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D5.3 Policy brief and business case of building transformation

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Abstract	The purpose of this report is to evaluate the outcomes of circular design principles for the life cycle extension of existing buildings, demonstrated in the CIRCuIT project and use the findings to provide municipal authorities and building owners the policy brief & business cases on circular life cycle extending strategies. Through twelve demonstrator projects, various circular retention principles were designed, tested and evaluated. Methods such as LCA have been used to calculate the environmental consequences of preserving rather than demolishing and building new, and the economics of circular retention have been examined through LCC calculations. Based on the results and experiences from the twelve demonstrator projects, three business cases and three policy briefs have been formed that argue in favour of extending life cycles of existing buildings through different transformation and refurbishment strategies. They are presented in this report. The work with the twelve demonstrator projects has given a deeper insight into the advantages and problems of using circular design principles. Since all the demonstrator projects showed that there were both environmental and financial savings to be gained by preserving and transforming than demolishing and building new, the overall recommendation is that the building owner, investors, and public authorities should prioritize circular retention principles through strategies for extending lifecycles (e.g., by refurbishment and transformation).

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List of abbreviations

BauGB	Baugesetzbuch
CE	Circular Economy
CES	Circular Economy Statement
DfD	Design for Disassembly
DKK	Danish Krone
EU	European Union
GWP	Global Warming Potential
HBauO	Hamburgische Bauordnung
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MCDM	Multi-criteria Decision-making
ODP	Ozone depletion potential
SAVE	Survey of Architectural Values in the Environment
SWMP	Site Waste Management Plan
TBL	Triple bottom line
WP	Work package

Executive Summary

Product life extension – in the case of buildings, life cycle extension, can be considered the first and foremost principle of circular economy. The CIRCuIT cities have investigated different design approaches to refurbishing and transforming existing buildings via case studies, with the motivation to find viable and replicable ways to keep buildings in use for longer. The current deliverable reports on the environmental, economic and socio-cultural performance of the investigated twelve case studies (or demonstrator projects), which are benchmarked against those of new buildings. Methodologically, the work on environmental impacts relies on Life Cycle Assessment (LCA) and the economic evaluation is based on Life Cycle Costing (LCC). In addition to the environmental and economic consequences summarized in the main body of this report, the deliverable is accompanied by appendixes that detail the experiences, barriers, and social aspects of each demonstrator. The results showed that in all demonstrator projects, there were large material savings because of the life cycle extension. The lower material consumption often also led to CO_2 savings. However, in existing buildings, high-energy consumption can also offset the total potential CO_2 savings if a building's energy efficiency is not improved as a part of the refurbishment. This shows that it is also important to reduce energy consumption in connection with circular retention of existing buildings. The economic calculations showed that savings could often be achieved in the construction phase because fewer materials and replacements were needed, which often also meant that the construction period could be reduced compared to new construction. However, to reduce construction costs and have the greatest possible environmental savings, it is important that a design strategy chosen is the one that makes the most optimal use of the existing building's layout and structure so that the need for replacements is minimized. Therefore, the CIRCuIT project also devised and tested tools to measure transformation potential of existing buildings to determine the most optimal design strategy.

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1. Introduction

This deliverable, policy brief and business case of building transformation, concludes the work of the CIRCuIT project on life-cycle extension of buildings. It originates from earlier work performed in the CIRCuIT project's, which dealt with building transformation. It is the third and last in the series of three reports, which summarise the process and learnings, as follows.

1.1 How to identify buildings for circular transformation?

As a lot of buildings are refurbished and their life cycle is extended on a business-as-usual basis, the work in CIRCuIT targeted buildings that are typically slated for demolition rather than chosen for redevelopment. Therefore, the work began by examining what kind of buildings had regularly been demolished in the CIRCuIT cities in the past. The results of this work have been reported in Huuhka *et al.*, (2021). Due to different availability of data, each of the CIRCuIT cities had to develop their own approach to identifying such buildings. Some of the methods work on the city level, while others are more appropriate for a neighbourhood level. The conducted analyses helped to select relevant building types for the next phase, where the transformation potential of case study buildings, i.e. demonstrators, was explored.

1.2 How to develop replicable design strategies and principles?

Next, the aim was to develop and apply replicable strategies and design principles for keeping buildings and neighbourhoods in circular use. The outcome consisted of twelve case studies for building types typically threatened by demolition, which demonstrate a range of techniques and procedures to support lifecycle extensions of buildings through transformation and renovation. The cases and results have been introduced in the report Manelius *et al.* (2022). Some of the findings from work with the twelve case studies were that while economic and social factors are part of the reasons for demolition, they also hold the potential to drive lifecycle extension.

1.3 How to evaluate the outcomes and make informed decisions?

The purpose of the current and final report is to summarise the learnings from calculating and documenting the environmental, social, and economic effects of the twelve case studies. The learnings are crystallised into three distinct business cases for business decision-makers as well as into three policy briefs for public policymakers. The next chapter briefly explains the method and cases used to extract the business cases and policy briefs reported herein. The more comprehensive results of each case can be found in the appendices and, when it comes to certain cases, in the scientific articles referenced. Chapter 3 gives the business cases and Chapter 4 the policy briefs. Chapters 5 and 6 provide concluding discussions and remarks.

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2. Method and cases

This report is the final quantification of the twelve demonstrator projects that have been developed and evaluated during the CIRCuIT project. The purpose is to calculate the derived environmental and economic effects and investigate socio-cultural aspect (where appropriate) of the circular design principles that have been tested on the demonstrator projects. For this, LCA and LCC calculations have been carried out for each demonstrator and the social prerequisites and derived effects have been assessed both quantitatively and qualitatively via area analyses, SAVE (Survey of Architectural Values in the Environment) assessments and MCDM (Multi-criteria Decision-making) mappings. Detailed descriptions, documentation for calculations and results from the twelve demonstrator projects can be found in the appendices.

Based on the results and experiences from the twelve demonstrator projects, three business cases and three policy briefs for how to extend life cycles of existing buildings through transformation and refurbishment strategies have been formed through workshops with CIRCuIT partners. The business cases were formed based on the most common business themes identified in the demonstrator projects. The policy briefs were developed together with the city officials from the four CIRCuIT cities based on identified barriers and obstacles between the demonstrator projects and current building legislation and urban planning practices.

Next, the cases, the results of which underlie the development of the business cases and policy briefs, are briefly introduced. Detailed information about all the demonstrator project can be found in the Appendixes.

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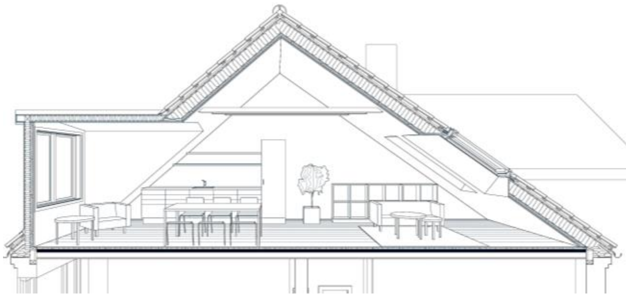
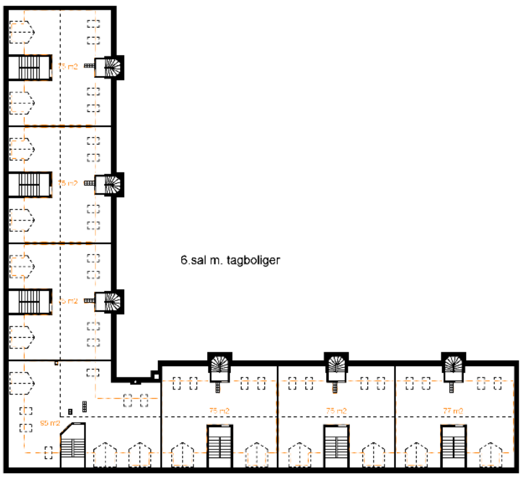
2.1 Copenhagen demonstrator projects

2.1.1 D1: Urban densification through circular roof conversions of 1900s housing





This case study explores the possibilities of urban densification of the Copenhagen city centre, without changing the look and feel of the city, through roof conversions. The case study examines the bonus of reusing the existing wood structural elements and 80 % of the roof tiles and thereby reduce the amount of virgin materials being used. The challenges posed to the case study lies mainly in municipal restrictions towards the creation of roof transformations and in consumer insurance of reusing the tile cladding. Overall, the roof top apartments lowered the environmental impacts from the materials in 6 out of the 7 impact categories compared to building new. Replicating the project is technically relatively easy. The process of designing and constructing new housing units on roof floors has been done many times before, and this is not the challenging part. There are currently 215,584 m^2 of similar roof spaces in Copenhagen, of which only 16% today is used for housing. Utilization of all the unused roof areas of the same type will, have the potential to contribute to additional housing for 4,480 more residents or 1,910 apartments in the municipality of Copenhagen.

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2.1.2 D2: Multi-strategy retention and transformation of 1970s housing estate

Many post-war social housing developments are at risk of generating social challenges because of large-scale monotony and material decay. Several circular design strategies are demonstrated for minimizing demolition such as balancing of tenant segments by subdivision and/or amalgamation of apartments or by introducing new typologies including terraced houses, collective housing, garden apartments, students housing, and apartments for families with disabled members or by only applying partial demolition of blocks rather than demolition of whole blocks. Furthermore, there is a focus on reusing and repurposing dismantled elements in order to bring down emissions. The results of the demonstrators show that the investment in energy saving refurbishment represents the biggest difference in CO_2 footprint, cutting it down to a half. The least favourable scenario from a climate perspective is to proceed with the current practice. Reuse of existing building parts resulted in a considerable CO_2-saving from substitution of new materials, but the most important gains seem to be from the social qualities.

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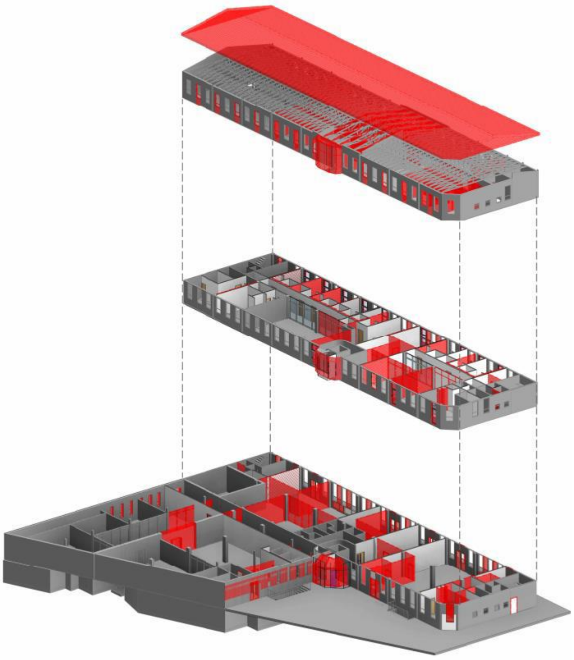
2.1.3 D3: Multi-resource preservation and densification of 1930s commercial plot



Buildings for industry account for the vast majority of demolished floor area in Denmark. On the other hand, the majority of the newly built floor area is residential. In the cities where there is a very high demand for affordable housing, industrial buildings are at great risk of demolition in connection with urban development. This demonstrator therefore investigated the possibilities of transforming office buildings into affordable student housing in a centrally located industrial area in the northern part of Copenhagen. Overall, the circular intervention improved the performance of the project on 4 out of the 7 indicators considered. The lower material consumption of the circular intervention resulted in a potential CO_2 saving of 23% by transforming the office building rather than building new. If the circular design principles are upscaled to other similar office buildings in Greater Copenhagen, it could potentially result in annual CO_2 saving of around 3,000 tonnes of CO_2e. Because the transformed building has a much higher energy consumption than new buildings, the CO_2 savings are somewhat offset by the circular transformation compared to building new. This therefore shows the importance of also focusing on energy-improving measures when preserving existing buildings.

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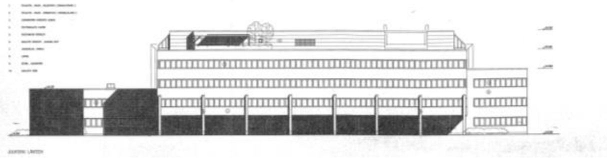
2.2 Vantaa demonstrator projects

2.2.1 D4: Office building conversion to housing, 1970–90s office buildings



Above: Original façade of office building, before adaptive reuse. Typical 1990s office building. Drawing: City of Vantaa archives.

Below: Floor plan after adaptive reuse into flats. Drawing: Malin Moisio.

This demonstrator has been developed for 1970–1990s office buildings in Vantaa. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques, by demonstrating the environmental and economic impacts of adaptive reuse of an existing building (conversion, change of function) in comparison to demolition and new construction (replacement) of corresponding volume. This was achieved through assessing the environmental and cost performance of both the conversion and replacement alternatives. It was found that the conversion of the existing building resulted in 19% lower carbon emissions during the 50-year assessment period when compared to replacement. Notably, this reduction is immediate, as it mainly consists of the avoided new construction. The economic analysis found the total costs of the refurbishment alternative to be approximately 37% lower than the replacement alternatives. This business case could potentially be replicated across most of the structurally and spatially corresponding building, stock that could potentially result in savings of 82,841 tonnes CO_2e across Vantaa.

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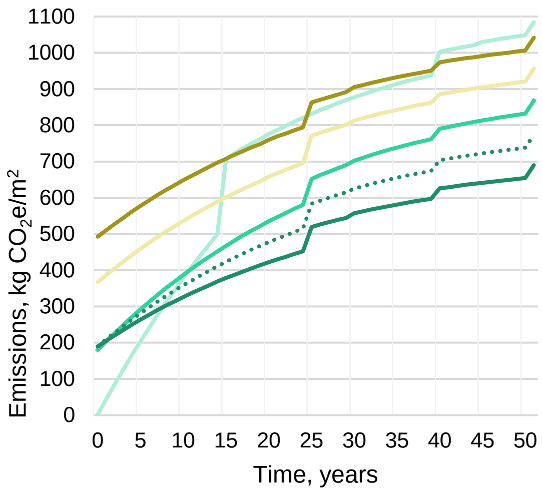
2.2.2 D5: Life cycle extension alternatives for a listed school building

Above: Korso school. Photo: Kimmo Nekkula.

Below: CO2 accumulation of different refurbishment scenarios. Source: Moisio et al. (In review).



This demonstrator has been developed for Korso school in Vantaa. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques, by demonstrating the environmental and economic impacts of different degrees on renovation in comparison to each other and to demolition and replacement new construction. This was achieved through assessing the environmental and cost performance of three different renovation alternatives and two demolition and replacement alternatives. It was found that through incorporating the renovation alternatives, environmental benefits of up to an 86% reduction in material use and a 34% reduction in life cycle emissions could be achieved. The economic analysis found that renovation could incur up to 40% lower costs than replacement. This business case could potentially be replicated across most of the structurally and architecturally corresponding building stock, which could potentially result in up to 30,545 tonnes CO_2e of emissions avoided across Vantaa.

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2.2.3 D6: Renovation and extension of 1970–80s public rental housing

Above: Typical 1970-80s blocks of flats. Photo: Kimmo Nekkula.

Below: Extension with two additional floors. Drawing: Malin Moisio.

This demonstrator has been devised for the development of 1970–80s public rental housing by extension and renovation in Vantaa. The project originally comprises a 2,859 m^2 plot on which there are two blocks of flats from the year 1979. The total gross floor area of the existing buildings is 3,784 m^2, of which Building 1 has 1,419 m^2 on 3 floors and Building 2 has 2,365 m^2 on 5 floors. The original buildings are made from prefabricated concrete panels using structural and spatial solutions typical to the era. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating the potential of refurbishment and vertical extension as an alternative to demolition and new construction. It was found that by utilizing the existing buildings, significant savings in emissions can be achieved. The economic analysis found that refurbishment and vertical extension can be notably less costly than demolition and new construction to the same extent. This business case could potentially be replicated across the corresponding 1970–80s building stock, as this stock is very homogenous. The replication could theoretically result in avoided emissions of up to 1,751,409 tonnes CO_2e across Vantaa.

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2.3 Hamburg demonstrator projects

2.3.1 D7: Transformation and densification on plot with a listed 1954 building

This demonstrator has been developed for the Godewindpark in Hamburg. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating how to transform an unused listed building into holiday apartments and a gym.

This was achieved through collaboration with the heritage authorities to clarify uncertainties, areas to be preserved, areas that could be modified and to what extent, and collaboration with the architects to harmoniously integrate both the modern high-quality features of new buildings with the heritage look of the existing building. Through the strengthening of the load bearing capacity of the existing structure, three additional levels for the holiday apartments were made possible.

It was found that through incorporating transformation, the heritage structure could be kept and environment benefits in terms of savings of 321 tonnes of material, 186 tonnes of waste and 74 tonnes of CO2e were achieved compared to new construction.

The economic analysis found that the total construction cast of the transformation was 4.2 % lower compared to demolishing and building new.

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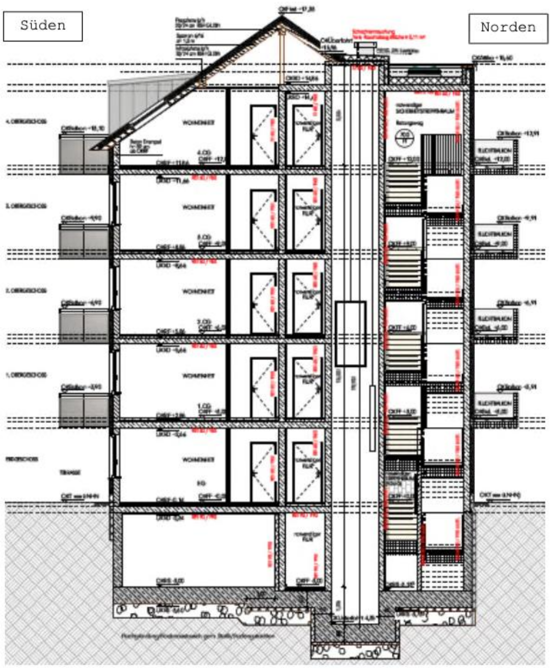
2.3.2 D8: Housing block renovation for 1960s housing typology



This business case has been developed for the Horner Geest typology from the 1960s in Hamburg. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating the ecological and environmental benefits of a modernisation intervention of a housing building.

This was achieved through a modernisation process of an existing building instead of demolishing it and build new.

It was found that through incorporating modernisation of the apartment building environment benefits in terms of carbon emission saving of 4.5 kg per m² living space for this type of housing building were achieved.

The economic analysis found that the total net costs of demolition and construction/modernization can be reduced of 20.9 % per m² living space.

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2.3.1 D9: Transformation of a multi-story parking garage from 1963

This demonstrator has been developed for the Gröninger Hof project in Hamburg. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating how to transform a multi-level car park building into a predominantly residential building.

This will be achieved by incorporating an intelligent design for the proposed future apartments that allows for generous living spaces while keeping the original height of the walls from the existing car park building.

It was found that through incorporating a partial reuse of the existing construction environment benefits in terms of reducing 2,613 tonnes of waste materials and 573 tonnes CO_2e emissions can be achieved.

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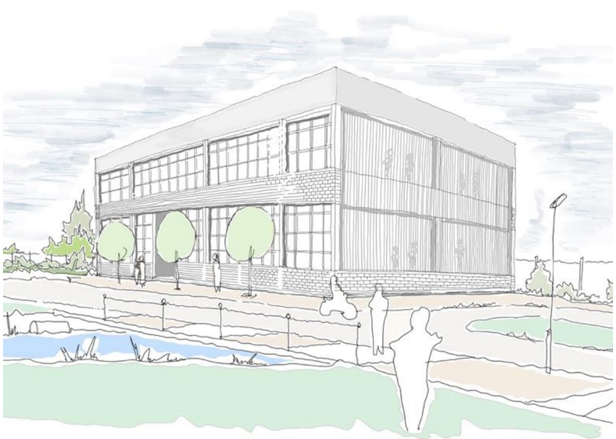
2.4 London demonstrator projects

2.4.1 D10: Life cycle extension alternatives for 1960s commercial building



This business case has been developed for Block F, Meridian Water, in London. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating retention of an existing building for meanwhile use during the rollout of a major regeneration project.

