

Life Cycle Assessment and Cost analysis of Circular Timber vs. Conventional Building Solutions: a Case Study of the Nydalen Factory, Oslo

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This paper evaluates the environmental and economic performance of a circular renovation project in Nydalen, Oslo, where reclaimed timber and designed for assembly and disassembly components were used in place of conventional materials. It applies life cycle assessment (LCA) and life cycle costing (LCC) to analyse impacts and costs across the building lifecycle.

This research is highly relevant to **Drastic's** objectives and its **Nordic Demonstrator**, which focuses on the use of reclaimed timber for innovative structural and load-bearing applications in temporary commercial buildings. It contributes directly to Demonstrator objectives by assessing the life-cycle environmental and cost performance of circular timber solutions, informing future potential uptake.

The connection to Drastic is strengthened by the involvement of project partner, **Omtre**, who contributed both to this research and who also co-lead Drastic's Nordic Demonstrator. Omtre's role helps align scientific advances in reclaimed timber assessment with the Demonstrator's practical objectives, furthering Drastic's broader efforts to advance circular, multi-cycle timber use.

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Life cycle assessment and cost analysis of circular timber vs. conventional building solutions: a case study of the Nydalen Factory, Oslo

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ABSTRACT

This study evaluates the environmental and economic performance of a circular renovation project in Nydalen, Oslo, where reclaimed timber and designed for assembly and disassembly components were used in place of conventional materials. Using an extended LCA and LCC system boundary that includes reuse and recycling (Module D), the analysis reveals substantial carbon savings, driven primarily by avoided impacts from biobased and reused materials, and highlights key cost trade-offs. Despite higher upfront costs, the circular solution showed long-term environmental benefits. The study demonstrates a practical application of LCA/LCC in capturing reuse potential, addressing methodological gaps in assessing circular construction.

INTRODUCTION

Sustainable construction is increasingly guided by circular economy principles, but evaluating circularity in practice remains methodologically challenging. This paper presents a case study of a renovated factory in Nydalen, Oslo, transformed into a circular hub using reclaimed timber provided by Omtre AS (Figure 1; Omtre AS, 2025). While Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) are standard tools for evaluating environmental and economic performance, their application to circular construction reveals methodological limitations.

Key challenges persist in integrating circularity indicators such as adaptability, reuse potential, and longevity into LCA and LCC frameworks (Lam et al., 2022; Larsen et al., 2022; dos Santos Gonçalves et al., 2025). In particular, the frequent omission or inconsistent treatment of reuse, recovery, recycling potential (Module D) undermines the ability of LCA to reflect material reuse or recycling benefits (Van Gulck et al., 2022). This is especially critical when reclaimed biobased materials like timber are involved, as current LCA methods struggle with accounting for biogenic carbon flows, storage, and substitution effects (Andersen et al., 2021; Rasmussen et al., 2023).

Rather than proposing new metrics, this paper extends the system boundary of traditional LCA/LCC to include reusing scenario at the end of life, offering practical insights into how reclaimed wood and circular construction practices can be evaluated more meaningfully. Drawing on recommendations from the EU-funded DRASTIC project (2025), the study illustrates a pragmatic approach to bridging methodological gaps in the sustainability assessment of the built environment (Rajagopalan et al., 2021; Buyle et al., 2019).

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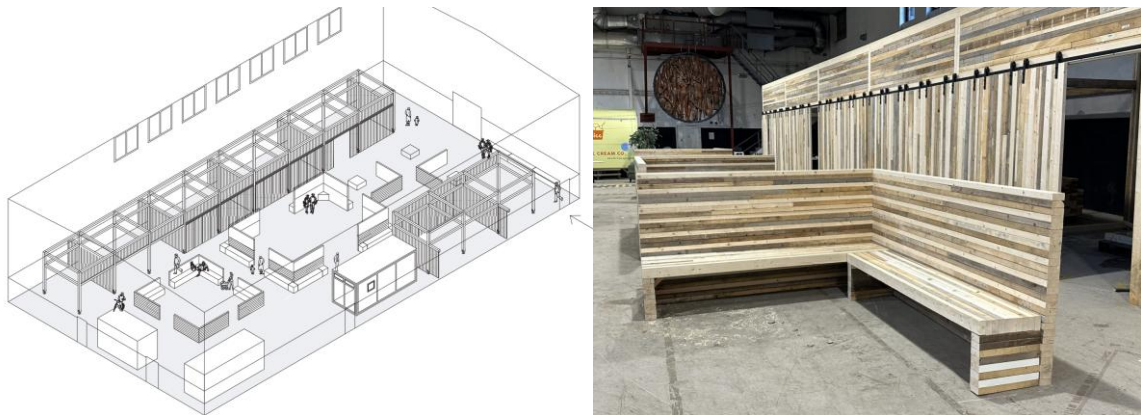


