrete foundation with expanded polystyrene (EPS) insulation. The load-bearing structure is mainly steel beams, while concrete hollow slabs are used for the office floor. The walls are made of prefabricated sandwich elements with steel sheets and polyisocyanurate (PIR) insulation. The roof consists of coated steel sheets, insulation, and a waterproofing membrane. The cost of erecting the building will be estimated, as well as the cost related to the activities within the scope of the carbon footprint. As explained in the next section, the carbon footprint has a more limited scope of activities than a cost assessment. The main design parameters of the building are listed in Table 2.

Table 2. Main parameters describing the concept building

Parameter	Value
Area ground floor	1800 m2
First floor	360 m2
Total floor space	2160 m2

2.3. *Carbon footprint*

The carbon footprint of the embodied emissions of the building has been assessed for a typical new building. The amount of materials is taken from the cost estimation carried out by Norbygg. The study has used the Reduzer software for carbon footprint of buildings [28]. The material data in the software is with both generic materials at the Norwegian market and specific data from environmental product declaration (EPD). The software follows the NS 3720 standard. The carbon footprint is based on NS 3720, but simplified according to the draft guidance for carbon footprint in the National Building code of Norway (TEK17) [29]. The scope of building parts is in this guidance limited to the main foundation, load-bearing structures and envelope. Technical systems such as ventilation is outside of the scope. The scope of life cycle modules is also limited to the building products production (A1-A3), transport to building site (A4), construction site (A5), maintenance (B2) and replacement (B4). The included building parts and life cycle modules are shown in Table 3.

Table 3. Scope of materials in carbon footprint assessment

Building part NS 3451	Modules EN 15978
21 Foundation	A1-A3, A4, A5, B2, B4
22 Superstructure	A1-A3, A4, A5, B2, B4
23 Outer walls	A1-A3, A4, A5, B2, B4
24 Inner walls	A1-A3, A4, A5, B2, B4
25 Slabs	A1-A3, A4, A5, B2, B4
26 Roofs	A1-A3, A4, A5, B2, B4

3. Results and discussion

3.1. *Screening green loans*

According to Table 4, there are criteria for green loans available related to energy efficiency renovations, building certification, renewable energy and low impact materials. The criteria for energy efficiency in renovation was given by all lending institutions. For building certification, two institutions used BREEAM-NOR. The others listed several types of building certifications, and also included "equivalent". The larger commercial banks seem to have several similar criteria, but for the smaller and specialised institutions the criteria for green loans are different. For instance, the public oriented loan givers had two of the same requirements on low impact materials and local energy supply. The local bank SB1 Hallingdal and Valdres had two criteria that none of the larger banks had. These were lower carbon footprint and lower energy use compared to building code references. Such requirements are not based on well know certifications, and would therefore need evaluation by the staff in the bank. These requirements might better promote actual green buildings, but are challenging for larger institutions due to the demands for qualified staff and individual assessments.

Table 4. Green loans and criteria

Type of criteria	Description	Financial institutions
Green public funding	The building project have received public funding	KBN
Major renovation	30 % reduction in energy use through renovation	Eiendomskreditt, DNB, Danske Bank, KBN
New building regulation compliance	If the building was built in 2012 or later.	Eiendomskreditt, DNB, Nordea
BREEAM Building certification	BREEAM-NOR excellent or outstanding	Eiendomskreditt, SB1 Hallingdal Valdres
General Building certification	BREEAM-NOR excellent or outstanding, Swan Ecolabel, Leed Gold, other equal level	DNB, Nordea, KLP, Danske Bank, KBN
Energy efficiency equipment	Lighting, windows, heating, water savings, charging stations, energy management, etc.	DNB, Danske Bank, KBN
Low carbon footprint building	20 % reduction in carbon footprint compared to building code	SB1 Hallingdal Valdres
Low energy building	20 % reduction in energy need compared to building code	SB1 Hallingdal Valdres
Low carbon footprint materials in new building	New buildings mainly with low carbon footprint materials such as mass timber, low carbon concrete or reused materials.	KLP, KBN
Local energy supply	Minimum 70 % of energy is self-supplied	KBN, KLP