This was achieved through an options appraisal process with triple bottom line (TBL) decision making to evaluate the transformation potential of an existing building. This was generalised into a set of principles that can be applied to other buildings to evaluate their own re-use potential.

It was found that through incorporating retention of parts of the existing building, environmental benefits in terms of savings in embodied carbon (62%) and material use (60%) were achieved. The economic analysis found that the circular intervention improved projected revenue generation over the 15-year meanwhile use lifespan and improved return on investment.

This business case could potentially be replicated across light industrial buildings that are subject to site regeneration plans, where meanwhile buildings are proposed, which could potentially result in 15,600 tonnes CO_2e embodied carbon savings across Greater London.

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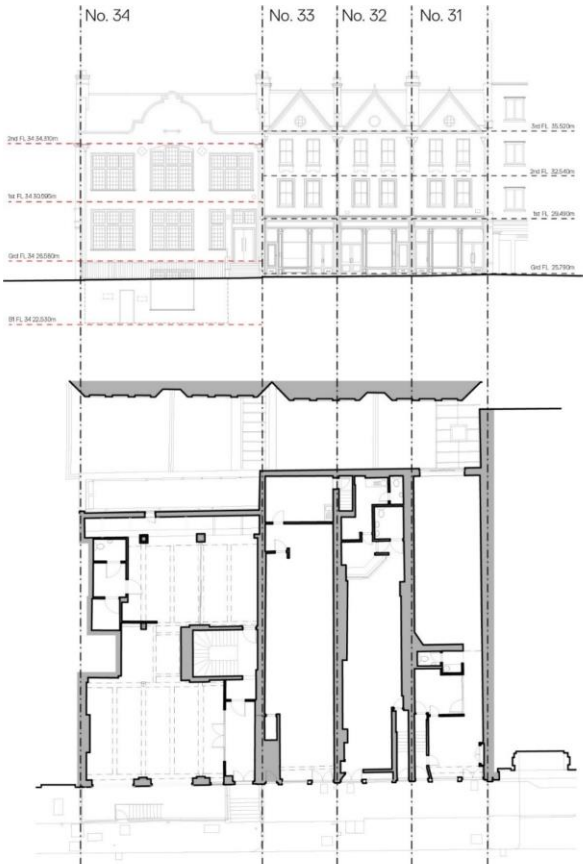
2.4.2 D11: Life cycle extension alternatives for historical mixed-use townhouses



This business case has been developed for 31-34 North Row in London. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating adaptive reuse and extending the lifespan of existing buildings by an additional 50 to 60 years. The existing buildings, as they currently stand, are deemed to be unsuited – in terms of floor to ceiling heights, proportion, and internal access – to be retained as part of any proposed residential developments. The threat of demolition for this specific building typology is prevalent across London for similar reasons.

It was found that through the transformation strategy, environmental benefits in terms of savings in embodied carbon (20%) were achieved. The economic analysis found that the circular intervention reduced capital expenditure by 10% and whole life costs by 7%.

This business case could potentially be replicated across a proportion of the nearly 23,000 tall terraced buildings of this era in Greater London. If it is assumed that 5% of these are subject to regeneration plans as part of multi-property development sites in the medium- to long-term, the replication of this business case could potentially result in 113,000 tonnes CO2e upfront embodied carbon savings across Greater London. This is equivalent to the annual emissions from 14,000 homes.

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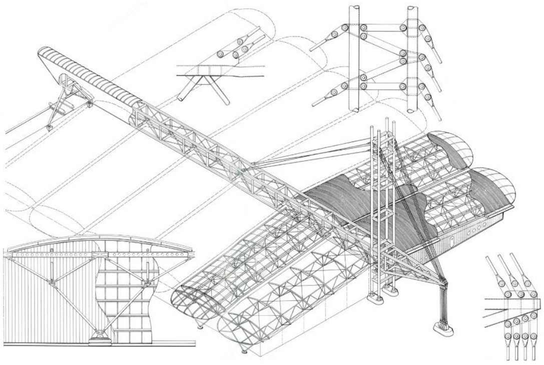
2.4.3 D12: Life cycle extension alternatives for a 1989 supermarket structure



This business case has been developed for the Homebase superstore in London. This project is aiming to increase the regenerative capacity of cities by increasing the uptake of circular construction techniques by demonstrating the economic and technical viability of applying the highest value transformation strategies to an out-of-town retail unit.

This was achieved through assessment of the building's suitability to be transformed for a range of other functions and by investigating the reuse potential of the primary structure and cladding.

The developer concluded that none of the transformation typologies are suitable for the site. However, it was found that by dismantling and re-erecting the entire structural frame on another site, environment benefits in terms of materials used, waste arising and whole life carbon emissions were achieved. The economic analysis found that by comparison to the base case, the circular construction intervention has resulted in a 15% saving in the capital construction cost and reduced the whole life costs by 2%.

This business case could potentially be replicated across other out-of-town retail units, which could potentially result in a reduction in whole life carbon emissions of 400,000 tonnes CO_2e across Greater London.

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3. Business cases

This section presents a summarisation of the business cases of all 12 demonstrators conducted in Work package 5. All 12 demonstrators have been analysed in the line of the Business case template that was previously created in CIRCuiT and presented in deliverable 7.2 and can be found in detail in the Appendix of this report. Though the intent in this report is to provide readers with a thorough understanding and deeper insight into the mechanisms behind each business case in relation to varies design approaches, CIRCuIT will follow-up the work when combining the knowledge of all business cases based on the 36 demonstrators in D9.7 Public Final report. The report, which target building owners, investors and in general a broader audience, will support the decision makers in committing to building's transformation and preservation.

This chapter presents three main circular business cases for existing buildings that have been identified in connection with the preparation and testing of CE principles in the twelve demonstrator projects. They argue for expanding the concept of value to more than pure economics, also including environmental and social value.

3.1 First business case: Lowering construction costs through structural retention

It is often mentioned that renovations and transformations are expensive and difficult. Therefore, many building owners choose to demolish and build new rather than preserve the existing building. A large part of the twelve demonstrator projects showed, however, that there were often potential construction cost savings by renovating and transforming. However, it may require that as much of the building as possible be preserved. Additionally, the need for replacements has a big impact on the price. Even adaptive reuse, which is often perceived as costly, proved more affordable than demolition and new build.

The demonstrator in Copenhagen regarding the transformation of the office building into student housing (D3) showed that the transformation could be simplified, and construction cost lowered by selecting a transformation strategy that utilizes the building's existing layout. The construction costs were therefore reduced because the need for partial demolition of internal building parts and the need for adding new materials was correspondingly reduced. In addition, the building's exterior and static building parts were also in good condition, which generally made the need for replacements small and resulted in a potential construction cost reduction of 57 %.

Similar, in all Vantaa demonstrators, life-cycle costs of refurbishment were as a rule lower than those of replacement (demolition and new construction). In the Korso school demonstrator (D5) three levels of renovation, from light refurbishment to heavy energy renovation, were examined. The lightest refurbishment (which combined a more extensive renovation at year 15) was the most affordable option. However, in terms of CO_2 emissions, this option was inferior to the heavier renovations, yet performed equal to a new concrete building. In terms

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of the heavier renovation alternatives, the energy renovation was only slightly more expensive as an investment than the 'regular' renovation. However, in the long run, the energy renovation accumulated fewer operational costs (energy costs) than the business-as-usual alternative. Depending on the future development of energy prices and discount rates, in some sensitivity analysis scenarios, the energy renovation could even become more affordable than the lightest refurbishment.

Another Vantaa demonstrator examined the conversion of a 1990s office building to housing (D4), which denoted an extensive renewal of the building's layout and building services, as well as e.g. retrofitting balconies. Despite the extensive changes, the initial investment costs of the adaptation were about half of those of the new build. At the end of the 50-year assessment period, the accumulated costs of the adaptive reuse were still about 37% smaller than those had the building been replaced with a new one. The difference in the costs is so substantial that no foreseeable change in energy pricing, discount rates, etc. will change the result in favour of the replacement.

When it comes to extending blocks of flats with additional floors in conjunction with renovation, the cost implications of the Vantaa demonstrator (D6) were not quite as unambiguous. The costs of both alternatives are almost equal with the current cost level for the first three decades, after which the extension and renovation become slightly more affordable. In addition, three additional cost scenarios were examined. In two of them, the extension is clearly more affordable than replacement throughout the life cycle, but in one, the situation is the opposite. This is a cost scenario in which the investment and operation costs will see a substantial increase, while the discount rate will be smaller than in the other two sensitivity analysis scenarios for costs. In addition, replacing construction parts can be more voluminous than what can be achieved with extending the blocks. This means the extension scenario will also feature construction somewhere else, potentially on a greenfield where new infrastructure needs to be erected. Here, the alternatives have almost equal initial investment costs, but over the long-term, the replacement alternative becomes slightly more affordable. However, if the costs of the new infrastructure construction from a larger area are allocated on the greenfield new build associated with the extension option, this alternative will be substantially more expensive than the replacement. This last case is the only exception to the rule otherwise established by the Vantaa demonstrators.

Another way to expand the housing area is to utilize the large amount of unused floor areas under pitched roofs on existing buildings. Cities have an interest in keeping its buildings well maintained and improving the energy efficiency of the older building stock as well as creating more housing in an affordable and sustainable fashion. Copenhagen's rooftop conversion demonstrator (D1) showed that by converting attics into apartments in combination with an already scheduled extensive renovation, the gain could be: The existing building is maintained, energy efficiency is improved, and new housing is created. The construction price for furnishing roof dwellings is, however, greater than the typical replacement and subsequent insulation of the roof. Nevertheless, because an income can subsequently be generated from

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ongoing rent or sale of apartments, the profit can be used to pay for the energy renovation of the rest of the building. Thereby, it is possible both to build more homes, use fewer materials and finance more extensive energy renovations of the existing building.

In London, all three demonstrator projects also presented a cost saving against their business-as-usual alternatives. The triple bottom line (TBL) approach taken in the demonstrator 'Block F' (D10) has informed the feasibility methodology used for decision-making by the client on other projects. The main challenge faced in D10 and the retail unit demonstrator D12 was the inability to navigate the perceived risks of negative program impact associated with deconstruction, storage, and remedial works. This can be mitigated by earlier consideration of reuse in the form of TBL comparative analysis as part of the initial commercial feasibility studies.

3.2 Second business case: Lowering greenhouse gas emissions & resource consumption

In a future with an increased focus on reducing CO_2 emissions from construction, new requirements for emissions may mean that investments must be made in low-emission materials and solutions. Adhering to the CO_2 limits set by regulators in governments and cities may soon be the only way to stay in the business. By reusing and preserving as much as possible of the existing buildings, either on-site or off-site, large CO_2 savings can be achieved compared to demolishing and building new.

This is demonstrated by the fact that all Vantaa cluster demonstrators documented substantial CO_2 and material savings. In the Korso school D5 demonstrator D5, which investigated different levels of refurbishment, all the four examined refurbishment scenarios saved about 85 % in material tonnes compared to a new concrete-framed building, and about 80 % compared to a wooden one. When it comes to the CO_2 savings, the results of the different scenarios diverged more (see Figure 1). This is because materials are mainly consumed in the construction and product phase, while CO_2 emissions are also created during operation, and the different scenarios have notably different operational energy consumptions. In terms of whole-life CO_2, even the lightest refurbishment option (R1) performs better than a typical new building, i.e. a concrete-framed building (N1). It is lower carbon for the first 15 years i.e. until the more extensive renovation (equal to R2) is conducted. After that, it performs in practice equally to the concrete new build. The lightest refurbishment alternative similarly outperforms the wooden new build (N2) until year 15; however afterwards, the wooden new-build becomes lower-carbon. Nevertheless, the heavier renovation alternatives (scenarios R2, R3 and R3b) all outperform both new build alternatives throughout the 50-year study period, making refurbishment clearly the most climate-friendly alternative.

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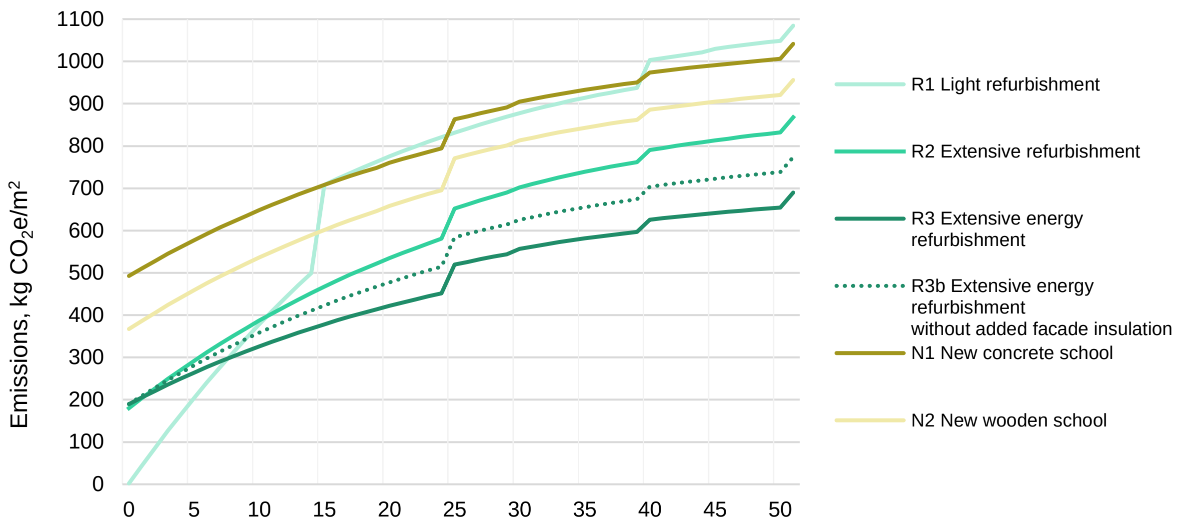

Figure 1. Accumulation of emissions in refurbishment alternatives R1–3(b) and replacement alternatives N1–2 during a 50-year period. Adapted from Moisio et al. (In review).

In the office-to-housing conversion D4 demonstrator, the adaptive reuse of the office building as housing also saved about 60 % in material tonnes in comparison to a new block of flats. The rate of dematerialisation is understandably lower than in the Korso school demonstrator because the change of usage of the building requires a more extensive overhaul of the building layout. The conversion remains lower-carbon throughout the 50-year study period. By year 50, it will have saved about 20% of CO_2 in comparison to a new build.

Finally, the housing extension and renovation D6 demonstrator also showcases the dematerialisation potential. In the first examined scenario pair, where the extended and new buildings are of the same size, the extension option saves circa 70% in materials used. In the second examined scenario pair, where the new build is higher than the extended building and the extension is thus coupled with a smaller greenfield building elsewhere, the material saving is smaller, circa 50%, due to the infrastructure construction associated with the greenfield building. In terms of CO_2 savings, the scenario pairs' results somewhat diverge. In the first pair, i.e. when the buildings are of the same size, the extension and renovation alternative remains lower-carbon throughout the 50-year study period. By year 50, it will have accumulated a little over 10% fewer emissions than the new build. However, in the second pair, the infrastructure construction associated with the additional greenfield building, connected to the extension option, somewhat changes the game. Depending on how extensively the infrastructure construction is allocated to the case, by year 50 it is either 4% lower carbon than new build (CO_2 of only immediate infrastructure allocated), or equal to it (CO_2 of supporting infrastructure from a wider area also allocated). Thus, depending on the situation, the extension and renovation is at best lower-carbon and at worst equal to demolition and new build in CO_2 emissions.

The Copenhagen demonstrator regarding the transformation of the office building into student housing (D3) is an example that although large material savings can be achieved by transforming rather than building new, the higher energy consumption of existing buildings is

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a challenge in terms of being able to realize the total potential in relation to CO_2 savings. If existing buildings have an energy consumption that is much higher than new construction, the CO_2 saving on the materials by transforming will be offset by the ongoing higher CO_2 emission for the energy consumption in the building. It is therefore also important to focus on energy-saving measures when existing buildings are transformed. However, energy-saving measures will typically mean that the need for supplied materials increases for either insulation or the replacement of windows and installations, and thereby the CO_2 emissions for the materials will also increase. It is therefore important to also consider the environmental impact of the energy-improving measures in relation to the energy saving in order to make the most optimal optimization. In the specific demonstrator, the replacement of windows, for example, was not selected, since the energy savings will be small compared to how many new materials would have to be added in connection with the transformation.

Likewise, all the London demonstrators showed CO_2 savings against their business-as-usual base cases driven primarily by the retention of primary structure and other applied finishes and fixtures. Accurately forecasting the quantum of material suitable for reuse in-situ has been challenging, owing to the limitations of non-intrusive surveys conducted to make such estimates. Undertaking more extensive/intrusive surveys during early feasibility studies could mitigate against this. However, this would also likely increase the time and cost of such studies for developers.

In the Copenhagen demonstrator D2, a prefab timber frame-based façade-panel system was chosen as the optimal solution for the façade renovation in terms of reducing cost, time, and carbon emissions. The panels are transported as storey-high elements for flat-packing, mounted by crane and fixed on the edges of floor slabs. As part of the project planning, it was investigated how the system could deliver full capacity for DfD, in particular by replacing nails and staples with screws. The facade-system has become a common solution for affordable housing and renovation. At the same time, the emissions from materials and production are very low due to the minimal material use combined with the CO_2-storing wood. The upfront emissions the façade system causes in the business-as-usual scenario are roughly equal to the DfD-compliant solution that offers neither material savings nor increased material consumption. The CO_2 savings are gained in a future redevelopment scenario where the elements are either reused directly, adjusted, or disassembled in components that can be reused in same function. The DfD-compliance eases reuse at highest possible level where the CO_2 and material savings are significant.

3.3 Third business case: Increase of property value

By preserving, it is sometimes possible to utilize qualities or advantages of the existing building or site that are not possible to achieve by building new. A very concrete example is the Copenhagen demonstrator transforming an office building into student accommodation (D3). Utilizing the existing building enabled a 50% higher plot ratio than what would have been permitted in new construction. Consequently, it was possible to rent out more floor space. The

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higher plot ratio of the transformation scenario meant that 23% higher annual earnings could be acquired.

Even though none of the Vantaa demonstrators explicitly quantified the increase of the property value, it can nevertheless be said for all of them that renovation increases the property values, as it brings the state of the buildings to or close to the present technical standard. For public non-profit operators, such as the City of Vantaa (Korso school demonstrator D5) or the municipal housing provider VAV (housing extension and renovation demonstrator D6), the property value is in fact not relevant, as the purpose of such an operator is not to generate profits on the market through sales. Therefore, what matters more are the costs, and they have already been discussed in Section 3.1. However, the Vantaa housing extension and renovation demonstrator (D6) can also be discussed in a different context. Similar properties can also be privately owned by the homeowners through the Finnish limited liability housing company system. In this system, the company owns the property and manages all structures and building services, as well as the shared spaces. People own shares of the company, and certain shares give them the right to use a certain flat. Shareholders pay a monthly fee to the company, which is used for covering the property's maintenance and repairs. In such a context, the extension of a building with additional floors can bring about economic benefits beyond the property value increase. Firstly, depending on the location, selling the building rights of the additional floors to developers can be leveraged to fund a part of the original building's renovation. Secondly, if properly timed, the original shareholders may also avoid paying for a roof renovation, as a new roof is built as a part of the additional floors. Thirdly, the construction of the additional floors brings new shareholders into the company. Any future maintenance and repair costs will therefore be shared by more people than previously, which takes some of the economic burden off the current shareholders' shoulders.

The Vantaa office to housing conversion demonstrator (D4) represents a case that would most likely be implemented by a private developer, but the approach could also be adopted by a municipal housing provider. The financial considerations of such a case depends quite heavily on the case-specific factors, such as location, ownership structure and demand/vacancy. Over the last decade, there has been overprovision of office space in the Helsinki Metropolitan Region, where the City of Vantaa is located. While new office space has been erected, many older office buildings have suffered from vacancies. Upgrading of older offices to the current standards could in principle have been the solution, but the current overprovision of new office space suggests it may no longer be a viable pathway. Therefore, conversion to other uses represents a route to making the property provide profits again. Housing is, in general, spatially fairly compatible with the characteristics of office buildings' layout. It can also be a more valuable function than the office function, as prices of housing in terms of rents or sales prices often are higher than those for offices.