Figure 1. Nydalen project design sketch by Malene L. Grimsgaard (left) and photo by Sebastian Larsson during the installation of the wooden structures and furniture (right).

MATERIALS AND METHODS

The Nydalen project features two main circular construction solutions: partition walls using Grape’s lock system designed for easy dismantling and reuse, and walls and benches made from Norsk Massivtre panels with reclaimed timber (Fig. 2). The functional unit for the LCA and LCC is the 310 m² of internal partition elements and furniture constructed with these solutions. The assessment focuses on these components and compares them to business-as-usual alternatives, steel stud walls with gypsum boards and benches made from virgin wood, to evaluate their relative environmental and economic performance.

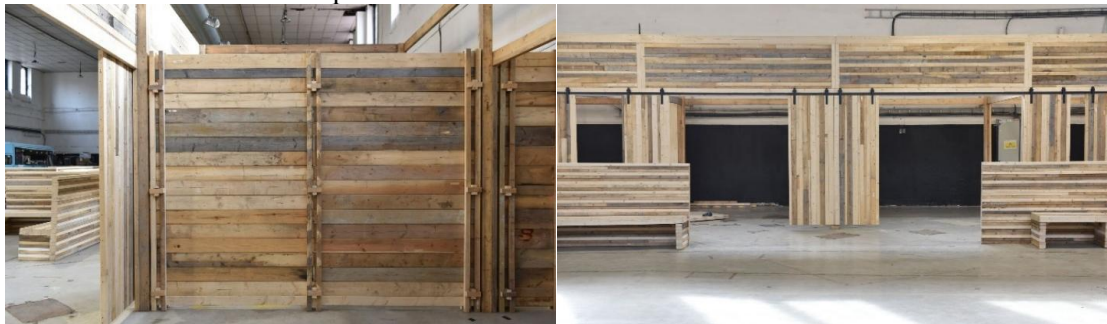


Figure 2 Walls developed by Grape without glue and screws for easy disassembly, maintain and reuse (left). Walls and benches built using Norsk Massivtre product in Nydalen project (right) (Photos by Grape).

The LCA followed a cut-off allocation approach, where environmental burdens are assigned only to processes beyond the point of material collection. This reflects the material’s previous life and avoids double counting of embodied impacts (Van Gulck et al., 2022). Reclaimed timber was used instead of virgin wood, significantly affecting the carbon profile. The analysis was performed using openLCA 2.1.1, with environmental impacts assessed according to the EN 15804+A2 methodology. In line with EN 15804+A2, biogenic carbon is considered neutral at the point of reuse, and no new sequestration is credited.

The system boundary of this study is defined based on a cradle-to-end-of-life approach in accordance with LCA methodology. It includes the following life cycle stages: Product stage (A1–A3), covering raw material supply, transportation, and manufacturing of the materials and products used. For reclaimed materials, this also includes the reclamation process, such as on-site sorting during demolition, transportation, and off-site cleaning and sorting (Table 1, see RT*);

Construction process stage (A4–A5), encompassing the transportation of materials to the construction site and their installation; and End-of-life stage (C1–C4), which involves demounting, waste disposal, and waste handling processes. The Use stage (B1–B7) is excluded. The hub has a defined lifespan of 10 years, due to its temporary status. Therefore, long-term operational and maintenance factors are omitted. The future reuse and recycle potential of these materials are considered in Module D, which quantifies the avoided impacts due to production and waste treatment/disposal of equivalent virgin materials beyond the current system boundary.