3.2. Cost assessment

The cost of erecting the building has been estimated by the contractor at a total of € 2 570 175 which corresponds to € 1190 per m^2 floor space (note that these prices are very context specific). The detailed list of costs is shown in Table 5, indicating both the costs within the scope of the carbon footprint and the total cost of the building. The scope of building activities in the carbon footprint as per the building code requirements leaves out groundwork and building site activities, heating, ventilation and air conditioning (HVAC), and electricity installation and automation. The activities left out of the carbon footprint are related to more than half of the cost of the new building erection. The buildings materials that are included in the carbon footprint are those that are needed for new buildings, but can be avoided when retrofitting is applied instead.

IOP Conf. Series: Earth and Environmental Science 1196 (2023) 012096 doi:10.1088/1755-1315/1196/1/012096

Table 5. Cost of the main part of building process and materials.

Activity	Cost [€ ex. VAT]	Cost of activities included in carbon footprint [€ ex. VAT]
Building, general	356079	0
Groundwork and foundation	240171	114651
Superstructure	282600	282600
Outer walls	151600	151600
Inner walls	317011	180179
Slabs	257777	257777
Roofs	175500	175500
Stairs, balcony	40320	40320
HVAC	409900	0
Electricity supply	280800	0
Data and automation	58417	0
Total	2570175	1202627
Per square meter	1190	557

3.3. *Carbon footprint*

The carbon footprint is shown in Figure 2, and the carbon footprint is estimated to 9 kg CO_2-eq. per square meter per year. This is higher than average from other studies [21], but there are some important differences. In Norway, the number of lifetime years has typically been set to 60 years, but is reduced to 50 years in the Building code guidance, this is therefore also used here. Another important part of the results is the replacement of façade elements is responsible for about 1 kg CO_2-eq. per square meter per year. The largest share of emissions is linked to the groundwork, load-bearing system and floors/slabs. These emissions sum up to about 4.5 kg CO_2-eq. per square meter per year. Accordingly, this indicates a large potential saving from renovating instead of raising a new building. The impacts of energy use and end-of-life not included.