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4. Policy briefs

In connection with the work with the twelve demonstrator projects and through workshops and interviews with the four CIRCuIT partner cities, some issues have been identified that can prevent the spread of circular building transformations in the cities. In addition, several political tools have also been identified which can or are already being used to promote circular building transformations in urban planning.

4.1 First policy: Actively assess transformation potential of existing building stock

Findings: CIRCuIT demonstrator projects showed that it is important that cities are proactive in being informed and informing others (building owners) about the potential for preservation through transformation much before the demolition is scheduled.

Proposed Policy: CIRCuIT recommends that municipalities dedicate more focus on identifying which buildings are suitable for transformation. When rezoning already developed areas with existing building stock, cities should consider the transformation potential of the buildings in the area, the positive environmental impacts, and devise city plans that enable, along with other city planning goals, the maximum retention of buildings with preservation potential. Cities should also proactively inform and negotiate with current and future building owners about the potential of preservation through circular design principles.

4.1.1 Statement for the first policy

Several of the demonstrators showed that it was important to investigate early the possibilities of applying life cycle extension alternatives to the existing buildings. Depending on the case, this could entail identifying harmful substances, investigating possibilities for extensions, or finding the best transformation strategy based on a building's existing layout. To do pre-redevelopment audits of buildings' transformation potential, there is a need for (1) criteria that define whether a building can be preserved and rebuilt, as well as (2) available building data for the building in question that can be used to assess the criteria. During CIRCuIT, several methods have been tested to measure the transformation potential of existing buildings at both building level and area level (see Huuhka *et al.*, 2022 and Manelius *et al.*, 2022).

4.1.2 Copenhagen's contribution to the policy

To assess and visualize the transformation potential of existing buildings, a test version of a transformation tool consisting of 64 criteria (Andersen et al., 2022) was set up and tested in connection with CIRCuIT. The criteria were selected based on a comprehensive review of previous tools or scientific studies dealing with flexibility and transformation. Experience from testing the tool on case buildings in the city of Aalborg and on the D3 demonstrator building showed that the acquisition of data for 64 criteria was extensive and therefore an obstacle in terms of time and in relation to spreading the tool to countries and cities with less data availability than Denmark. A light version of the tool was therefore created with 20 transformation criteria. A test of the transformation tool on the same case building in the city of Aalborg showed that the twenty criteria could give an assessment of the transformation

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potential close to what the 64 criteria could give. In addition, the tool was also developed with several different building functions. It is fit to assess the adaptive reuse potential of buildings into offices, educational use, childcare facilities, housing, hotels, and shops.

The calculation of the conservation value can be used in the municipalities' case processing of demolition cases by expanding the decision-making base beyond the initial project plan. These transformation potential assessments can support informed decision making, considering the potential building use more holistically and improve the dialogue with the building developers. In this dialogue, municipality case workers and urban planners can challenge the conventional demolish and new-built scenario proactively and constructively based on the building's transformation potential. These suggestions can initiate a negotiation between the municipality and the developer in which the municipality can support the transformation scenario by targeting the content of the local plan in the name of circularity to fulfil its transformation potential. In the Danish policy context, there are some rules of the Building Regulation which are non-negotiable and can't be easily changed or disregarded. However, the interpretation of the planning legislation is up to the case workers and urban planners of the municipality. The urban planners translate the overall directives of the national- and regional-level plans into municipality plans which is then further translated into local plans by urban planners. This gives an opportunity to engage in a dialogue with developers and negotiate the circularity performance and initiatives of the building development project. In practice, this means that the developers could be allowed some compromises when renovation and transformation of an old building is proven to have clear environmental benefits to make this scenario feasible for the developer. In the current policy framework, the rules which are negotiable is mainly regarding aesthetics of the building, as material choice, and structural building typology is outside the direct influence of the municipality.

The transformation analysis tools that have been developed and tested in CIRCuIT are not ready-made 'plug and play' tools since they still have to be adapted to the contexts of individual cities. Context-specific factors to consider encompass e.g., what has an impact on whether a building is transformed or not in a given city, as well as the level of available data on existing buildings in the city. A future development of the tool should also be based on knock out criteria that needs to be fulfilled before the score is calculated since some criteria, as hazardous substance, can be the determining factors in relation to what ether a transformation is possible. Experiences with the tools and talking to architects and engineers suggest that there are some criteria, such as room height or the presence of harmful substances, that are paramount for whether a building can be transformed or not.

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Table 1: Criterion 1-20 in the light version of the tested transformation potential tool (Andersen and Jensen, 2022).

Dimensions and Flexibility				
		3 points	**2 points**	**1 point**
1) *Free room height measured from floor to ceiling*	Same for all	≥ 3.00 m	≥ 2.6 m	< 2.60 m
2) *Building depth from exterior wall to exterior wall*	Office	12,50 m ≤ building depth < 14,50 m	10,00 m ≤ building depth < 16,50 m	10,00 m > building depth > 16,50 m
	Educational	-	-	-
	Childcare	-	-	-
	Housing	building depth < 11.5 m	11,5 m ≤ building depth < 13,5 m	building depth ≥ 13,50 m
	Hotel	12.5 m ≤ building depth < 14.5 m	10.0 m ≤ building depth < 16.5 m	10.0 m > building depth > 16.5 m
	Shops	-	-	-
3) *Corridor width*	Same for all	Corridor width ≥ 1.80 m	Corridor width ≥ 1.5 m	Corridor width ≥ 1 m
4) *Window proportion of the facade*	Same for all	< 20%	< 40%	≥ 40%
5) *Distance between technical shafts*	Office	< 20 m	30-20 m	> 30 m
	Educational	< 20 m	30-20 m	> 30 m
	Childcare	< 20 m	30-20 m	> 30 m
	Housing	< 10 m	10-15 m	> 15 m
	Hotel	< 10 m	10-15 m	> 15 m
	Shops	< 20 m	30-20 m	> 30 m
Position and Adaptability				
6) *Vertical access to the building*	Same for all	(gross floor area / number of access cores) ≤ 400 m2	(gross floor area / number of access cores) ≤ 1200 m2	(gross floor area / number of access cores) > 1200 m2
7) *Adaptability of technical installations*	Same for all	Can be expanded without extensive constructive changes	Can be expanded with minor constructive changes	Can only expanded with extensive constructive changes
8) *Non-load-bearing facades*	Same for all	Yes	Partly	No
9) *Modular systems have been implemented*	Same for all	Yes	Partly	No
10) *Horizontal zone division*	Same for all	3 > building functions	2 ≥ building functions	1 building function
Disassembly and Accessibility				
11) *Accessibility to installations*	Same for all	Good	Sufficient	Bad
12) *Easy replacements of building components*	Same for all	Good: can be removed by hand or with simple tools	Sufficient: in addition to manual work, also requires some cutting or grinding	Bad: separation that can only be done destructively with heavy machinery
13) *Presence of hazardous materials*	Same for all	≥ 1987	≤ 1949	1950-1986
14) *Energy efficiency*	Same for all	A2020-A2010	B-D	E-G
15) *Condition of the building*	Same for all	Good	Sufficient	Bad
Capacity and Expandability				

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***16)** Space efficiency: usable area (NA) / total gross area (SBA)*	Office	≥ 75%	≥ 48%	< 48%
	Educational	≥ 75%	≥ 48%	< 48%
	Childcare	≥ 75%	≥ 48%	< 48%
	Housing	≥ 80%	≥ 60%	< 60%
	Hotel	≥ 70%	≥ 43%	< 43%
	Shops	≥ 90%	≥ 70%	< 70%
***17)** Capacity of the load-bearing structure (sufficient load-bearing capacity for extra floors)*	Same for all	Yes	Partly	No
***18)** Capacity of the installation ducts*	Same for all	Yes	Partly	No
***19)** Opportunities for horizontal extensions of building*	Same for all	50 % ≥ Surplus space of site	30 % ≥ Surplus space of site	10 % ≥ Surplus space of site
***20)** Extension or reuse of stairs and elevators*	Same for all	Yes	Partly	No

4.1.3 London's contribution to the policy

In London, developers for certain projects are required to illustrate to the city why transformation was not suitable for the site. The assessment happens early in the planning process and has driven the conversation about transformation in the city. Requiring the assessment to happen even earlier in the process could further strengthen it.

The policy is embedded in the 2021 London Plan SI 7. It states that all 'referrable' planning applications – these are applications with potential strategic importance to the mayor due to its size or number of housing units – are required to submit a Circular Economy Statement (CE statement, CES) alongside a Whole Life Carbon Assessment. The CES guidance was in development from 2018 with the latest version published in March 2022 following extensive consultation with industry and individuals. As part of the CES process, a pre-demolition or pre-redevelopment audit is 'strongly encouraged' to be completed in the London Plan Guidance at the pre-application stage. A pre-redevelopment audit is required where existing buildings are on the site. It is similar to a pre-demolition audit but assesses whether existing buildings, structures, and materials can be retained, refurbished, or incorporated into the new development. These are expected to be carried out by a third party and independently verified or peer-reviewed and submitted as supporting evidence alongside the CES.

4.1.4 Hamburg's contribution to the policy

For a city like Hamburg, the central focus is on the possible creation of living space. In addition to conventional renovation tasks for existing buildings, this also applies to considerations of converting office buildings or other functional buildings in suitable locations into residential space more easily than before. For this reason, in 2021 the federal state of Hamburg became the first federal state in Germany to create the prerequisite for the application of Section 31 (3) of the Building Code (BauGB) with an ordinance determining that Hamburg is considered an area with a tight housing market. With its application and adaption of Section 69 of the Hamburg Building Code (HBauO), the basis for converting an existing property despite a

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development plan into residential space is given and has been used for the first time with the Gröninger Hof building project (D9).

Despite a thorough survey, extensive contamination of the building fabric was only discovered in this pilot case during the preparatory phase for construction – after an architectural competition had already been held. Similar cases have been found in other similar buildings throughout Germany over the years. It becomes apparent that it is not realistic to identify all hazardous substances or other contamination at an early stage, as it involves costly and time-consuming resources. Instead, it is advisable to record all experiences from pilot projects in existing properties in a kind of open-source platform, so that interested building owners and planners of a comparable existing building can obtain low-threshold information about potential risks for pollutants and contamination. In this way, targeted investigations about transformation potential can be initiated in good time.

4.1.5 Vantaa's contribution to the policy

The City of Vantaa has organized a series of Recourse Wisdom Roadmap Booster during the spring of 2023 to find ways to extend the life cycles of existing buildings. City officials and expert from all key functions took part in them. There are several suggestions arising from these workshops. One is an improved dialogue with the users to tolerate 'imperfection' in the name of circularity. This means that the end users could allow some compromises to their needs for the space allocations when the renovation and transformation of an old building is proved to have clear environmental and/or economic benefits. Another suggestion is to add secondary uses in building permits. Inspection and guidance would be more flexible and proactive. Furthermore, city zoning could be more flexible for different possible uses of buildings. In new buildings, there will be requirements to have designed-in flexibility that enables later changes in layouts with minimal structural alterations and environmental impacts. Incentives to add flexibility will be taken into use. A checklist for city officials and later for all property owners will be developed.

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4.2 Second policy: Enforce circular financial mechanisms to encourage building retention and transformation

Findings: Even though most of the CIRCuIT transformation demonstrators showed that there were financial savings to be gained by transforming rather than demolishing and building new, there are still financial conditions or other considerations, such as risk management, that make the transformation more expensive, less profitable, or otherwise less attractive to business decision-makers.

Proposed Policy: CIRCuIT recommend a review of the processes in the municipalities in relation to how transformation projects are taxed in relation to new construction and streamline the legislation so that finances-wise, transformation projects are equalized or prioritized compared to new construction.

4.2.1 Statement for the second policy

By removing financial barriers to transformation projects, it can become more economically advantageous to preserve rather than tear down and build new. This can also help to remove some of the risks in transformation projects that investors point to as the main reason why many buildings are demolished rather than preserved. In addition, the introduction of circular design principles also changes the way we build, which can often be more time- and labour-intensive, and therefore this must also be considered in the existing rules in relation to the taxation of construction projects.

4.2.2 Copenhagen's contribution to the policy

An example of this from Copenhagen is the § 23 The Municipal Property Tax Act. It is a tax in Danish legislation that can be levied by the municipal administration to cover urban operating costs incurred in connection with commercial properties (including urban wear and tear, waste management, etc.). Once this type of tax is assigned to a commercial property, under current legislation it is not possible for the city administration to revoke this tax, even if the building is undergoing renovation or transformation, unless it will no longer be commercial after the intervention. In practice this means that if a commercial building undergoes renovation or transformation, the property owner would have to continue paying the coverage tax even during the renovation phase. However, if the building is demolished to make way for new construction, the tax ceases when the demolition starts. For older properties, whose future preservation depends on such life-cycle extension strategies, the consequence is that the coverage tax creates an economic incentive to prioritize demolition and new build over preservation. To give a real-life example, the tax plays a significant role in the City of Copenhagen project to transform a 70,000 m^2 former tunnel factory into a new mixed-use district. The tunnel factory is estimated to be charged 20–25 million DKK per year during the transformation period, which will be a total charge of approximately 60–80 million DKK until the expected completion of the project in 2026. In terms of environmental savings, the transformation project is the best course of action, but there is also no doubt that the transformation project is disenfranchised by the current legislation on the coverage tax.

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4.2.3 London's contribution to the policy

In the UK, retrofit projects are taxed at 20% VAT while new build projects usually have a rate of between 0% and 5% VAT. This disparity disincentives retrofit and renovation projects as they comparatively carry a cost penalty. Many architects have pointed to the VAT disparity as an active disincentive to their client to choose the retrofit as a path when presented with various design options. The 'RetroFirst' campaign in the UK led by Architects' Journal is looking to lobby against these skewed incentives. They are supported by other large industry movements such as Architects Declare which has mobilised architectural firms across the country to support action against in the climate crisis.

4.2.4 Hamburg's contribution to the policy

So far, there has been no explicit promotion of circular construction at national level in Germany. At the federal state level, too, funding offers from the Hamburg Investment and Development Bank (IFB) are limited to the energy-efficient modernisation of buildings. Since there are around 25,000 commercial and non-residential buildings in Hamburg, a considerable proportion of which are more than 50 years old, the Hamburg Senate provides targeted funding for the refurbishment of these buildings. Small and medium-sized enterprises are subsidised with up to 20% and large enterprises with 15% of the investment costs, which do not have to be reimbursed on a later time.

4.2.5 Vantaa's contribution to the policy

Vantaa is planning to make it easier in city planning to renovate, transform and take buildings into a temporary use. Making the renovation permit process easier and introducing incentives are some of the planned measures. If possible from the legal prespective, one incentive could comprise of a 'fast lane' of the building inspection for circular economy projects. However, the criteria for circularity need to be further determined to define what kind of applications would be eligible for the fast lane.

Vantaa will also offer help, knowledge, and tools for developers to achieve the optimal level of renovation. The city wants to increase temporary use of buildings. There could be a portal or app to match the demand and supply for spaces on the city level. The rules and guidelines for temporary use by building type will be made. Transformed buildings could also have some financial benefits e.g. in the form of a lower real estate tax, but this financial incentive is still in its early planning stages. Also, the national Green deal on Circular Economy is under preparation and it is expected to include financial incentive mechanisms. However, at the time of writing this report, they are still unknown.

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4.3 Third policy: Add preservation status for buildings on the basis of environmental value

Findings: All the assessed demonstrator projects show large material savings thanks to the circular retention strategy. Since transformation is less material intensive than new construction because most of the existing building parts are preserved, a derived effect is also potential large CO_2 savings from the reduced need to produce new building materials.

Proposed Policy: CIRCuIT recommends that current or future environmental preservation value should be implemented in the municipalities' work with urban development and handling applications for demolition.

4.3.1 Statement for the third policy

In a future where materials become both more expensive and less accessible, there is a need to introduce a new value statement of existing buildings in relation to their potential to contribute with material and CO_2 savings through preservation. By introducing a value for the environmental savings that can be achieved by preserving the building through circular retention, the municipalities get both a regulatory and informative tool to preserve and transform existing buildings.

4.3.2 Copenhagen's contribution to the policy

To promote circular conservation strategies, it is important in the cities and at national level to increase the focus and awareness on current and future qualities and values of the existing building stock. In the current legal framework of Denmark, there is a limited foundation for the city to require building developers to transform buildings based on the CIRCuIT designed transformation potential assessment tools or any other pre-assessments of the potential environmental savings. Based on the most recent Danish Building Regulations (Social- Bolig- og Ældreministeriet, 2019) (BR18) the municipality only has the agency to refuse demolition of a building if it is listed in the national register of buildings worthy of preservation based on architectural value. The 'SAVE' methodology (Survey of Architectural Values in the Environment, see Kulturarvsstyrelsen [2011]) defines the criteria of which buildings are assessed. The methodology scores the buildings' preservation potential on a scale from 1 to 9 based on the architectural value of the building, its cultural heritage, aesthetics, or the buildings importance for the surrounding area (Kulturarvsstyrelsen, 2011). In the city master plan, the city administration defines the threshold score for preservation, and local plans are developed to reflect this.

However, within the current framework there is a small gap for the municipality to refuse demolition based on preservation potential even if the building is not listed. If the municipality wants to prevent demolition, it can do so by imposing a demolition ban for individual buildings under the Planning Act. If the municipality wishes to preserve a building which is (1) not listed as worthy of preservation according to the SAVE register and the city plan, or (2) not already determined as a building to be preserved in a local plan, the authorities can still assign a prohibition against demolition if the municipality develops a new local plan for that specific

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building or area within a year. However, making a local plan is a time-consuming administrative process, which needs to go through a series of steps for approval before it enters info force. For that reason, this procedure cannot be the approach for preserving buildings on a larger scale. To systematically preserve buildings based on environmental savings potential, systematic methods of assessing which buildings are worthy of preserving based on a life-cycle perspective must be developed to decrease the administrative burden. Central registers, such as the SAVE methodology, can be a systematic way of highlighting on which buildings this administrative process is worthy of undertaking, thus minimising the administrative workload. However, it has some methodological flaws and a limited scope that inhibits its potential for avoiding demolitions systemically.

A general gap in the SAVE register is that only buildings built before 1960 are evaluated. Therefore, it is not possible to list buildings from after that period based on this methodology. This limits the buildings covered by this framework significantly, creating a limited legal foundation to refuse demolition applications for post-war and modern buildings. This may be part of the reason why these are overrepresented in the demolition statistics, as discussed in CIRCuIT deliverable 5.1 (Huuhka *et al.*, 2021) about the city mappings. It is proposed that expanding the scope of the SAVE methodology to also include post 1960s buildings would significantly improve the legal foundation to favour of building preservation in demolition applications decision making.

As a way of addressing the limited scope of the SAVE methodology, the City of Copenhagen has started a campaign called 'The Soul of the City' to increase the number of buildings deemed as worthy of preserving based on public opinion. In this campaign, citizens can nominate and vote for buildings to be listed for future preservation. The most popular buildings are then flagged for the city administration if a demolition application is issued for the top voted buildings in the future. This is an unconventional bottom-up approach to supplementing the existing SAVE register.

However, besides the limited scope of the current initiatives for building preservation, there is also a gap in terms of which aspects are considered. The SAVE register and the 'Soul of the City' campaign both highlight buildings for preservation based on the architectural and cultural value leaving a blind spot regarding the environmental aspects, such as emissions saving potential. The planning divisions of The City of Copenhagen are currently exploring options for screening emissions saving potential systematically across the city to supplement the architectural and cultural scoring systems. For systematic decision-support towards preservation, a tool for systematically screening and highlighting the buildings with the highest emissions saving potential is needed. This kind of tools would provide the city planners with estimates to support claims of environmental savings for preservation, which could help develop systematic workflows for including environmental considerations in urban development.

In conclusion, expanding the scope of the SAVE register further – both in terms of criteria and ages of buildings covered in the framework – would be a significant factor in supporting the

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city's work on building preservation. To develop tools to inform urban planners on the environmental saving potential would strengthen the information base on which urban planners can pursue preservation of buildings based environmental considerations. For successful implementation of these tools, it is furthermore suggested the Planning Act is adjusted to expand the type of requirements that can be included in local plans (i.e. environmental threshold values, maximum carbon footprint per m^2, etc.) to increase the cities' agency in supporting resource efficient urban development based on building preservation and transformation.