Module D is calculated using the next formula, which was developed based on the substitution method according to EN 15804+A2: **Impact module D** = $I_{reuse/recycle} - I_{new\ materials} - I_{waste\ treatment}$ where $I_{reuse/recycle}$ is the impact associated with preparing materials for reuse or recycling (e.g., transportation to storage, repair, maintenance, cleaning, sorting, melting, or crushing); $I_{new\ materials}$ is the impact of producing the equivalent virgin materials and $I_{waste\ treatment}$ is the impact that would have occurred from the end-of-life treatment or disposal of those virgin materials. It is important to clarify that biogenic carbon regarding $I_{new\ materials}$ is not accounted for in the calculation, because carbon sequestration never takes place, but biogenic emissions generated due to waste treatment are included. For instance, the avoided climate change – biogenic from incineration process is included.

In the Nydalen case, 90% of the components are assumed to be reused in the next cycle based on supplier estimations. In contrast, for the BAU scenario, it is assumed that 90% of steel waste and 20% of gypsum board waste are fully recycled into new equivalent products (Table 1), consistent with typical Norwegian construction waste management statistics (Statistics Norway, 2020).

Table 1 Inventory Data

	<i>Nydalen project</i>	<i>Business as usual scenario</i>
	4 h labour	
RT*	90 t*km lorry 16ton, EURO 6 5.0E-7 item sawmill construction, EUR	Not applicable
A1-A4	16.1 m ³ – reclaimed timber, NO 3.7 m ³ – virgin timber, NO 57 kg screws, GLO 18 pcs metallic sliding door fitting, GLO ~ 70 km – lorry 16ton, EUR 6	324 kg – light steel frame 216 m ² gypsum plasterboard 28 kg – screws 6.7 m ³ virgin timber 18 pcs metallic sliding door fitting ~ 5 km – lorry 16ton, EUR 6
A5	60 h labour 2 h machine operation, diesel	155h labour 2 h machine operation
C1-4	46.5 h labour 2 h machine operation, diesel ~ 30 km lorry 32ton, EURO 6 1.98 m ³ waste wood, incineration 5.7 kg scrap steel, landfill	120h labour ~ 30 km lorry 32ton, EURO 6 6.7 m ³ waste wood, incineration 172.8 m ² gypsum board waste, landfill 53.2 kg scrap steel, landfill
D	-17.82 m ³ wood elements, reused -51.3kg screws, reused -18 pcs metallic sliding door fitting, reused	-478.8 kg steel, recycled -43.2 m ² gypsum board, recycled

*RT= Reclaimed timber; 1 m³

The LCC followed the same system boundary as the LCA and was carried out using an Excel-based model, aligned with the principles of EN 16627. A real-term approach was used, where prices exclude inflation and only a 4% real discount rate, as recommended by the Norwegian Ministry of Finance, was applied. Currency conversion from NOK to EUR was based on the exchange rate on

the day of calculation (April 3, 2025). Most cost data, including materials, labor, transportation, installation, and waste disposal, were informed by contractor feedback, previous project experience, and reference prices from local service providers.

Table 1 presents a detailed overview of material quantities and sources. Datasets were sourced from Ecoinvent 3.10 at the unit process level, representing European markets for steel and gypsum boards, global markets for specific fitting parts sourced out of Europe, and regional markets (Norway/Sweden) for timber products. Transportation distances for Module A2 are included in the data sets. In addition, primary data was provided by OMTRE AS, the project manager, along with components supplier Norsk Massivtre, and Grape AS. Their input enabled accurate modeling of both environmental and economic aspects, including real-world data on demounting time, transport, and storage.

RESULTS AND DISCUSSION

The life cycle assessment of the Nydalen project (Table 2) reveals a clear environmental advantage over the conventional BAU scenario, primarily driven by the substantial emission savings in Module D. By incorporating the reuse potential of the circular building components, the project achieves a net carbon benefit of $-10,138.79$ kg CO₂-eq, in contrast to a net emission of $3,343.50$ kg CO₂-eq in the BAU case. These avoided impacts, especially in biogenic carbon emissions, highlight the importance of extending system boundaries beyond end-of-life to include the benefits of material substitution. The BAU scenario, despite initially sequestering carbon through virgin timber use, ultimately results in higher emissions when this carbon is released at the end of life without substitution. This contrast underscores the importance of reuse strategies, particularly when using biobased materials, to mitigate climate change impacts in the construction sector.