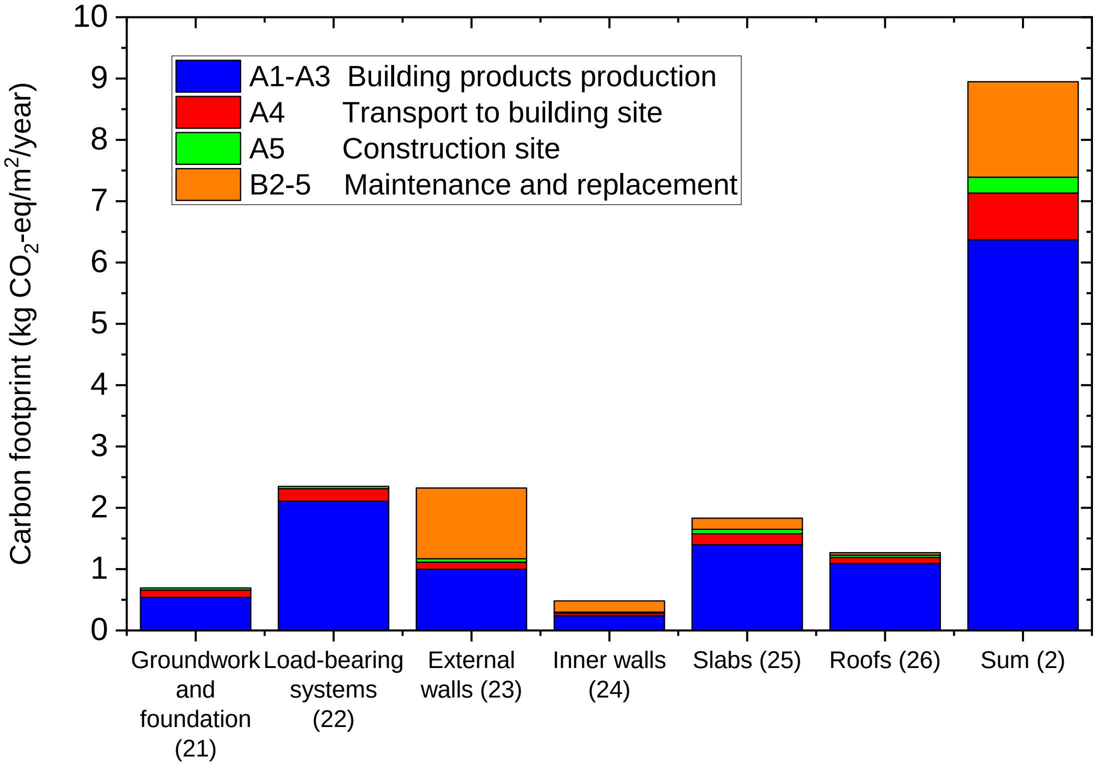

Figure 2. Carbon footprint of the concept building

4. Conclusions

This paper investigated the potential of developing elements of a new business model for retrofitting buildings with green finance. The green finance opportunities were investigated with a screening study of Norwegian lending institutions. A case study for a new building was estimated for the cost and carbon footprint as a benchmark for a potential rehabilitation. A new building was selected for the availability of the case study data. The results of the screening study show that the institutions studied offered better loans for rehabilitation that can provide 30 % lower energy use. There are some providers that also consider potential savings of reuse and use of low impact materials. The potential magnitude of the value to the building owners with these green loans are however yet to be studied. For the assessment of carbon footprint and costs, the carbon footprint only provides activities linked to half of the cost of a new building. Most of the emissions are related to concrete and steel in foundation and load-bearing structures. Accordingly, this would suggest large savings if retrofitting is used instead of replacing with new buildings. The assessment did however not include energy use and end-of-life. A retrofit building might not be as energy efficient as a new building. Further work is therefore needed with specific data for a retrofit case study.

Acknowledgements

Authors wish to thank the Interreg for funding the Greenbizz-project and its many collaborating business. Especially we would like to thank the Norbygg staff for providing data for this case study. The authors also wish to thank students from the course on SFB31321 Project management at Østfold University college. Through the project assignments they help with the work on mapping financial potentials for building green.

References

[1] McKinsey & Company 2009 Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve. Available at: https://www.mckinsey.com/capabilities/sustainability/our-insights/pathways-to-a-low-carbon-economy

[2] Tellnes L, Eide S, Kristjansdottir T and Kron M 2013 Assessment of carbon footprint of laminated veneer lumber elements in a six story housing–comparison to a steel and concrete solution *Portugal SB13. Contribution of sustainable bilding to meet EU* 20-

[3] Nykamp H 2020 Policy Mix for a Transition to Sustainability: Green Buildings in Norway *Sustainability* **12** 446

[4] Chen X, Qu K, Calautit J, Ekambaram A, Lu W, Fox C, Gan G and Riffat S 2020 Multi-criteria assessment approach for a residential building retrofit in Norway *Energy and Buildings* **215** 109668

[5] Bertoldi P, Economidou M, Palermo V, Boza-Kiss B and Todeschi V 2021 How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU *WIREs Energy and Environment* **10** e384

[6] Leskinen N, Vimpari J and Junnila S 2020 A Review of the Impact of Green Building Certification on the Cash Flows and Values of Commercial Properties. In: *Sustainability,*

[7] Amiri A, Emami N, Ottelin J, Sorvari J, Marteinsson B, Heinonen J and Junnila S 2021 Embodied emissions of buildings - A forgotten factor in green building certificates *Energy and Buildings* **241** 110962

[8] Pan W and Maxey L 2013 Challenges and opportunities of low or zero carbon building: prospects of business models. In: *CIB World Building Congress,* (Brisbane, Australia

[9] Abuzeinab A, Arif M, Qadri M A and Kulonda D 2017 Green business models in the construction sector: an analysis of outcomes and benefits *Construction Innovation*