4.3.3 London's contribution to the policy

Since 1947 the UK has 'listed' buildings of particular architectural merit to ensure they are preserved and protected. Restrictions for categories I, II, and II* vary, but all cannot be demolished without special permission. Recently Will Arnold, head of Institute of Structural Engineers IstructE, has put out the call to the industry to add a grade III listed status for all buildings – protecting all from needless demolition without a thorough review. The goal of the campaign is not to stop demolition entirely but to reorder priorities within the construction sector and ensure due care is taken when demolishing existing structures.

4.3.4 Vantaa's contribution to the policy

The Korso school D5 demonstrator examined the renovation alternatives of a heritage-listed building in conjunction with the preservation of the heritage value. It is an example of a building with heritage value in its neighbourhood, but presently no use in the original function, so finding a new usage is the only pathway to preservation. Therefore, it operates at the intersection of current architectural and historical value based preservation schemes, but also demonstrates environmental value preservation, and how these two can be made compatible with one another.

Out of the renovation alternatives examined in the demonstrator, the lightest refurbishment buys time to find a more permanent usage for the building. It improves the indoor air quality enough to enable temporary usages, but assumes a more extensive renovation will need to follow by year 15. The environmental results show that buying time is a feasible approach even if the building's present energy efficiency is poor. Combined with the more extensive renovation at year 15, which improves the energy efficiency, the lightest alternative still performs equal to a typical new build, a concrete building, in terms of the CO_2 emissions. The two examined heavier renovation alternatives are compatible with a permanent change of usage. Both of them outperform new build environmentally. The energy renovation outperforms the 'regular' renovation, however the most extensive energy renovation is not well compatible with the heritage value of the building, as it changes the appearance of the building too much though the addition of insulation on top of the facades. Thus, a more heritage-compatible alternative for the energy renovation was devised, the environmental performance of which falls between those of the most extensive energy renovation and the regular renovation. The demonstrator suggests that sensible compromises can be found for heritage value-preserving energy renovation of listed buildings.

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The City of Vantaa is planning to include renovation feasibility assessment as part of the demolition permit process for certain types of buildings. It still needs to be specified how thorough an assessment will be required. Embodied carbon will most likely be one key criteria. Other possible criteria would be age, gross floor area (m^2), preservation values, purpose of use and location (district). Building inspection authorities will need to be trained for the process.

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5. Summarising findings and final recommendations

The work with the twelve circular demonstrator projects in the CIRCuIT project has given a deeper insight into the advantages and problems of building transformation as a means of circular economy. All the demonstrator projects showed that there were both environmental and financial savings to be gained by preserving and transforming existing buildings than demolishing them and building new. **Therefore, the overall recommendation is that the building owners, investors, and public authorities should prioritize circular retention principles through transformation. It is especially important that possibilities of transformation are investigated as early as possible, before the demolition decision is made.** Political instruments, such as requirements for screening potentials for transformation before demolition, or the Danish SAVE system, can be expanded to also cover potentials for transformation and thereby be used to inform and require the preservation of existing buildings.

However, there were also some challenges during transformation, which could be divided into building-specific challenges and regulatory challenges. Of the building-specific challenges, was harmful substances in the existing building parts often the biggest barrier to whether a building can be transformed or not. **This therefore underpins the recommendation to investigate the transformation potential as early in the process as possible so that all limiting factors, such as harmful substances, can be identified before the design plans for transformation are developed.** Another building-specific challenge was that the existing buildings often had a much higher energy consumption than new buildings. The large CO_2 saving that could be achieved from the lower material consumption during transformation was therefore often offset by the significantly higher energy consumption in existing buildings, unless this consumption was decreased as a part of the refurbishment. **A recommendation is therefore to focus on also improving energy efficiency significantly when old existing buildings are transformed.**

Of the regulatory challenges, it was especially the requirement in the construction phase of the transformation that was an obstacle, often because the transformation projects needs to fulfil the same rules as new construction, which existing buildings may have difficulty complying. For example, the introduction of new roof dwellings in unused roof spaces of old multi-storey buildings in Copenhagen often also meant that disabled access routes, lifts and possibly parking spaces had to be made. This could drastically increase the cost of the transformation and thereby make it unprofitable to use the roof spaces, even though they constitute a great potential with only 18% of them in use today as dwellings. It also turned out that in several of the cities there were fiscal conditions which meant that transformation and refurbishment were taxed higher than demolition with subsequent new construction. **The final recommendation is therefore that new construction and for transformation projects are equalized and that it is further investigated in all cities how this issue can be handled within the current legal framework.**

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The final summary of recommendations by the CIRCuIT consortium are:

- Building owners, investors and public authorities should prioritize circular retention principles.
- Assessing transformation potential of existing building stock and information about opportunities for transformation should be done as early as possible.
- Introduction of preservation status for buildings based on how much environmental value they can provide should be a priority in relation to urban development.
- Legislators and municipalities should enforce financial mechanisms to encourage building retention and transformation.
- Legislators and municipalities should equalize the framework in construction legislation for new construction and transformations projects. Further, should cities investigate how this issue can be handled within the current legal framework for regulating construction.

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Appendices

Demonstrator	**D1: Business case for Urban densification through circular roof conversions of 1900s housing, Copenhagen.**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Benedicte Krone (Plan1) & Mette Damgaard Nielsen (Plan1). With contributions by: Rune Andersen (DTU)

1. Mission statement, background and political decisions

The city centre of Copenhagen, is very much defined by large areas of masoned, multistorey housing, the majority of these constructed in the period 1850-1950's, even though the typology became common in the city around the late 1700's.

Even though these building are not listed, they have significant architectural and cultural value, in that they make up the fabric of the city and are an essential part of what makes Copenhagen feel like Copenhagen.

This case study explores the possibilities of urban densification of the Copenhagen city centre, without changing the look and feel of the city, through roof conversions. By adding the focus of circular construction, the intent is to make probable that converting roofs into apartments is a viable, affordable and sustainable way to create a large number of new housing m^2 in a dense city centre.

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The city roofs hold great potential for sustainable densification.
Seen here is Nørrebro with the typical multistorey housing typology.

2. Project details

The case buildings selected for this study, represented the two most common rooftop typologies: a slate/asphalt clad flattop roof and a tile clad gable roof. In the business case calculations, the gable roof typology was chosen as the most suitable.

The initial case study included speculations regarding the material in- and output of a number of different material components of the roofs, but in this calculation, it was decided to only opt to include the reuse of tile cladding, as the only change from the "business as usual" construction method. The main objective was to compare the LCA and LCC data of a converted-roof-apartment to the data of newly constructed apartments of similar size, to see which (or if any) sustainable advantages the roof conversions have.

The selected case study building was a classic multistorey housing building with a footprint of 700m^2 and existing 4670m^2 of housing (5 floors, 70 apartments). It was built in 1937.

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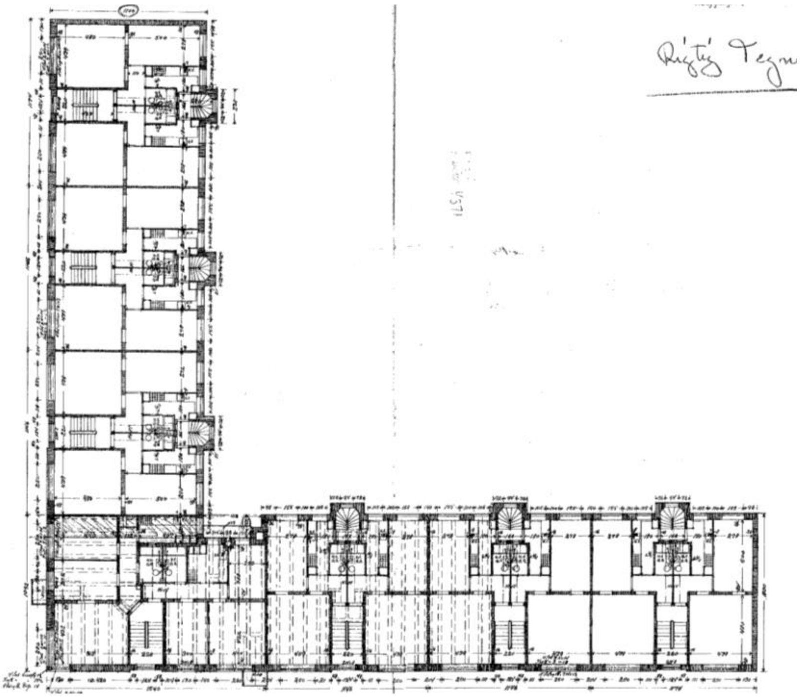
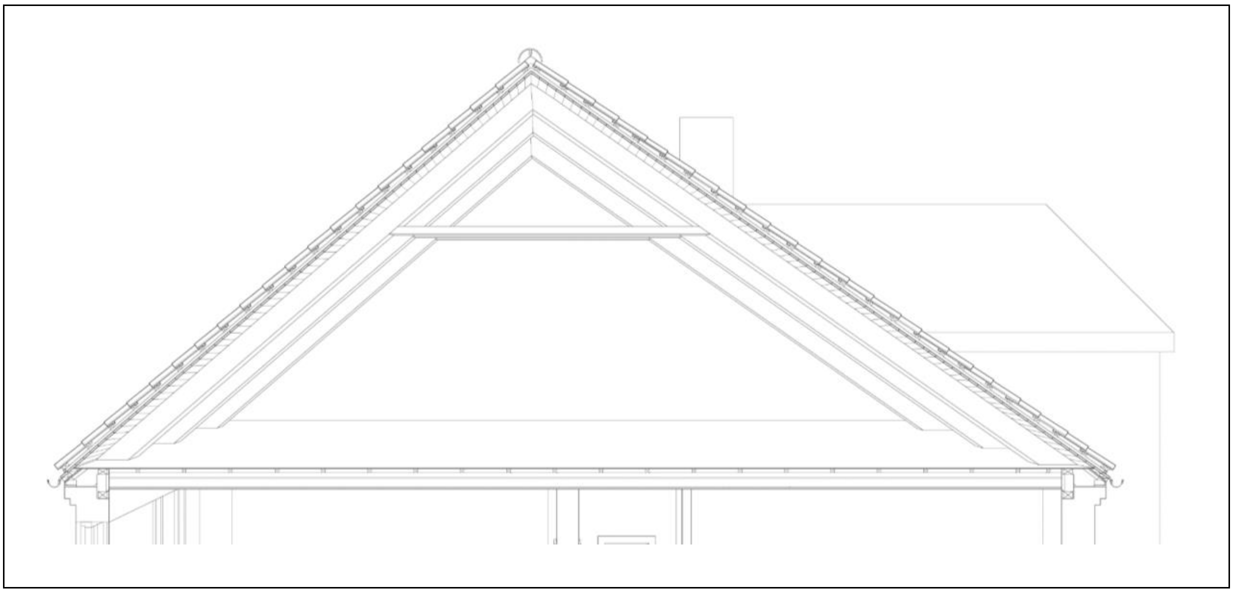


Original drawings of a regular apartment floorplan.

The building has been renovated and maintained over time, but it’s main function of housing remains, as is typical for these buildings. The roof floor is used for storage and for drying clothes today.

Transforming the spaces into apartments of course requires adding materials to the new construction, as opposed to simply renovating, such as added insulation, plaster walls, kitchen, bath etc. All these added building materials are accounted for in the calculations.



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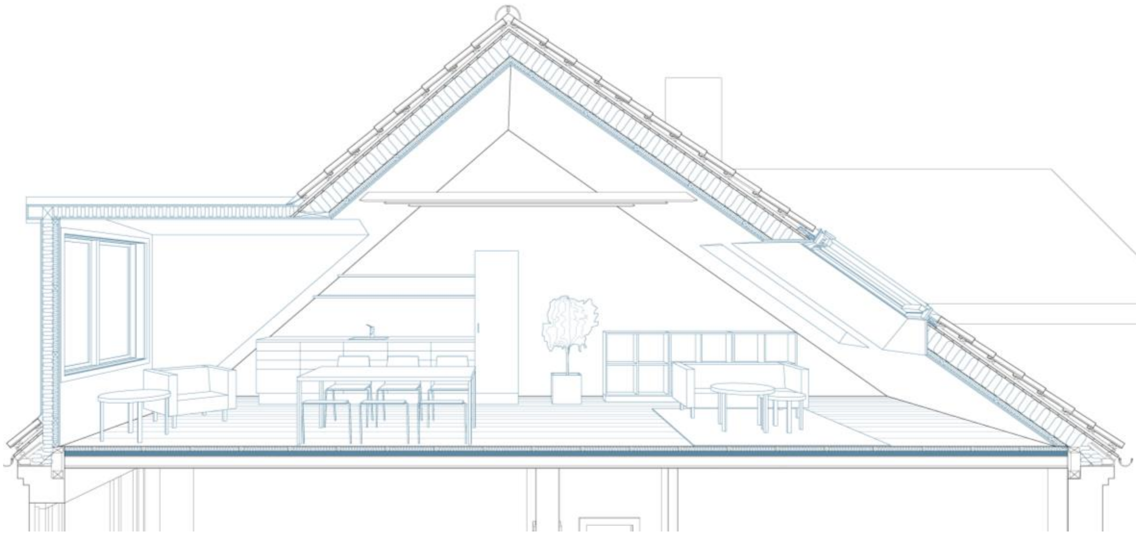
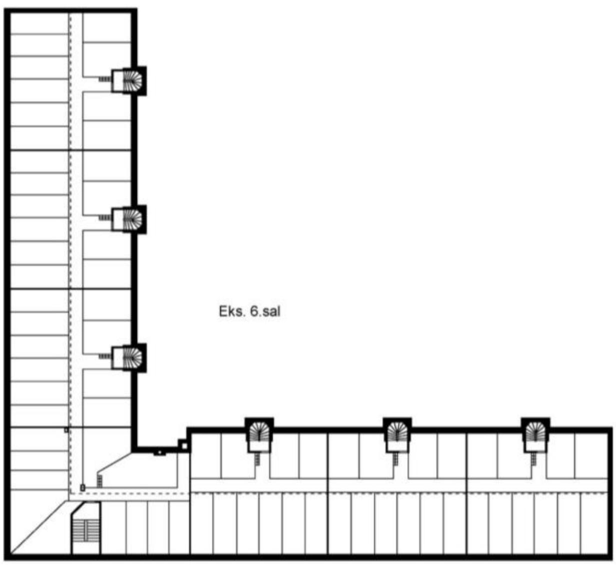
Existing roof floor.



Future apartment.

Exempted from the calculations are the possible material use for creating/renovating storage rooms in the basements. A premise for the case study is that the existing heating and water supply systems have the capacity to be extended to the new floor, so any materials that would be required to make a major change in the supply systems are not accounted for.

In the project 7 new apartments were created, averaging 75m^2.



Existing roof floorplan, with storage rooms.

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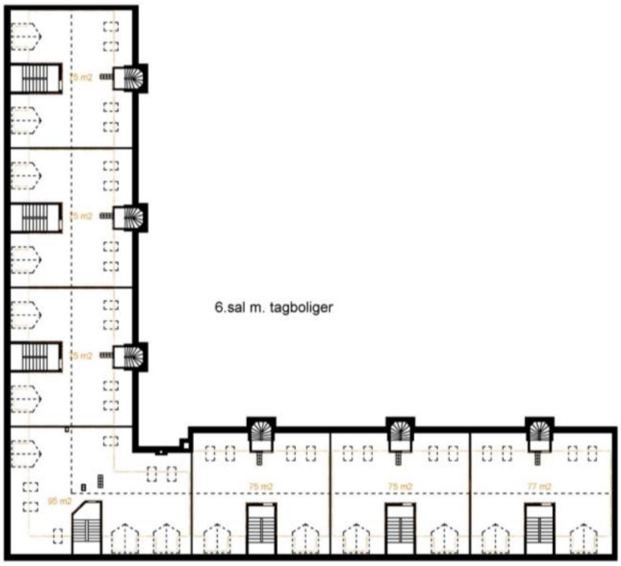

Future floorplan, with proposed placement of dormers and skylights, and with the main staircases extended to reach the new floor. Individual rooms are not shown.

The project is a theoretical case study but based on several already concluded roof transformations. An actual building project has therefore not been carried out, but the analyses use the data collections from real projects. The development of the project is primarily carried out by architects from Plan1, with the assistance and guidance of DTU.

3. Objective

Many of the materials used for making the roof transformations have the potential to be replaced with more sustainable materials/techniques, but the purpose of the case has been to make a scenario which could be easily scaled up and carried out, without contending with existing rules and regulations for buildings. Changing materials into more experimental and untested products would reduce the realism of the case study, as they would not be able to achieve a building permit.

Thus, the case study examines only the bonus of reusing the existing tile cladding on the roof, as this is a feasible approach to add to a roof transformation project. By adding the reuse of 80% of the existing cladding, the amount of virgin materials being used was brought down.

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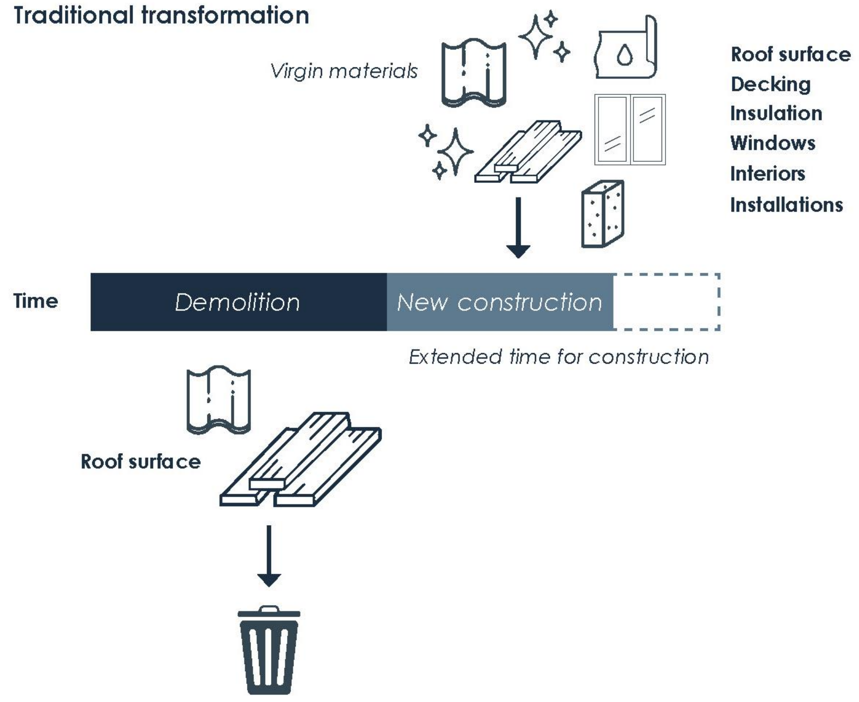
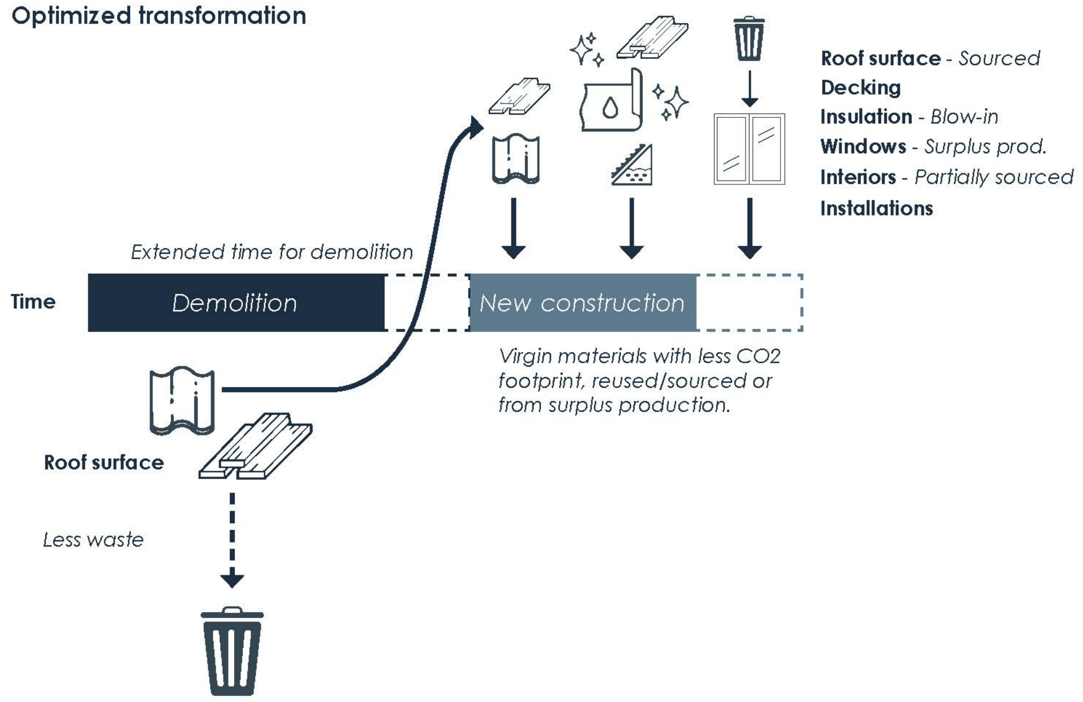


Material flow diagram for traditional roof transformations, as opposed to simple renovation.