Table 2 Results LCA (kg CO₂ eq)

<i>Project</i>	<i>Impact Category</i>	<i>A1-A3</i>	<i>A4</i>	<i>A5</i>	<i>CI-C4</i>	<i>D</i>	<i>Total</i>
Nydalen	CC, Total	5838.70	137.44	8.69	1860.70	-17984.32	-10138.79
	CC, Biogenic	4590.76	0.13	0.02	1785.54	-16069.71	-9693.26
	CC, Fossil	1245.90	137.25	8.67	75.08	-1907.93	-441.05
	CC, LULUC	2.04	0.06	0.00	0.08	-6.68	-4.48
BAU	CC, Total	2031.23	6.13	9.49	6406.97	-1047.86	3343.50
	CC, Biogenic	4114.99	0.01	0.05	6042.16	-14.86	1912.36
	CC, Fossil	2079.80	6.12	9.44	364.45	-1032.67	1427.13
	CC, LULUC	3.96	0.00	0.01	0.36	-0.33	4.01

*CC= Climate Change; LULUC= Land use and land use change

Table 3 Results LCC (EUR)

<i>Project</i>	<i>A1-A3</i>	<i>A4</i>	<i>A5</i>	<i>CI-C4</i>	<i>D</i>	<i>Total</i>
Nydalen	43078.73	792.00	3379.20	3232.42	-16763.65	33718.70
BAU	10615.13	176.00	8395.20	7383.46	0.00	26569.80

Although the product stage (A1–A3) in Nydalen has higher impacts due to labor and energy intensive processing of reclaimed timber, the fossil-related emissions in this stage are still 60% lower compared to BAU. This is attributed to the replacement of energy and emission intensive virgin materials with reclaimed timber. The results also show marginal benefits in climate change–

LULUC, reflecting slight reductions in land-use change through avoided extraction of primary timber resources. The most decisive contribution comes from Module D, which offsets emissions from both fossil and biogenic sources and reinforces the value of substitution accounting in circular construction assessments. Additionally, the lower end-of-life impacts in Nydalen (C1–C4) reflect its design for disassembly and simplified material separation, contrasting with the higher disposal burdens seen in the BAU approach.

In terms of life cycle cost (Table 2), the Nydalen solution incurs substantially higher costs in the product stage, driven by manual sorting, cleaning, and preparation of reclaimed timber, and the lack of industrial processing infrastructure. High labor rates in Norway further exacerbate these expenses, making A1–A3 the dominant cost contributor. However, this disadvantage is partially compensated by lower installation costs in A5, resulting from the use of modular and easy assembly components, which simplifies on-site assembly. Transportation costs (A4) are slightly higher due to the logistics of handling reclaimed materials from a further source. At the end-of-life stage, Nydalen again performs better, with reduced costs due to recoverable materials and fewer disposal burdens compared to BAU.

The most significant economic advantage for Nydalen emerges in Module D, where a credit of –€16,763.65 reflects the avoided cost of virgin materials, disposal savings, and potential residual value of reclaimed components. The BAU scenario, by contrast, lacks these savings and produces limited or depreciable returns from material recovery and recycling. Despite the higher initial investment, Nydalen’s total life cycle cost is only 27% greater than BAU, which may be justifiable considering its substantial environmental benefits, policy alignment with circular economy targets, and potential future cost internalization through carbon pricing or material scarcity.

CONCLUSION

The Nydalen project demonstrates that integrating circular design strategies and reclaimed materials into construction can lead to substantial reductions in life cycle carbon emissions. While the approach entails higher initial costs, particularly in material processing and labor-intensive preparation of reused elements, these are partially offset by downstream savings in installation, end-of-life, and material substitution stages. The results highlight the critical role of Module D in capturing the environmental benefits of reuse and recycling, which are often excluded in conventional cradle-to-grave assessments. However, the project also reveals the economic challenges of current circular construction practices, particularly the lack of industrial infrastructure for handling reclaimed materials. This underscores the urgent need for further development and scaling of industrial processes to improve the cost-effectiveness, efficiency, and accessibility of material reuse in the building sector, but also to explore the impact of different business models enabling multiple use cycles on the LCC and LCA results. While focused on low-performance requirements, the findings provide a valuable foundation for expanding circular strategies into more demanding renovation contexts, supporting both climate goals and the transition to a more resource-resilient built environment.

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