[10] Carlson K and Pressnail D K D 2018 Value impacts of energy efficiency retrofits on commercial office buildings in Toronto, Canada *Energy and Buildings* **162** 154-62

[11] Hansen A R, Jensen O M and Kragh J 2013 *Sammenhæng mellem energimærkning og salgspris: Netværk for energirenovering*: SBI forlag)

[12] Moschetti R, Brattebø H, Skeie K S and Lien A G 2018 Performing quantitative analyses towards sustainable business models in building energy renovation projects: Analytic process and case study *Journal of Cleaner Production* **199** 1092-106

[13] Nußholz J L K, Rasmussen F N, Whalen K and Plepys A 2020 Material reuse in buildings: Implications of a circular business model for sustainable value creation *Journal of Cleaner Production* **245** 118546

[14] Torvanger A, Maltais A and Marginean I 2021 Green bonds in Sweden and Norway: What are the success factors? *Journal of Cleaner Production* **324** 129177

[15] Ayub A and Atid M 2022 Tillämpningen av grön finansiering och dess effekt på hållbarhet i fastighetsbolag: En explorativ studie kring sambandet mellan grön finansiering och miljöprestation i den svenska fastighetsmarknaden. (Stockholm, Sweden: KTH)

[16] Saeed Meo M and Karim M Z A 2022 The role of green finance in reducing CO2 emissions: An empirical analysis *Borsa Istanbul Review* **22** 169-78

[17] De Wolf C, Hoxha E and Fivet C 2020 Comparison of environmental assessment methods when reusing building components: A case study *Sustainable Cities and Society* **61** 102322

[18] EPD-Norge 2022 Vellykket 20 års feiring!!!!! ed The Norwegian EPD Foundation (Oslo, Norway)

[19] Etienne D, Lisa W and Laetitia D 2022 Evaluating ‘reuse’ in the current LCA framework – Impact of reuse and reusability in different life cycle stages *IOP Conference Series: Earth and Environmental Science* **1078** 012015

[20] Schlanbusch R D, Fufa S M, Häkkinen T, Vares S, Birgisdottir H and Ylmén P 2016 Experiences with LCA in the Nordic Building Industry – Challenges, Needs and Solutions *Energy Procedia* **96** 82-93
[21] Wiik M K, Selvig E, Fuglseth M, Lausselet C, Resch E, Andresen I, Brattebø H and Hahn U 2020 GHG emission requirements and benchmark values for Norwegian buildings *IOP Conference Series: Earth and Environmental Science* **588** 022005
[22] Resch E, Wiik M K, Tellnes L G, Andresen I, Selvig E and Stoknes S 2022 FutureBuilt Zero - A simplified dynamic LCA method with requirements for low carbon emissions from buildings *IOP Conference Series: Earth and Environmental Science* **1078** 012047
[23] Vandervaeren C, Fufa S M and Kallaos J 2022 Level(s) compared to European and Norwegian standards for life cycle assessment of buildings *IOP Conference Series: Earth and Environmental Science* **1078** 012056
[24] Haanstra W, Braaksma A J J and van Dongen L A M 2021 Designing a hybrid methodology for the Life Cycle Valuation of capital goods *CIRP Journal of Manufacturing Science and Technology* **32** 382-95
[25] de Almeida Pais J E, Raposo H D N, Farinha J T, Cardoso A J M and Marques P A 2021 Optimizing the Life Cycle of Physical Assets through an Integrated Life Cycle Assessment Method *Energies* **14** 6128
[26] Greenbizz 2022 THE GREENBIZZ PROJECT. www.greenbizz.eu
[27] Halecker B 2015 Action case study - A research strategy based on abduction for relevant and rigorous management research *International Journal of Business Research* **15** 23-32
[28] Reduzer 2022 Reduzer - carbon footprints of construction projects. www.reduzer.com
[29] DIBK 2022 Veilder for utarbeidelse av klimagassregnskap. (Oslo, Norway: Norwegian Building Authority) p 39