Material flow diagram for optimized roof transformation, including several possible sources for circular reuse of discarded materials.

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The practical approach for reusing tile cladding is as follows: When demolishing the old roof, the tiles are slided down instead of thrown. The individual tiles are then checked for integrity and either stacked for reuse or discarded (to be crushed to a powder and reused in new bricks). The reuse of tiles extends the time period for demolition a little and requires a designated area in the building site for the storage of tiles. Before putting the tiles back, they should also be cleaned for algae etc.

4. Technical analysis

4.1 Challenges

By not including experimental materials or techniques to this part of the analyses, the case study scenario does not face any practical/technical challenges. It is fully possible to execute the proposed transformations, with reuse of tile cladding.

The challenges posed to the case study lies mainly in municipal restrictions towards the creation of roof transformations and in consumer insurance of reusing the tile cladding.

The existing municipal/building regulations require several dispensations to create new apartments: establishing more parking per new apartment, establishing elevators for apartments above the 5th floor, establishing more recreational areas on the same cadastre.

Challenges regarding the reuse of cladding lie mainly in the fact that contractors and insurance companies cannot (or are unwilling to) deliver the same guaranties for the new roof as they would when using virgin tiles.

There is also the challenge of making the conversions financially attractive for the builders. Today the added costs of transforming a roof floor into apartments rather than just renovating, are too high for most housing owners to consider, even with the increased rent income from future apartment residents. One solution is to sell the entire roof floor to a developer and create a separate owner’s or cooperative association, but this is not favourable for the existing apartment owners of that building.

4.2 Solutions

The municipality of Copenhagen are already willing to give dispensation for the mentioned requirements, but making more standardized and lenient regulations specifically for roof conversions would greatly ease the process of achieving a building permit and would encourage people to carry put these types of projects.

Until testing a certifications of reused tile cladding is available, it is difficult to imagine how the issue of insurance and guaranties can be solved. The financial risk of using reused tiles

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lie solely on the consumer (usually cooperative or owners associations). A risk only few are willing to take on.

Solving the issue of financial profitability could be assisted by making financial support available, as is already the case for other types of urban renewal today. The municipality could support circular urban densification by including roof conversions to the list of urban renewal project types that receives partial funding.

4.3 Lessons learnt

The case showed that creating new housing via roof conversions is technically uncomplicated, but it is the legislative barriers and the overall financial aspects for the builders (cooperative or owners associations) that hinder the upscaling of roof apartments in general.

The reuse of tiles is likewise technically unproblematic but is challenged by the lack of certification and testing of durability.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the LCA performance has been compared to a base case of new construction, without circular objectives. For this project the base case is the average environmental impact calculated from 60 new constructed Danish reference buildings[1].

The baseline for the economic assessment is the construction costs, maintenance price and expected income from rent over 50 years, by building a new building on the same cadastre.

5.2 Environmental performance indicators

Environmental performance has been assessed against a range of environmental Life Cycle Assessment (LCA) indicators. The indicators selected for this project are highlighted in Table 1. All environmental impacts are calculated on an annual basis and are divided by the total heated area.

Table 1. Environmental LCA performance indicators

Indicator name	Unit
Global Warming Potential (GWP)	kgCO2e/m²/year
Ozone Layer Depletion Potential (ODP)	kgCFC11e/m²/year
Photochemical Oxidation Potential (POCP)	$kgC_2H_4/m^2/year$
Acidification Potential (AP)	$kgSO_2e/m^2/year$
Eutrophication Potential (EP)	$kgPO_4{}^3e/m^2/year$
Depletion of Abiotic Resources – Elemental Reserves (ADPe)	kgSb e/m²/year

[1] SBI 2020:04 - Klimapåvirkning fra 60 bygninger

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Indicator name	Unit
Depletion of Abiotic Resources – Fossil Fuels (ADPf)	$MJ/m^2/year$

The LCA for the environmental performance is calculated in the Danish LCA program named LCAByg. The data used for the LCA is the German ÖKOBAUDAT database.

5.3 Environmental performance results

Overall, the roof top apartments improved the performance of the project in 6 out of the 7 indicators.

This is made clear since the overall need for new materials when constructing roof top apartments are lower pr square meter than when constructing new housing. One of the main reasons for this, is the fact that the existing building already has a foundation as well as all the technical installations required for housing (heating, water and electricity for instance) and so the material costs of establishing these are reduced. On the other hand, the relatively small scale of each building site, requires a longer building period for each realized m2 of housing.

Adding the recycling of tile cladding for the new roof, greatly impacts the low-level output for many of the indicators.

Table 2. Environmental performance results

Indicator name	New construction baseline	Roof top apartments
Global Warming Potential (GWP)	7.07E+00 $kgCO2e/m^2/year$	3.66E+00 $kgCO2e/m^2/year$
Ozone Layer Depletion Potential (ODP)	2.00E-08 $kgCFC11e/m^2/year$	2.25E-8 $kgCFC11e/m^2/year$
Photochemical Oxidation Potential (POCP)	3.63E-03 $kgC_2H_4/m^2/year$	1.30E-03 $kgC_2H_4/m^2/year$
Acidification Potential (AP)	1.79E-02 $kgSO_2e/m^2/year$	1.06E-02 $kgSO_2e/m^2/year$
Eutrophication Potential (EP)	2.42E-03 $kgPO_4{}^3e/m^2/year$	1.83E-03 $kgPO_4{}^3e/m^2/year$
Depletion of Abiotic Resources – Elemental Reserves (ADPe)	1.05E-04 $kgSb\ e/m^2/year$	4.99E-05 $kgSb\ e/m^2/year$
Depletion of Abiotic Resources – Fossil Fuels (ADPf)	7.21E+01 $MJ/m^2/year$	4.83E+01 $MJ/m^2/year$

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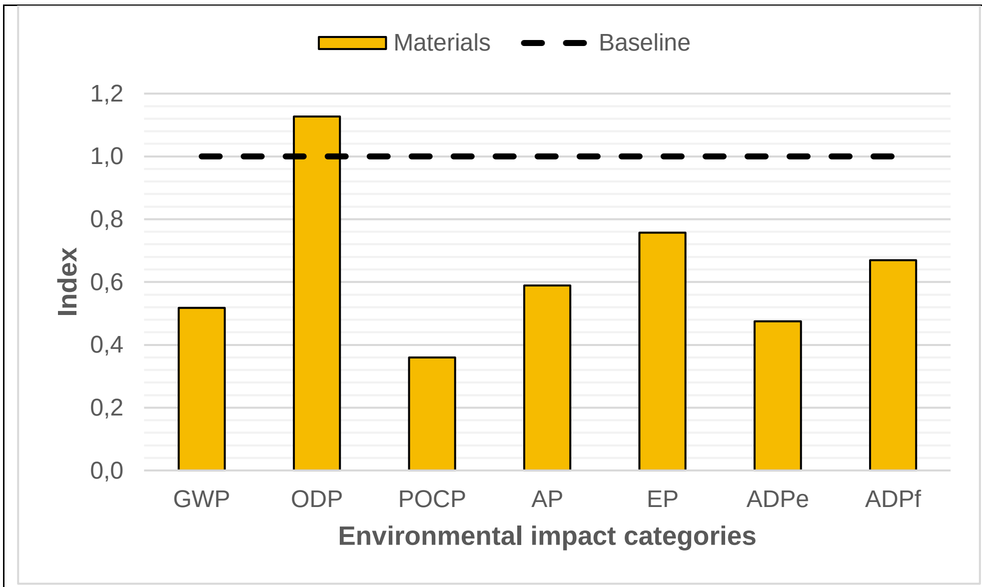

Figure 1. Environmental impact comparison of the roof top apartments in relation to the new construction baseline scenario.

The only indicator which wasn't improved compared to the base line of new construction is the Ozone Layer Depletion Potential (ODP). There are one building part in particular that causes this indicator to be quite high, which is the roof dormers. The roof dormers are covered with zinc, which emits a quite high level of ODP.

Replacing zinc with an alternative material would reduce the ODP but would increase the level of maintenance and replacement intervals.

Working to implement sustainable/circular materials and techniques would further improve the performance of the project, but here the goal was to compare the roof conversion as an overall strategy for creating new housing rather than comparing the difference of individual material performance.

6. Economic analysis

6.1 Economic analysis indicators

The economic analysis has been considered in relation to the four components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing; construction costs, operation costs, maintenance & Replacement costs, along with the relevant components of whole life cost; cleaning and income.

Since it is quite difficult to calculate how expensive the costs of operation, cleaning and income will evolve over the lifespan of the project isolated for the roof top apartments and not for the entire building, it has been chosen only to look at the construction costs and the maintenance and repair costs.

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The LCC is calculated in the Danish LCC tool LCC Byg with input data from the Danish Molio price database. For the life cycle costs and income, a 50-year period has been assessed.

6.2 Economic analysis results

The economic analysis found that in comparison to new housing construction, the new roof top apartments are quite similar in construction and constructions site costs, while the maintenance and replacement costs are lower.

Like the environmental performance calculations, this is because the individual building sites are small and because building on top of an existing setting, you need to perform customized adjustments and a large scaffolding compared to the square meters of housing established. When construction is spread out over numerous small sites, instead of building massively on bare land, the economy of scale is lowered.

The maintenance and replacement costs per square meter for the roof conversions are only 40% of that of new housing construction. The reason for this is the fact that the building below the roof apartments (the cooperative or owners association) also pays for the ongoing maintenance of the roof.

Table 3. Economic analysis

All costs are shown pr square meter	New housing construction	Roof top transformation	Difference
Construction costs	€ 1.803	€ 1.606	-11%
Construction site costs	€ 229	€ 250	9%
Maintenance & Replacement costs	€ 708	€ 284	-60%

Figure 2. Economic analysis comparison.

7. Scaling the impact and assessment of needs

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7.1 City level potential

This business case could potentially be replicated across all buildings with unutilized gable roofs and even other roof typologies (as discussed in the 5.2 deliverable). Applying this strategy to Copenhagen would result in a massive densification of the city, without having to demolish any existing buildings to do so or building new on green fields. It would also improve the energy efficiency of the buildings on which the conversions were executed.

For buildings with a roof area of over 300 m^2 and more than two stories high built between 1901 and 1949 with the same roof structure as the case building, there are currently 215,584 m^2 of roof space, of which only 16% today is used for housing. There are 181,561 m^2 of unused roof spaces in Copenhagen that, with the circular design strategy from the demonstrator, can be transformed into housing resulting in a potential saving of 30,865 tonnes of CO2eq from building materials over 50 years. The average area per person in apartments in Copenhagen is around 40.5 m^2 per person, and newly constructed apartments have an average size of 95 m^2. Utilization of all unused roof areas will, therefore, also have the potential to contribute to additional housing for 4,480 more residents or 1,910 apartments in the municipality of Copenhagen.

7.2 Realising the potential

Replicating the project is technically relatively easy. The process of designing and constructing new housing units on roof floors has been done many times before, and this is not the challenging part.

The greatest challenges for this demonstration to be applied city-wide is the challenges of financial support for the builders as well as the infrastructural challenges if the city is intensely densified. The availability of recreational spaces, car and bike parking capacity, public transport etc. as well as the supply systems would need to be adjusted.

In the case of reusing tile cladding for roof conversions or renovations, this could easily be made more attractive to implement by testing and certifying this method of construction, so the builders don't bear the financial risk of renovation in a more circular fashion. Looking aside from the roof conversions, the reuse of tile cladding as a standard practice when renovating roofs, would lower the environmental costs.

To further examine the realized pros and cons of roof conversions, the municipality of Copenhagen could carry out a demonstrator neighbourhood, identifying an area with a substantial amount of tile clad gable roofs in need of renovating, and offering financial support to selected owners/cooperative associations to establish roof apartments. This would provide important data on the performance and challenges arising when applying the strategy on a larger scale.

A less ambitious approach for the municipality would be to develop a legislative rule set specifically for roof conversions, that would make the process of permitting roof apartments easier.

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Demonstrator	**D2: Multi-strategy retention and transformation of 1970s housing estate, Copenhagen**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
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1. Mission statement, background and political decisions

Many post-war social housing developments are at risk of generating social challenges because of large-scale monotony and material tristesse: The share of resourceful households declines while people with poorer backgrounds – in terms of education, income, ethnicity – accumulate in the development. A large major in the Danish parliament passed a law for regulating the socio-economic composition of 20 developments chosen by statistical indicators including education, income, employment, ethnicity, criminality. The means, stipulated in the law, were radical since selective demolition was made a mandatory element in the refurbishments. Other measures include forced displacement, partial sale, reservation of residences for selected segments – elderly, students, people with physical disabilities etc. The law-program - often colloquially referred to as 'the ghetto-package' - has been criticized for being contradictorily decoupled from the ambitious climate policy adopted by the same parliament majority. The debate is still on-going, and a national resistance group are actively opposing the implementations.

This project contributes to the discussion of whether to use demolition as a tool for solving social problems while at the same time seeks to expand the repertory by including the possible repurposing of dismantled concrete elements from local selective demolitions as a material *and* a social resource in the reorganisation of the development.

Providing this repertory is made consciously though the case-project bridges over two Circuit work-packages – WP4 and WP5. However, it is the experience from this and other similar projects that circular principles are connected, combined and complementing each other across the scale hierarchy of buildings, parts and materials.

The aim of the project is to demonstrate the differences in carbon-footprints and generated value related to four scenarios:

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1. ‘Do nothing’, i.e. no demolition and no renovation. This, of course, a contra-factual, imaginative scenario, but it serves as a baseline for the alternatives.

2. Energy renovation, including post-insulation of roofs, facades and windows. This is a realistic alternative had it not been for the specific law-program requiring demolition.

3. Demolition according to the law-program, including replacement by standard new construction. This is the planned scenario currently being executed in design and construction.

4. Demolition as above but including reuse of dismantled concrete elements. This is a scenario currently investigated for its realization potential. In a funded innovation project, it is proposed how dismantled building parts and component can be repurposed in new functions as elements in new construction. The technical and economic aspect is of course one objective but of even importance is the social and cultural potential as the repurposed elements contributes to an air of informality and freshness – even humour - which is in radical contrast to the over-defined, technocratic monotony of the original architecture.

By assessing these alternatives, a set of recommendations are produced for political decision-makers, administrative authorities, public and private clients and grassroots.

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Figure 1: Taastrupgård originally consists of 915 residences. Appr. 2500 people are currently living in the area. The population represents 50 nationalities. The illustration shows the before and after the refurbishment. Refurbishment plan by Vandkunsten Architects.

2. Project details

Taastrupgård is situated in the suburban municipality Taastrup – a part of the greater Copenhagen district. It was built between 1968-1971 originally containing 915 residences all of them apartments with access from common staircases. The site plan was composed with very few elements: A giant parking lot along the access road, a wall-like chain of five-storey blocks parallel to road and parking, and – perpendicular to this - an endless series of three storey blocks in two rows separated by a pathway. Long and narrow balconies with concrete railings was the dominant identity-giving architectural element.

Approximately 2500 people are currently living in the area. The population represents 50 nationalities among which as little as 20% are native Danes. Apart from the Danes, the dominant ethnicities are Turkish, Moroccan, and Somali who have been living in parallel societies in three generations – many of them without basic Danish language skills.

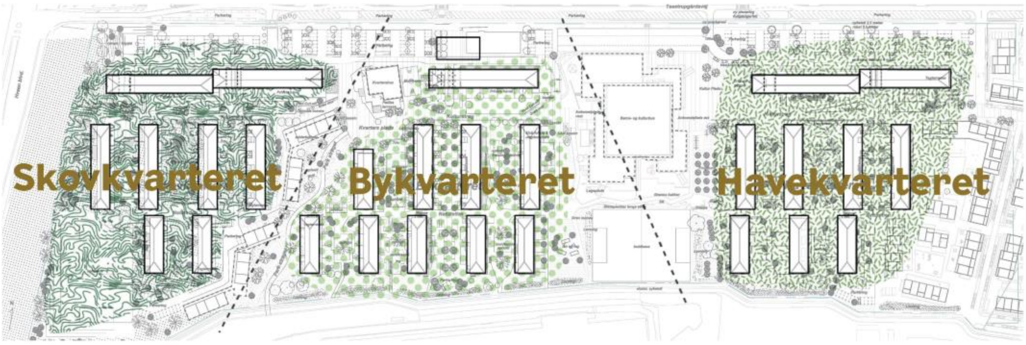

Figure 2: Principle for subdividing the area into three neighbourhoods by selective demolition.

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Vandkunsten Architects designed a masterplan for the refurbishment on commission from the public client corporation KAB, a major operator in development and management of social housing in Copenhagen. The most important elements of the plan are the following:

1. Downscaling: Subdivision into three neighbourhoods with individual identities inspired by three themes: Wood, City and Garden.

2. Minimization of demolition: Creative calculation and balancing of tenant segments by subdivision and/or amalgamation of apartments. 622 housing units remain.

3. Reusing / repurposing of dismantled elements in order to bring down emissions.

4. Partly demolition of blocks rather than demolition of whole blocks. To create variation in scale.

5. Densification by means of new building types and typologies: School, culture house, housing collectives for elderly, sports fields.

6. New housing typologies including terraced houses, collective housing, garden apartments, housing for students, apartments for families with disabled members.

7. Improvement of landscape and infrastructure for pedestrians and bicycles providing better connections to the surrounding area including train-stations.

8. Tight connections to the neighbouring new development towards east.

Figure 3: The tree neighbourhoods separated by elements of densification and differentiation: School, sports, culture house, housing for elderly.

The tenant's assembly – which is the formal client – approved of the plan in 2021 and the project planning is in the technical design stage (RIBA 4) starting with a pilot block in order to take learnings and receive the tenants evaluations before upscaling to the project. The construction is planned to take place from 2023-2031.

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As an addition to the original brief the Danish philanthropic foundation Realdania funded in 2021 an analysis of the reuse potential of concrete elements dismantled under demolition and refurbishment. The findings were found to be so promising that an implementation is intended in the upscaled project. The first step has been taken since the demolition project include careful dismantling of elements and on-site storage.

Figure 4: Examples of the differentiation according to the three themes: Wood, City, Garden.

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Figure 5: Present state of blocks.

3. Objective

Size. The demolishment obligation - even after the masterplan's attempts to minimize it - amounts to 15.000 tons of concrete being excavated from Taastrupgård - roughly equal to 2.000 t CO2e.

Impact. The politicians that took the decision to make demolition a mandatory element in the refurbishment of the development was not informed about the climate impact of their decision. To improve the basis for future decisions the first objective of this project is to assess the climate impact of demolition and belonging replacement with new off-site on construction and compare this to retaining the buildings with or without energy-refurbishment and with or without material reuse.

Time. An argument frequently used pro demolition is that the substituting buildings will perform better in operation and thus saving energy for heating. Will these savings be offset by the carbon-footprint of material production and processing? The time-dimension may be crucial: the share of fossil energy sources in all lifecycle stages, the expected future change in composition of energy-mix, and the contribution of up-front-emissions with resulting risk of irreversible climate change.

Repurposing. The secondary objective of the project is – as a plan B - to reuse a maximum of concrete parts at a maximal reuse level, knowing well that the potential is restricted by the quality of the concrete material which differs according to the functions of components. Structural concrete such as floor slabs or wall elements can only be replaced in indoor functions which often excludes direct reuse (use in the same function). Instead, repurposing (reuse in a new function) is often a more productive option, particularly if the new function is as an element with a longer expected lifetime than the original function. Repurposing aims for

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upcycling at component level. This strategy is supplemented by local downcycling where concrete elements are crushed to gravel on-site and used for road-fill accelerating the carbonatization process.

Social effects. Since the reason behind the decision to demolish and transform is based on the wish to improve social conditions, it makes sense to introduce a social dimension to both objectives:

Social gains from demolition (change of development physical structure and demography). Demolition with substituting new construction elsewhere will disrupt the existing inappropriate distribution of social segments. A large share of the population will move to other parts of the municipality/region and a number of new types of residents may be attracted. All according to the political strategy. The backside is that other developments may be affected by the arrival of large groups of exiled inhabitants from Taastrupgård. Negative social offset effects are not covered by calculations and therefore not included in the business-case. Thus, the political strategy based on demolition is a social experiment where two alternatives – the status quo and the aggressive transformation – eventually can be compared. However, third alternatives such as reinforced social efforts in the existing are not a part of the experiment, which excludes the possibility to draw final conclusions.

Social gains from transformation of buildings and repurposing of components. These can be obtained through the combination of two effects: First, transformation and repurposing almost always means dimension and appearance different from new constructions and hence from the usual, the habitual, the ordinary and the expected. These elements of surprise are in aesthetical theory known as 'enstrangement' and is in architectural design a means to generate and strengthen building identity and avoid anonymity. Second, insofar that the activities are visible, decodable, and recognized by users and spectators, the reused elements come with a narrative and a history which adds a time dimension to architecture. By representing a narrative and a history the buildings become less indifferent to people – something which is known to even generate economic value due to provenance. Provenance gives no guarantee for the preservation of a building but increases the likelihood of avoiding future demolition and should be considered as a long-term preservation strategy.

4. Technical analysis

4.1 Challenges

Objective 1. Alternative scenarios.

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GWP - consequenses of Scenario 1-4 *Unit: CO2e/m2/y*										
Scenario (80 year)	*LCA-phase*	A1-3	B4	B6	C3	C4	A-D	pr. m2	Area m2	**Total**
1. Do nothing but maintain	*indlejret*	0,45	0,94	-	-	-		14,16	79.304	**1.123.177**
	drift			12,77						
2. Energy renovation	*indlejret*	0,16	0,77	-	0,62	0,06		7,18	79.304	**569.667**
	drift			5,58						
3. Partial full replacement										
a. Renovation (as S2)	*indlejret*	0,16	0,77	-	0,62	0,06				
	drift			5,58				7,18	50.044	**359.483**
b. New construction standard high (2023)					0,68	0,45	8,00	9,13	29.260	267.144
c. New construction low (2030)					0,68	0,45	4,50	5,63	29.260	164.734
3A: a. + b. = business-as-usual								16,31	79.304	**626.627**
3B: a. + c. = ambitious								12,81	79.304	**524.217**
4. Partial repurposing (landscape project)										
Unit: CO2e										
a. Project with repurposing of concrete										-
b. Project with new construction										850.000

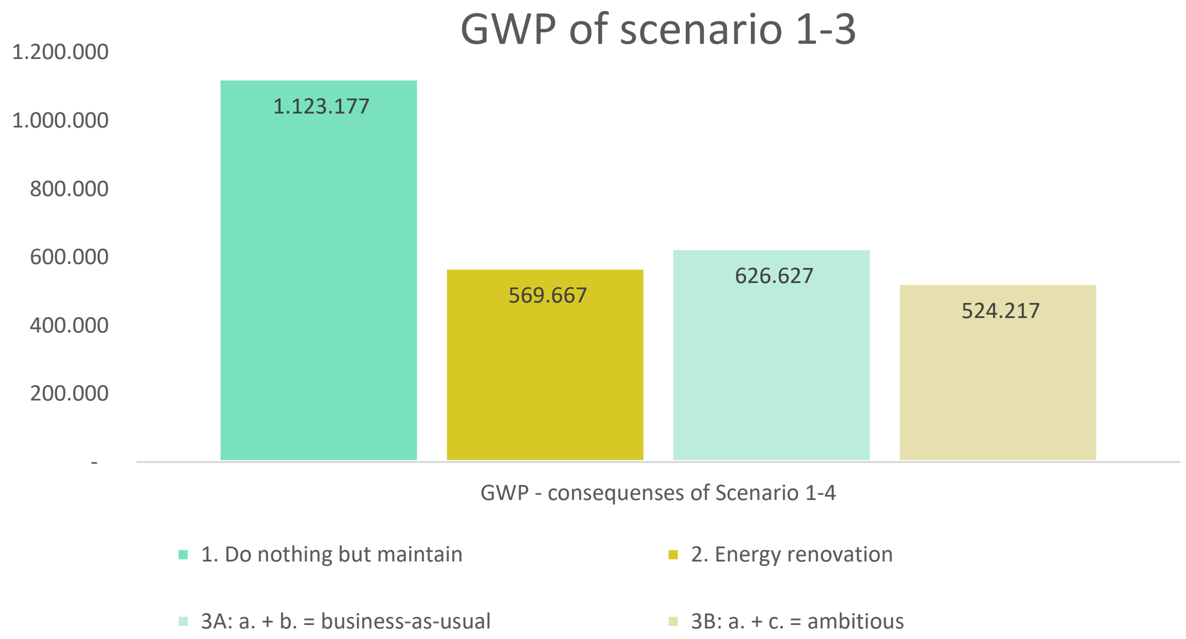

Figure 6: GWP consequences of Scenarios 1-3

Scenario 1:

In the ‘do-nothing’ scenario the CO2-emissions from a continuation of the existing use including replacement of building parts according to standard intervals (B4) and energy for operation (B6) was calculated. Decarbonisation of energy-sources is estimated conservatively and according to governmental (LCA-Byg) guidelines. Energy consume is based on

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maintenance data from the operating organisation (KAB). The resulting footprint is 14,57 CO2eq/m2/year.

Uncertainties and reservations:

No energy-saving or life-extending or -shortening improvements are attributed replacements.

Possible more ambitious political actions to increase the share of renewable energy in the supply mix are ignored.

Scenario 2:

In the energy-renovation scenario, the refurbishing of the building and the resulting energy need for operations has been calculated based on the actual realisation project for the retained building blocks. Energy consume is based on calculations by Wissenberg as part of the project planning. The resulting footprint is 6,40 CO2eq/m2/year.

Uncertainties and reservations:

The calculation is based on the actual renovation project which has a budget in the higher end and several transformational activities are included such as new space plans and changed roof geometry. An average energy-renovation with post-insulation of roofs and facades may have lower up-front emissions.

Scenario 3:

In the partial renovation scenario which includes demolition, transformation and energy-renovation a two-fold calculation has been made; 3A and 3B. The demolished blocks and housing units will be replaced by new construction elsewhere. The level of CO2-emmissions from new construction depends on ambitions and when in time the construction will take place, the latter due to stricter legal requirements by each year. Scenario 3A assumes the legal standard for sustainable building in 2023 which is 8 CO2eq/m2/year. With addition of the footprint from demolition it reaches 9,13 CO2eq/m2/year. The legal requirement in 2030 calculated in scenario 3B is expected to be 4,5 CO2eq/m2/year. With addition of the footprint from demolition it reaches 5,63 CO2eq/m2/year.

The twofold calculation makes sense because the renovation process will run over 10 years and the successive replacements by new construction will meet different requirements.

Objective 2. Repurposing of concrete elements and reuse of downcycled concrete.

In a pre-demolition audit the technical drawings of the original project for Taastrupgård have been screened and compared to destructive analysis on-site to optimize both the dismantling logistics and the transformation design for remaining buildings. A typical challenge is that the

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executed constructions have changed during the long construction period, so the detailing differs significantly despite the uniform look. Fortunately, a so-called 'dry assembly system' with mechanical joints instead has been used widely which allows the demolition contractor to loosen the elements and lift them with very few damages.

To screen the functional potential based on technical and toxicological analysis an explorative design process is needed in which the usable elements are combined with a multiplicity of building parts serving a multiplicity of functions. All proposals must be evaluated according to logistics, cost and technical quality which results in a catalogue of possible solutions. The solutions are presented to the board of tenants' representatives who prioritize between them. Eventually, the contracting costs will become known with the contracting tender bids. All in all, a hard elimination race.

Some of the proposals can easily be disqualified by exceeding the budget such as a terraced landscape made of stacked balcony railings as a new entrance to the development – a recreative and welcoming pedestrian connection to a shopping square west to the areal. However, the planning of this proposal is not given up since it might be an obvious subject for applying for external funding.

Aggregated concrete from demolition is used as filling under paved surfaces. The estimation is that all the concrete can be utilised locally for either repurposing or filling which means a 100% reduction of transportation and residual waste for landfill.

Figure 7: Example of staircase-elements repurposed as recreative landscape elements (top) and balcony railings used for terracing (bottom).

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4.2 Solutions

Objective 1:

The demolition of blocks is taking place according to the political act and the masterplan by Vandkunsten Architects. In writing, no new construction has yet been initiated within the municipality specifically to replace the lost housing units. This means that the tenants have been offered rehousing in vacant buildings within the district. Some might have moved to other districts or chosen alternatives such as privately owned or privately rented housing. This also means that there are so far no evidence or indications of the actual level of carbon-footprint.

In order to provide a supply of new housing types, the masterplan proposed rather far-reaching transformation with interventions in access systems and structural building parts. Also, to create variation in scale and appearance a relatively large number of housing blocks was affected by the selective demolition. In this sense solutions have not been ground on common technical sense or sheer rationality. This indicates that both the CO2-footprint and the costs might have been less if not the social transformation had been in focus.

Objective 2:

Elements destined for reuse were selected based on technical quality, expected lifetime, costs, logistics, functionality, and aesthetics. These criteria allow for a range of varied solutions. It was decided to make use of the elements mainly in the exterior. Solution categories includes high-quality urban pavements, recreative furniture, landscape terracing, park interiors but also low-quality rough pavements of floor slab elements where deterioration over time would be accepted as an intended characteristic.

The solutions are tested in the project for the pilot block and evaluated before upscaled execution. An important part of the test-process is to optimize logistics for handling the elements under and after dismantling. Some elements are easily dismantled without damaging others are more challenging particularly in case of cast joints or hidden fixations.

In writing, the demolition process is finished, and elements are stored on-site. The construction of the refurbished landscape will take place during 2023. In early 2024 the results can be evaluated. Careful handling of reused elements are not part of current contracting practices and the contractors' experiences from construction is crucial to take learning from the project. Increased use of craning will be needed to handle the elements for paving and landscaping, an unusual tool for a landscape gardener which will probably involve some training or cross-disciplinary collaboration.

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4.3 Lessons learnt

Objective 1, scenario 1-3

The LCA-calculation gave rise to some interesting points about the feasibility of different policies:

Energy renovation pays. The investment in energy saving refurbishment represents the biggest difference in CO2 footprint cutting it down to the half. The absolute less favourable scenario from a climate perspective is to proceed the current practice. This strongly supports the EU Taxonomy requirements.

The kind of new construction matters. The GWP can be considerable reduced by planning the compensating housing to replace demolished buildings with low-emission solutions. It is an interesting and even somewhat surprising finding, that scenario 3B implies – uncertainties unforetold – that a solution might exist where demolition and full replacement was optimal for the climate.

Demolition and replacement is an expensive solution. The Taastrupgård-case is per se a deficit business. Whether it pays in a wider societal perspective due to reduces pressure on the social institutions for welfare, justice and health is hard or impossible to ascertain and may depend on the masterplan's success. The case indicates though a potential for taking political decisions with based on a social agenda and connect them tightly to a strategy for low climate impact.

Execution matters. The success of the masterplan - measured as the residents' cohesion to the place, low eviction, differentiated demography, low criminality, feeling of security etc. – will be pivotal to fulfil the intended purpose. The spatial quality, the variations, and the landscape quality are planning measures that the masterplan strongly rely on. The repurposing of concrete elements contributes to this strategy.

Objective 2, scenario 4

With the explorative analysis and the resulting catalogue of solutions it has become overwhelmingly clear that repurposing as a circular methodology offers several new design-based values. The solutions are technical but simple and can be categorized as low-tech construction. The design is accordingly easy to decode, and its narrative is easy to understand and retell for lay people.

The mere quantity of elements enables the architect to offer abundant recreational facilities which would otherwise be impossible within the restricted budgets of public housing. Reuse is often associated with poverty and scarcity, but in this case, it is rather providing luxury. Besides such common functional luxury - which will support the social quality – the unique identity generated from the reuse-based design will contribute to raise the attraction-value and reputation of the former stigmatized area.

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However, it is worth to note that a large part of the solutions in Taastrupgård are reliant on a higher degree of reversibility in its structural system than is normally found in similar post-war developments where cast joints between prefabricated reinforced concrete elements constitute the normal. To separate such elements without excessive damaging involves expensive diamond cutting.

A considerable CO_2-saving effect from substitution of new materials can be found but the most important gains seem to be from the social qualities. The project will serve as an inspiration for other cases while the direct upscaling potential through imitation will be strongly dependent on context in particular the structural system.

5. Performance measures

5.1 Baseline, indicators and scope

The LCA for the environmental performance is calculated in the Danish LCA program named LCAByg along with its database.

All scenarios are based on a lifespan of 80 years. The same assumptions for decarbonisation of energy have been used in all scenarios. Only GWP is evaluated in the case. Information on other LCA parameters is to be found in the appendix.

Scenario 1. The baseline chosen is the do-nothing-scenario since there is no acute technical need to renovate. Nevertheless, a normal maintenance scenario will be included as a realistic part of this scenario.

Scenario 2. Instead of using fictious or generic data for calculating the most normal scenario - an energy renovation including post-insulation of roofs and facades – the data of the actual project has been used.

Scenario 3. For the new construction two levels of requirements to up-front CO2 emissions are used to represent respectively the range of options and the development over time.

Scenario 4. Imbedded CO2 in dismantled and repurposed or aggregated concrete elements are calculated as CO eq.

More. A fifth scenario might have been suggested; to demolish without replacement. This is what has actually happened so far, as described above, since no particular new social housing projects has been initiated. In this case the project would contribute to the reduction of the total housing area implying a more efficient use of off-site square-meters. However, such a scenario – which might be categorised as an aggressive 'degrowth-strategy' is far beyond the scope for current policies.

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6. Economic analysis

6.1 Economic analysis indicators

An LCC analysis has not been conducted due to the political character of the renovation strategy. Instead, up-front construction costs have been compared based on the approved renovation budget (see appendix) and – concerning the new construction - the Danish building cost index and the law amendment on maximal costs pr. m2 for Danish social housing. In scenarios 3A and 3B both renovation and new construction is relevant (see appendix).

Construction costs				
Unit: DKK (= EUR0,132)	*Renovation*	*Demolition*	*New construction*	*Total*
Scenario 1	-	-	-	-
Scenario 2	1.285.210.843	-	-	1.285.210.843
Scenario 3A	809.682.831	111.714.973	731.500.000	1.652.897.804
Scenario 3B	809.682.831	111.714.973	731.500.000	1.652.897.804

6.2 Economic analysis results

Of the scenarios 1-3 are only scenario 2 and 3A+B compatible with the requirements of the EU Taxonomy Compass (https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity/224/view). Hence, scenario 1 becomes irrelevant even if it in a strictly economic perspective might be feasible. And even if it could be considered feasible, the business-case would be significantly undermined in case of increasing energy prices, making the scenario a risky business.

Scenarios 3A and 3B are assumed to have similar costs despite the displacement in time which means that all prices refer to 2022.

The renovation and demolition costs are according to budget and are likely to increase after tendering, whereas the cost of new construction is locked due to the legally fixed maximum which can not be trespassed under any circumstances.

The difference between scenario 2 and 3 (DKK 367.686.961) can be seen as the additional costs of the social transformation required by the adoption of the law to prevent parallel societies. The cost is equivalent to roughly 15.000 m2 or 150 housing units.

7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across the whole of Europe or wherever you may find socially challenged developments. The absolute key point of the Taastrupgård-case is that social policy and climate policy need to go hand in hand and that it is actually possible.

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In the greater Copenhagen area multiple challenged developments exist. Few of them in a category of scale similar to Taastrupgård but similar strategies might be deployed in less comprehensive versions. Aspects of the Taastrup-case with a replicating potential are such as:

Energy renovation. This is a generally applicable action which reduces the future need for energy, no matter how the energy mix is composed. Furthermore, it contributes to self-sufficiency which stabilized the society and reduces the dependency of capricious supplyers, fluctuating markets etc.

Selective interventions. Noticeable and/or spectacular interventions in the building mass can change the character and atmosphere of a development without causing large-scale emissions. New construction as densification might become an integrated part of a strategy along with new housing type generated by inventive transformation.

Repurposing of dismantled elements. As a means to obtaining character and atmosphere, repurposing of elements can be used to generate a time dimension, humoristic features or allow an abundancy of material use which would otherwise be expensive and inappropriate.

Potential environmental and economic impact

It is always a discussion how the impacts of urban quality can be measured. If Taastrupgård had been privately owned an increase in sales price for apartments or public value assessment for taxation would be a strong indicator. But for non-profit social housing developments profits are collected as saved social costings across the societys multiple systems. Since the law act on preventing parallel societies was proposed and adopted because of concerns about the social costs of dysfunctional housing development, it could be taken for granted that there is a general agreement that it in general is good business for the society as a whole to transform socially challenged developments.

By combining this understanding with a concern for the climate consequences of the transformative actions it might be a win-win for society and climate. Social sustainability does not necessarily burden the climate.

There seems to be a particular environmental gain in case the socially justified initiatives come along with ambitious solutions to reduce climate impacts. If new construction as replacement for demolished housing are planned to comply with stricter requirements as normal, a transformation project can become a driver for industrial developments in parallel to solving a social task.

Apart from ambitious programmes for reducing climate impact from new materials, repurposing and other kind of reuse might find a place in the toolbox.

7.2 Realising the potential

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Suggested steps to be taken to realise the potential found in the Taastrupgård case:

Step 1: Defining the means of the policy with respect to the climate. In the Taastrupgård case which is an effectuation of a national legislation which imposes particular means (demolition) without any alternatives. In a climate perspective this is not recommendable unless appropriate requirements to comply with climate goals are defined in parallel. This should be a consideration for decision makers at national as well as municipal levels.

Step 2: Defining the appropriate requirements to comply with climate goals. It can be actions on governmental level via the building code or municipally decided requirements such as material impact, energy consumption in operation, reuse, circularity etc. Depending on what democratic authority that puts the requirements to practice different tools are available; national law, local plan framework, tendering conditions, contractual negotiations. In Denmark the Nation Building Foundation (Landsbyggefonden) is a key player in that administrates the grants for renovations which constitute the major share of financing of social housing renovation. The NBF, though under governmental control, holds the power to define conditions for granting financing.

Step 3: Ensuring project quality. The Taastrupgård case demonstrates the amounts of financial resources at risk if the social targets are not met in terms of residents' satisfaction and effects are not measurable as savings in multiple social systems. The municipal planning authorities including departments for environment, technical and aesthetic matters, infrastructure etc. must be able to cooperate in common understanding of the overarching goals. Interests and responsibilities are often conflicting, and dilemmas and controversies must be handled with respect to both social purpose and sustainability goals.

Step 4: Defining success criteria and how they are measured. While it is relatively easy to quantify carbon-emissions and costs, it takes more advances methodologies to plan and evaluate social effects- in particular long term. In Denmark, however, there are very detailed statistics for individual developments that holds available data on demography, educational level, criminal statistics, income etc. These are used for pointing out which developments should be covered by the law to prevent parallel societies but they might also be used for benchmarking results of renovation and transformation. More detailed information on sources for success or failure can be harvested from anthropological and sociological enquiries. Knowing from experience what work will assist authorities and other actors to maintain focus and find solutions as opposed to sub-optimisation of individual responsibilities.

Step 5: Leadership and management. Skills to facilitate the challenging collaboration about simultaneously pursuing targets for social quality and climate considerations must be developed. This might involve deployment of dedicated coordination officers in the municipal administration, a practice which can be found in some administrations but not all. It might also lead to the development of digital tools for communicating and scaling parameters of relevance such as cost, carbon footprint, lifetime, reversibility, flexibility, aesthetical preferences etc. It

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would be obvious coupling the planning tools and facilitating of collaboration with the residents' democratic process that is an integrated part of a Danish renovation project.

Demonstrator	**D3: Multi-resource preservation and densification of 1930s commercial plot**
Deliverable	D5.3 Policy brief and business case of building transformation
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Dissemination level	Public
Work Package	5, 7
Author(s)	Rune Andersen (DTU). With contributions by: Alina Barun, Kin Sun Tsang & Tomislav Martinović (DTU)

1. Mission statement, background and political decisions

Buildings for industry account for the vast majority of demolished square meters in Denmark. On the other hand, the majority of the newly built square meters are residential. In the cities where there is a very high demand for affordable housing, industrial buildings are at great risk of demolition in connection with urban development. This project will therefore investigate the possibilities of transforming office buildings into affordable housing in a centrally located industrial area in the northern part of Copenhagen.

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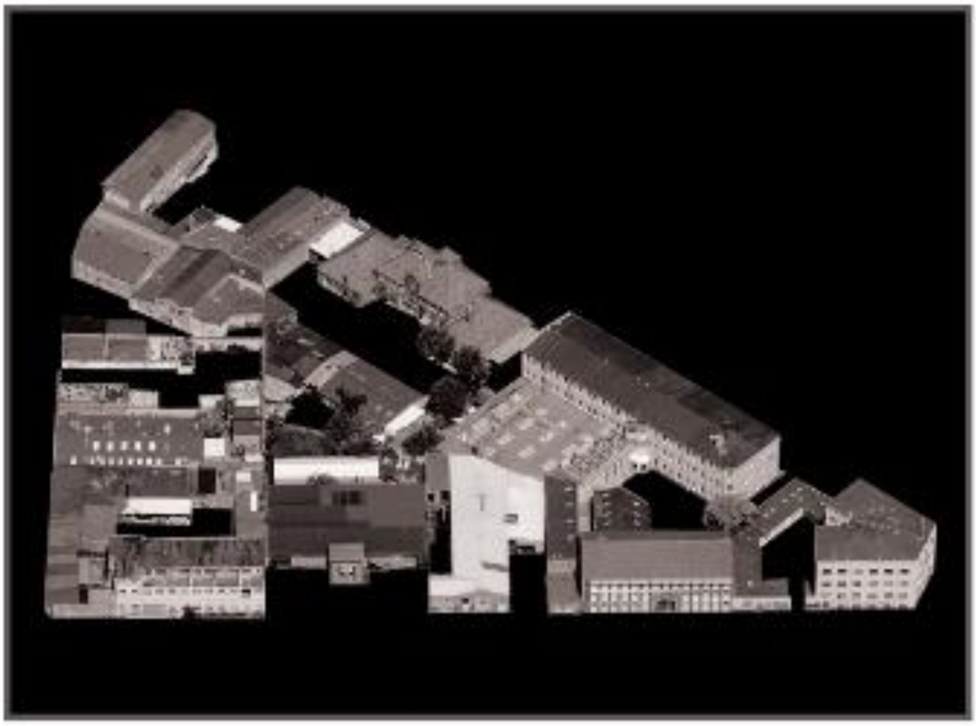

Figure 1: The Case area consists of a mixture of different industrial buildings from different construction periods.

The aim of the project is to demonstrate how the demolition of old office buildings can be avoided through transformation in an environmentally and economically sound manner and at the same time contribute with solutions to solve the social challenge in many European cities around the lack of affordable housing.

2. Project details

The case building from the area selected for this study is a three-storey office building with a total area of 3,597 m^2 distributed over three floors and a used basement. The building was originally built as a two-storey factory building (See Figure 2) in 1934 for the production of electrical components.

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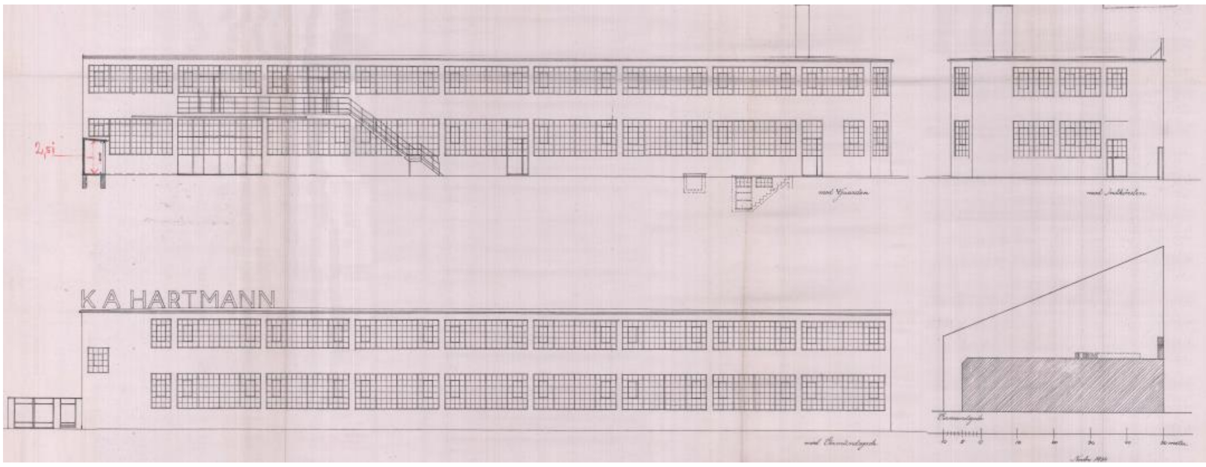

Figure 2: Original building drawings of the case building when it was built as factory in 1937.

The building has been remodeled several times throughout its lifetime. During World War II, the building was damaged during a bomb blast inside the main building. After the war, the building was therefore reinforced with concrete in case the static system had been damaged. The expansion of the static system also made it possible for an extra floor to be added in 1952 (See Figure 3), giving the main building its current dimensions. In 1977, several smaller buildings in the yard are demolished and the existing building is expanded with a one storey side building with offices.

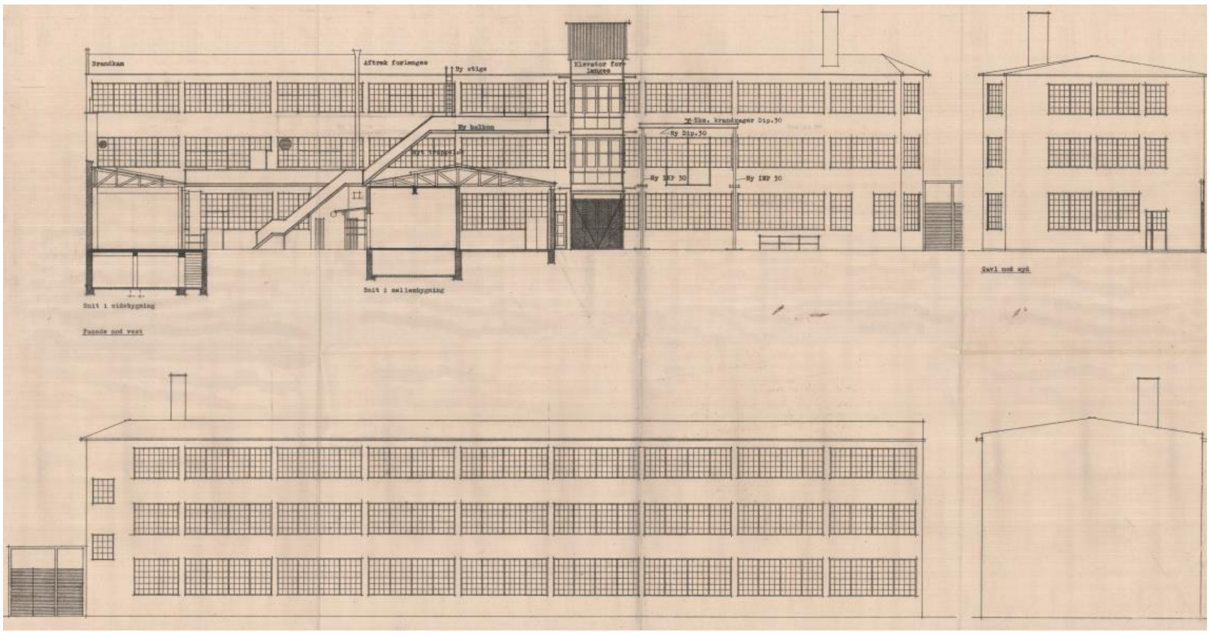

Figure 3: Original building after addition of extra floor to the factory building in 1952.

After the production closes, the main building is transformed into offices in 1989 so that the primary building use on the property now is offices. The building is divided into medium-sized offices and the old large factory windows is replaced with smaller windows. The new 1 storey side building, which was built as offices, was converted into a canteen. The last major change to the building, apart from ongoing changes to the interior layout, was in 1997 when

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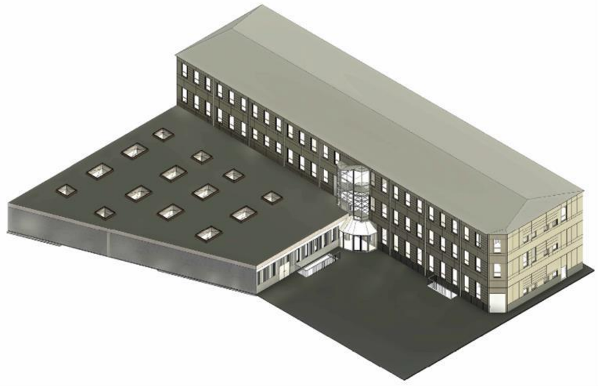
the facade of the building was renovated and re-insulated where the building was also covered with aluminium facade panels (See Figure 4).

	
Figure 4: The Case building as it appears today after it was transformed into offices in 1989.	*Figure 5: The 3D BIM model created for assessments and visualizations.*

The project is a theoretical case study which analyzes the possibilities and potentials for the transformation of office buildings. An actual building project has therefore not been carried out, but the analyses are based on extensive data collection and physical on-site inspections. The development of the project is primarily carried out by researchers and students from DTU with the involvement of architects, authorities and building owners.

3. Objective

Since industrial buildings in densely populated areas in Copenhagen are at great risk of demolition, the purpose of this demonstrator is to investigate options for preserving as much as possible of the existing building by transforming it into housing trough adaptive reuse. The circular principle is to preserve as much of the existing building elements as possible. The project will also demonstrate how the adaptation of the design strategy to the layout of the existing building can result in the greatest environmental savings because due to fewer materials and components that needed to be replaced (See Figure 6).

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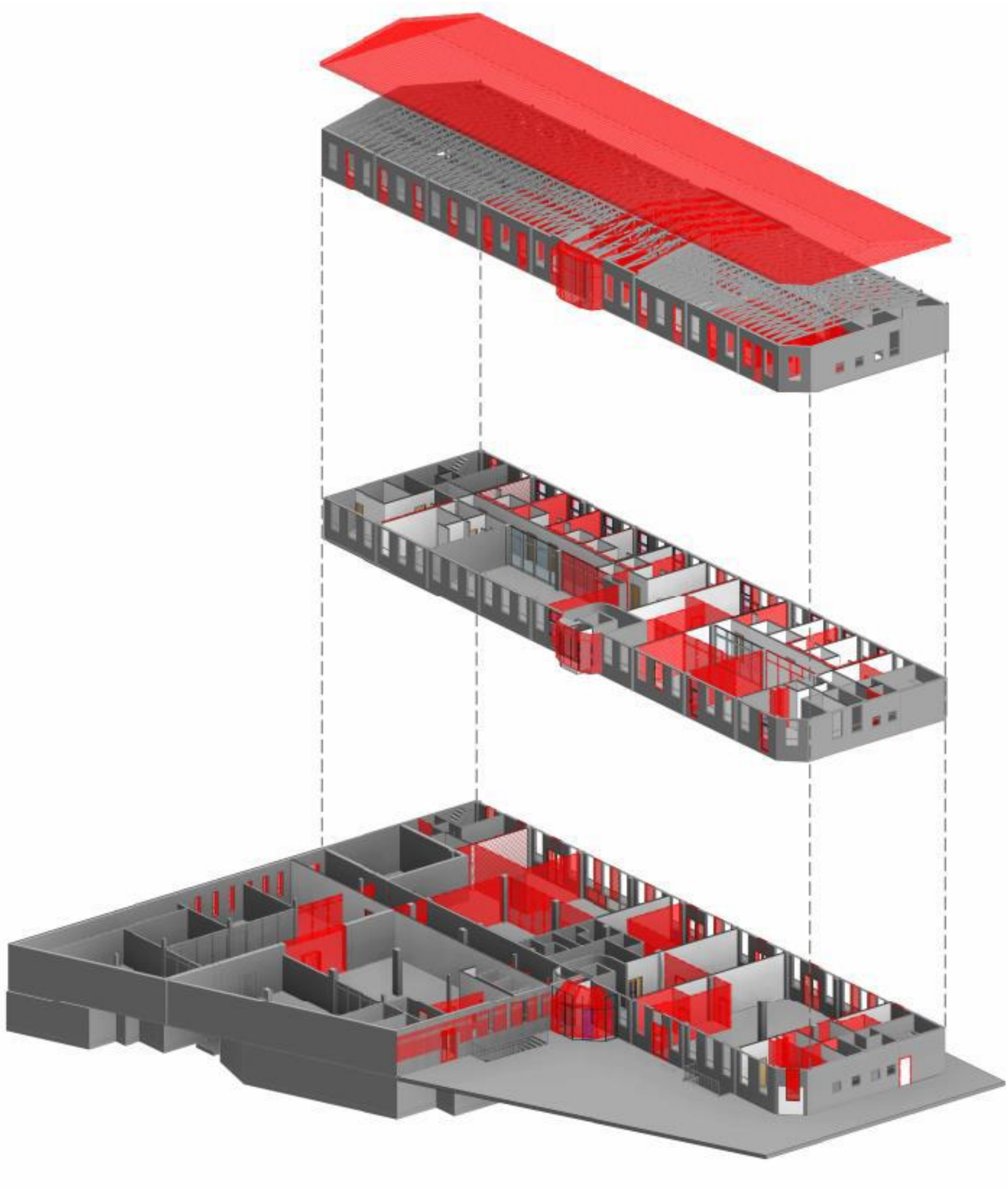

Figure 6: Proposed changes to the case building in connection with the transformation from office to residential. Building components that either need to be replaced or added are marked in red.

4. Technical analysis

4.1 Energy efficiency

Since buildings are over 90 years old, they have a higher energy consumption than new buildings. The building has been continuously renovated for energy, where the facades have recently been extensively insulated. The windows in the façade are mainly double-glazed but

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there are some single-glazed skylights in the old canteen in the side building. The three-storey main building is heated via district heating, but the side building is primarily heated with electric radiators. An energy calculation based on data from the energy label for the existing building showed that the existing building has an annual district heat consumption of 62.5 kWh/m² and an electricity consumption (mainly for heating) of 63.3 kWh/m² which gives the existing building and annual energy consumption of 125.8 kWh/m².

4.2 Structural system and load-bearing capacity

Since the building's structural system had previously been reinforced, the possibilities of adding an extra floor were investigated. A 3D model of the building's static system was made on the basis of old building drawings from Copenhagen Municipality's building case archive. Static calculations showed that there was not enough load bearing capacity to add an extra floor. This therefore meant that the building's original area was retained and not expanded. However, the analysis of the load-bearing system showed that the building is mainly based on columns, which makes it easy to change the layout of the building without having to remove and replace load-bearing walls.

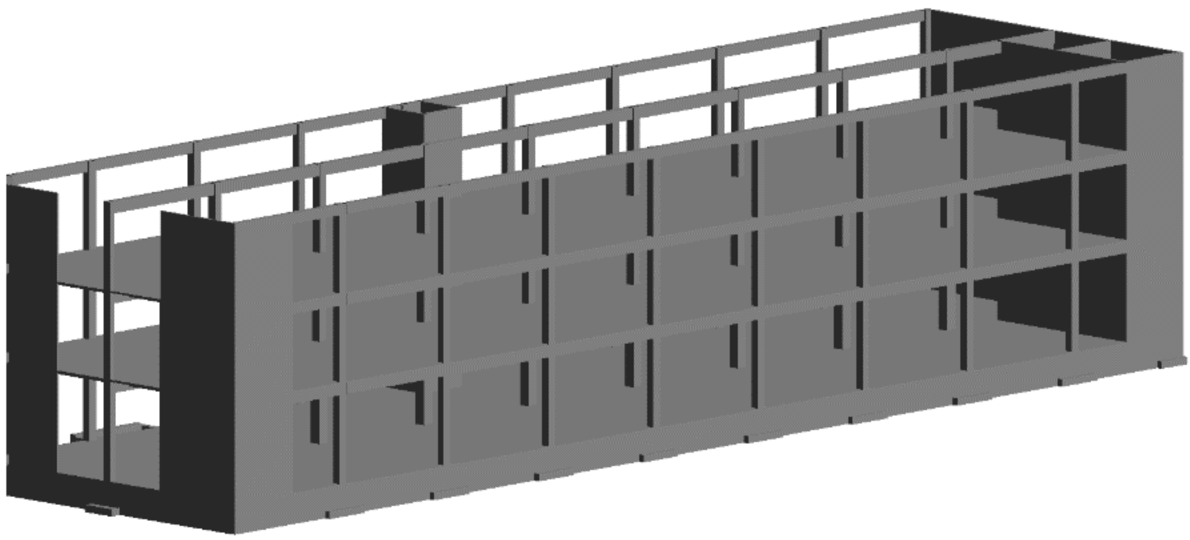

Figure 7: 3D model of the case building's static system.

4.3 Transformation potential

An initial feasibility study was carried out in order to calculate the building's transformation potential through 62 indicators that is divided into four main categories. The transformation potential tool is developed and tested throughout CIRCuIT. The transformation potential is rated on a scale from one to nine where one is the highest possible transformation potential and nine is the lowest possible transformation potential. The results of the calculation of the transformation potential for the four main categories for the existing building can be seen in Figure 8.

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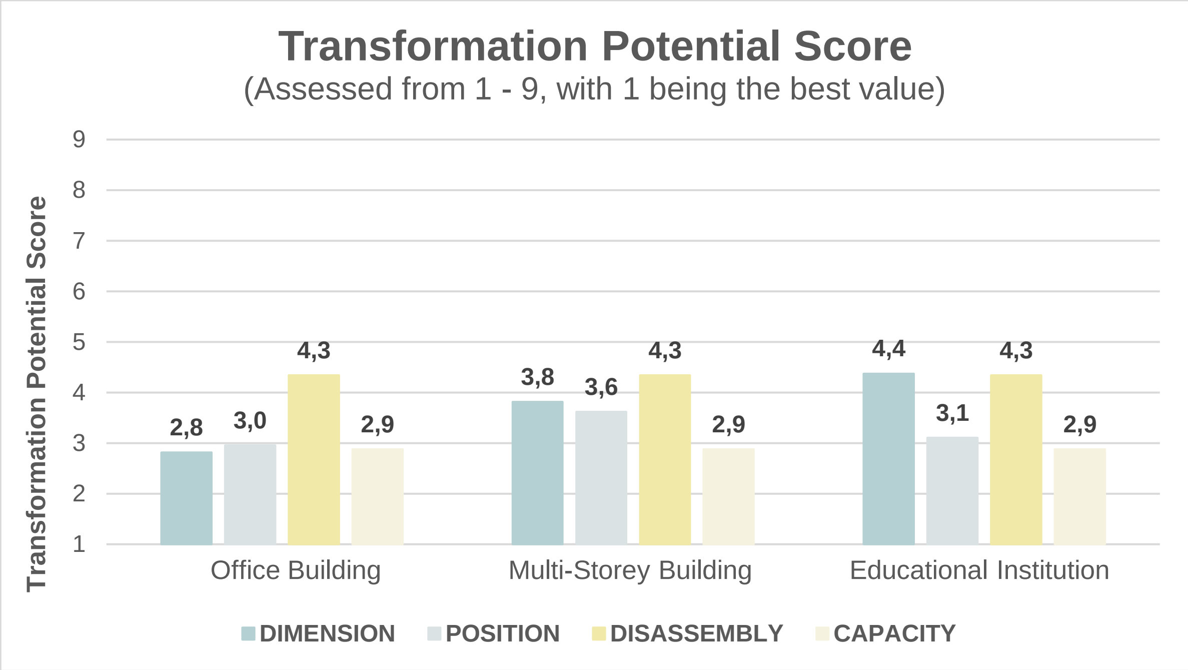

Figure 8: Calculation of transformation potential

Overall, the existing building has a potential for transformation at the higher end. The calculations showed that the building has the greatest potential for transformation in relation to being converted into offices, which intuitively makes sense because the building is already being used for offices and therefore the original design thereafter. Teaching use was the use with the second highest potential for transformation, which may be connected to the fact that the ground floor is already used for teaching today. Conversion to housing therefore had the worst transformation potential, but the difference between the three uses was relatively small.

4.4 Transformation from office to student housing

In connection with the transformation strategy, as much of the existing building was used as possible. In order to reduce the number of internal walls removed and added, small offices were converted into 22 one-person studio apartments ranging in size from 20 m^2 to 29 m^2 (See Figure 9) and 7 two-person studio apartments ranging in size from 32 m^2 to 45 m^2. Former common areas and kitchens could be used largely directly and will therefore only require minor remodelling. all student residences have access to a small balcony and therefore one of the windows in each student residence have to be replaced with a door. The ground floor is currently used for teaching, and was therefore one of the places in the building that required the most changes. In order to support service businesses such as coffee shops, the lower floor was divided into several smaller units and the facade facing the street is being opened up with new doors and larger window sections. The added windows in the facade facing the road are windows that are being removed elsewhere in the building in connection with balconies.

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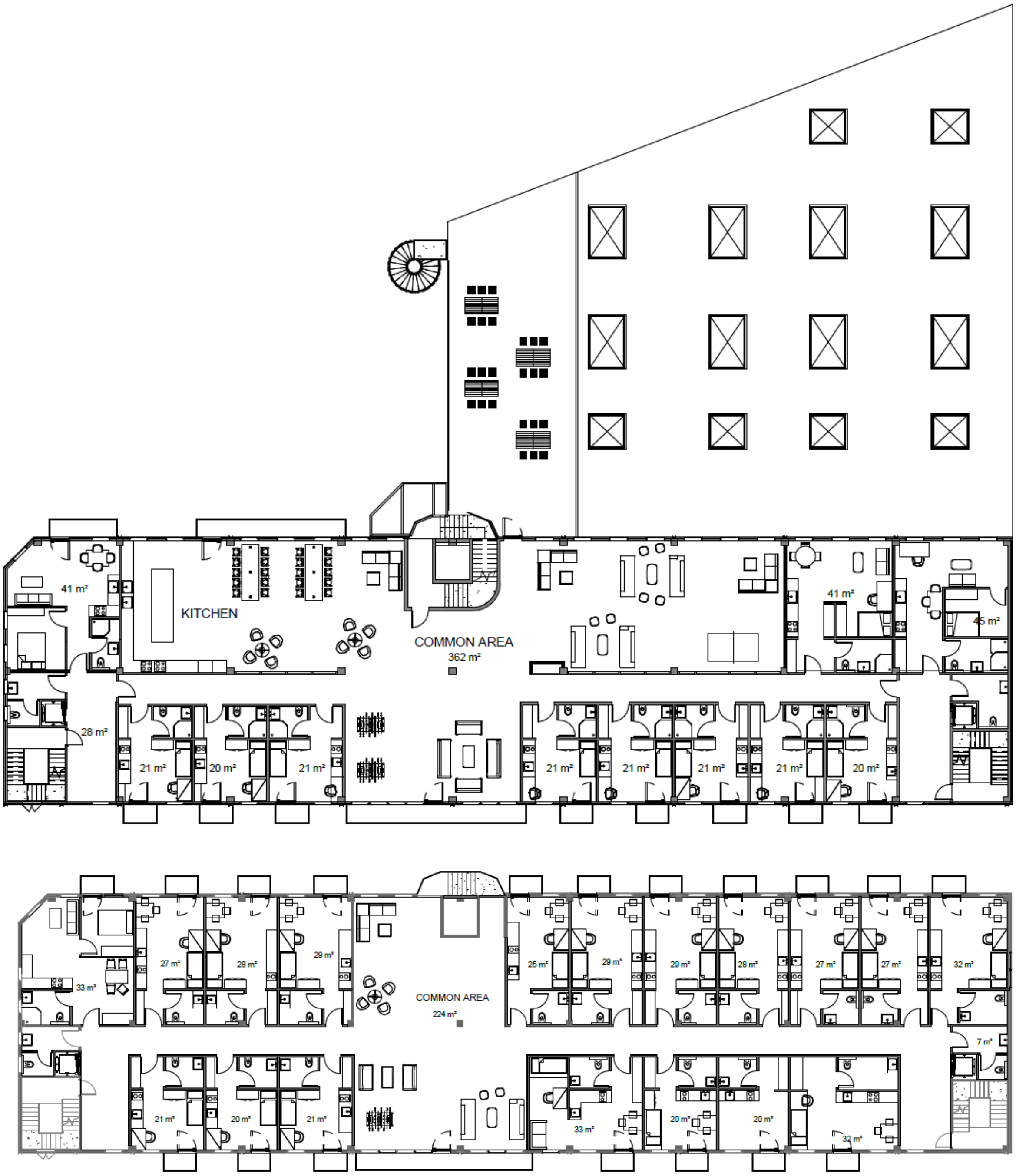

Figure 9. Layout of the first and second floor of the transformed building containing student apartments.

As part of energy-improving measures for systems, circulation pumps were replaced with new, more energy-efficient ones and, in addition, the electric heating in the canteen building was converted to district heating. The facade of the main building was recently renovated for energy, but the facades of the canteen had not been retrofitted, and this is therefore one of the measures that can be carried out. In addition, the skylights in the canteen were also improved with two additional insulating layers of glass. This lowered the total annual energy consumption from 125.8 kWh/m² per year to 88.8 kWh/m² per year. A further reduction of 10.5

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kWh/m² per year can be achieved if all windows are replaced. However, the windows were in good condition, so to keep construction costs and material consumption down, the original windows were kept.

Figure 10. Visualization of the interior layout of one of the student apartments.

Staircases and lifts are already dimensioned to be able to support homes and can therefore be preserved. The glass section at the main staircase will be replaced. The roof covering is asphalt and was assessed as having to be replaced in connection with a renovation. However, it is not profitable to increase the insulation in the roof structure, so the replacement of the roof covering only represents a minor increase in construction costs. Inside, new wooden floors will be added on top of the old linoleum floors, ceilings will be replaced and all old surfaces will be painted. The doors to the apartments will also be replaced with new fire-resistant doors and toilets and showers will be built in all apartments.

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Figure 11. Visualization of the courtyard behind the transformed building scenario, with added balconies, new wooden cladding on the old canteen and a new glass entrance.

Figure 12. Visualization of the transformed building scenario, where the building is opened up towards the street level which enables a better relation to the area.

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4.5 Lessons learnt

The importance of understanding the building's history and the changes that have historically been made to the building. Here, public data plays a big role because the publicly available database made it possible to gain access to building drawings and descriptions of conversions. This made it possible to make static calculations and model a 3D model of the building's constructions and layout that could support the design process in relation to identification of limitations and thus selecting the best design solutions.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the performance has been compared to a base case without circular construction objectives. For this project, the base case is the average environmental impact calculated from 60 new constructed Danish reference buildings[2].

The baseline for the economic assessment is the construction costs, maintenance price, costs for energy supply from a case study of new construction and the expected income from rent over 50 years, by building a new building on the same cadastre.

5.2 Environmental performance indicators

Environmental performance has been assessed against a range of environmental Life Cycle Assessment (LCA) indicators. The indicators selected for this project are highlighted in Table 1. All environmental impacts are calculated on an annual basis and are divided by the total heated area.

Table 4. Environmental LCA performance indicators

Indicator name	Unit
Global Warming Potential (GWP)	$kgCO2e/m^2/year$
Ozone Layer Depletion Potential (ODP)	$kgCFC11e/m^2/year$
Photochemical Oxidation Potential (POCP)	$kgC_2H_4/m^2/year$
Acidification Potential (AP)	$kgSO_2e/m^2/year$
Eutrophication Potential (EP)	$kgPO_4{}^3e/m^2/year$
Depletion of Abiotic Resources – Elemental Reserves (ADPe)	$kgSb\ e/m^2/year$
Depletion of Abiotic Resources – Fossil Fuels (ADPf)	$MJ/m^2/year$

The LCA for the environmental performance is calculated in the Danish LCA program named LCAByg. The data used for the LCA is the German ÖKOBAUDAT database.

5.3 Environmental performance results

Overall, the circular intervention improved the performance of the project on 4 out of the 7 indicators considered.

[2] SBI 2020:04 - Klimapåvirkning fra 60 bygninger

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The biggest improvement was in Ozone Layer Depletion Potential (ODP), which was improved by 96%. This was mainly due to the reduced emissions from materials in the transformation scenario. Likewise, the lower material consumption meant that there is a potential CO_2 saving of 23% by transforming the office building rather than building new.

The transformed building has an annual energy consumption for heat and building operation that is more than twice as high as that permitted for new construction. As a results of the higher energy consumption the transformed building performs worse than new construction in the impact categories Photochemical Oxidation Potential (0.3 % higher), Acidification Potential (46 % higher) and in Eutrophication Potential (96 % higher).

Table 5. Environmental performance results

Indicator name	New construction baseline	Transformation
Global Warming Potential (GWP)	9.52E+00 kgCO2e/m²/year	7.36E+00 kgCO2e/m²/year
Ozone Layer Depletion Potential (ODP)	1.96E-08 kgCFC11e/m²/year	7.84E-10 kgCFC11e/m²/year
Photochemical Oxidation Potential (POCP)	4.82E-03 $kgC_2H_4/m^2/year$	4.84E-03 $kgC_2H_4/m^2/year$
Acidification Potential (AP)	2.94E-02 $kgSO_2e/m^2/year$	4.29E-02 $kgSO_2e/m^2/year$
Eutrophication Potential (EP)	4.53E-03 $kgPO_4{}^3e/m^2/year$	8.89E-03 $kgPO_4{}^3e/m^2/year$
Depletion of Abiotic Resources – Elemental Reserves (ADPe)	2.64E-04 kgSb e/m²/year	8.56E-05 kgSb e/m²/year
Depletion of Abiotic Resources – Fossil Fuels (ADPf)	9.29E+01 MJ/m²/year	7.08E+01 MJ/m²/year

The global warming impact of transforming the building and service it for 50 years is equivalent to 1,177,462.6 kg of CO_2e. A new building of similar size is estimated to have a potential global warming impact of 1,523,200 kg CO2e over a period on 50 years. It is estimated that 345,737 kg of CO_2e can be saved over a 50-year period when keeping and transforming the building rather than demolishing and building new.

Most of the CO2 savings are results of the lower materials consumption in the transformation. The CO_2 emissions from materials in the transformation scenario are therefore around 6.5 times lower than the average CO_2 impact from materials in new construction. In relation to environmental impact from materials are the transformation scenario performing better than new construction across all seven-impact categories where the biggest saving is within ozone layer depletion that is almost 26 times lower than new construction, which is mainly because the windows are not changed.

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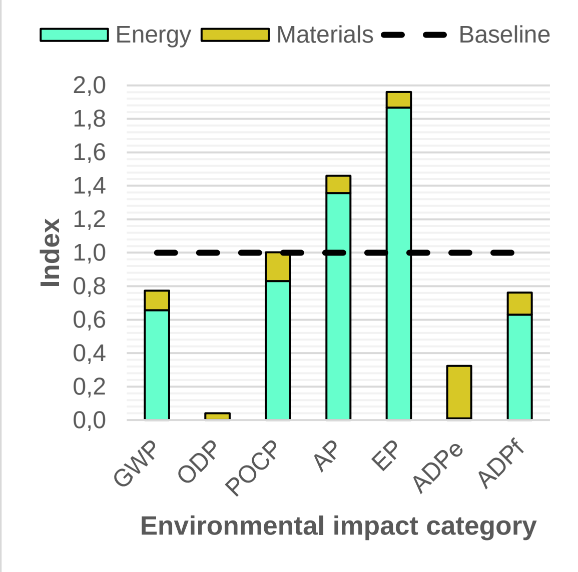

Figure 13. Environmental impact comparison of the circular transformation scenario in relation to the new construction baseline scenario.

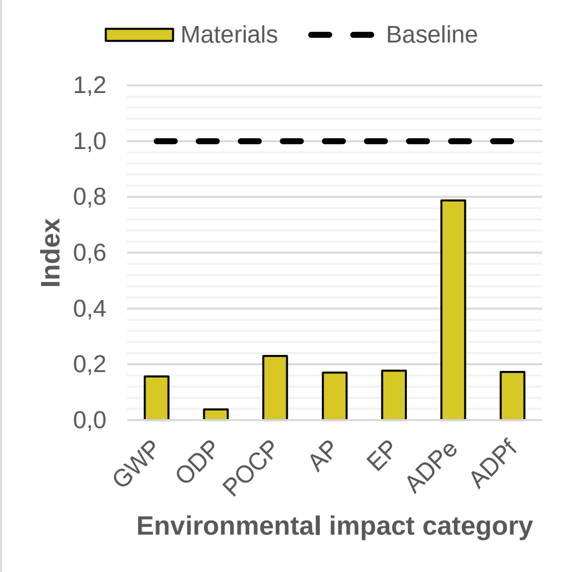

Figure 14. Comparison of the environmental impacts of the added materials in the transformation scenario in relation to the added materials in the baseline new construction scenario.

The calculated energy consumption of the transformed building is higher than the normal energy consumption for new buildings. Over a 50 years period this results in almost three time's higher CO_2 emissions from energy than in new construction. The higher impact from the energy in the transformation scenarios levels out some of the CO_2 savings from the materials which is the main reason when the CO_2 saving from transformation is only 23 % compared to new construction. However, further energy savings will require extensive replacement of building parts and thereby increase the amount of materials and the associated impacts from materials and therefore does not act as a real alternative to further reduce environmental impacts.

6. Economic analysis

6.1 Economic analysis indicators

The economic analysis has been considered in relation to the four components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing; construction costs, operation costs, maintenance & Replacement costs, along with the relevant components of whole life cost and income.

The LCC is calculated in the Danish LCC tool LCCByg with input data from the Danish Molio price database. For the life cycle costs and income, a 50 year period has been assessed. Since this is a theoretical study and not actual measured data and because prices are generally uncertain, the results for the transformed building have been multiplied by an uncertainty factor of 20%.

6.2 Economic analysis results

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This analysis found that in comparison to the base case, the circular construction intervention resulted in a decrease in the construction costs of 57% compared to the housing baseline and 44 % compared to the office baseline. The age and energy condition of the existing building results in operation costs for energy supply that are around 70% higher than for new housing and 2.5 times higher than the energy cost in the office baseline. However, there are currently large fluctuations in energy prices so the real costs of energy supply can be difficult to compare with previous baselines. Maintenance & Replace costs for the transformation only cover the building elements that are replaced in connection with the circular intervention. Future replacement of windows etc. is therefore not included in the transformation. Replacements of the added building parts, however, constitute a large cost compared to new construction baselines, so if costs for replacement and maintenance of the rest of the existing building components are also included, it must be expected that maintenance costs in the transformation scenario will be much greater than with new construction. The expected annual income is 23% higher for the transformed building compared to new construction of housing since the building area for the transformation scenario (3,210 m^2) is 50 % higher than what is allowed for new construction with a maximum plot ratio of 110 % (2,122 m^2) and thus more square meters can be rented out by transforming rather than building new.

Table 6. Economic analysis

	New construction [Housing]	New construction [Office]	Transformation
Construction	€ 3,851,035	€ 2,970,660	€ 1,654,647
Maintenance & Replace costs	€ 1,512,103	€ 1,909,710	€ 963,983*
Supply	€ 778,410	€ 371,333	€ 1,330,777
Income	€ 6,608,219	€ 4,518,320	€ 8,163,761

* Only replacement and maintenance of added components.

7. Scaling the impact and assessment of needs

7.1 City level potential

The office building can be very different in layout, materials and energy consumption. The case building in this studio was previously transformed from production to offices and therefore the case building is unique. The typical office layout, the supporting system of concrete and the energy consumption are, however, relatively comparable to many of the office buildings built in the period 1950-1990 which are being demolished today. An overall estimate, which is however associated with some uncertainty, can therefore be that the circular principles applied in the business case could potentially be replicated across the 28,000 square meters of office

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buildings with more than one floor that annual is demolished in Greater Copenhagen which could potentially result in an annual CO_2 saving of around 3,000 tonnes of CO_2e.

7.2 Realising the potential

No major financial or regulatory barrier was identified in relation to applying the circular design principle from this demonstrator. In order to be able to realize the full potential, it is important to inform about the possibilities found in existing buildings in relation to both reducing material consumption, CO2 emissions and construction costs by transforming rather than demolishing and building new. In addition, it will also require an increased focus from municipalities in relation to requiring feasibility studies of transformability when a building owner applies for demolition. Finally, it is also important to have a willingness from investors and building owners to choose circular design solutions rather than classic conventional building practices.

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Demonstrator	**D4: Office building conversion to housing, 1970–90s office buildings, Vantaa**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Tapio Kaasalainen and Satu Huuhka (TAU). With contributions by: Malin Moisio, Emmi Salmio, Aapo Räsänen, Jukka Lahdensivu and Mario Kolkwitz (TAU), and Tiina Haaspuro (HSY).

1. Mission statement, background and political decisions

Relatively young office buildings from the 1970s to 1990s are one of the building types and cohorts that are presently demolished in large numbers in Vantaa and more generally in the Helsinki region. These buildings' technical service lives have usually not been exhausted in terms of the building frames. Nevertheless, repair needs of facades and outdated building services and space plans may exist. The threat of demolition towards the typology is also partially connected to the overprovision of office space in the region, which has increased substantially due to vigorous new construction during the last decades, as well as companies' changing preferences for the locations of their premises. Simultaneously, the need for housing remains high in the region.

The project explores the possibility and potential to convert vacant or underutilized office buildings into housing and compares the environmental and costs performance of such transformation to that of a corresponding new build. Extending the life span of a building supports a transition to a circular economy by avoiding unnecessary demolition and construction.

2. Project details

The project comprises an office building from 1992 located Vantaa. The target was to find an average-sized and spatially representative building for the study. The case building was selected from a larger stock of office buildings, identified as average-sized with the help of Vantaa's building register. The building in question is privately-owned and its owners were not contacted to inform them about the research. Rather, the research was made with the help of public information, namely building drawings from archives of the building inspection authority of the City of Vantaa. For these reasons, the exact location of the building will not be disclosed. The building's identity is not relevant, as its purpose is to represent a cohort.

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Spatially, the building represents a double corridor layout with a somewhat deep building frame (approximately 17 meters) typical for office buildings of the era (Figure 1). The frame of the building is made of reinforced concrete, using a post and beam structure with hollow-core slabs for the floors and ceiling, which is also a typical solution. Some buildings in the same cohort would instead use load-bearing walls, typically along the central corridor(s) and the façade. For the purpose of conversion into housing this would pose some limitations compared to the current case, though relatively few considering the most potential spatial arrangements (Figure 2).

The conversion and new build alternatives' environmental and economic performance are assessed through calculations based on theoretical changes to the current situation, i.e. this is a virtual demonstrator. The presented alternatives' design and LCA calculations were conducted by researchers at Tampere University. LCC calculations were conducted by Finnish Consulting Group (FCG) Ltd, as commissioned by HSY.

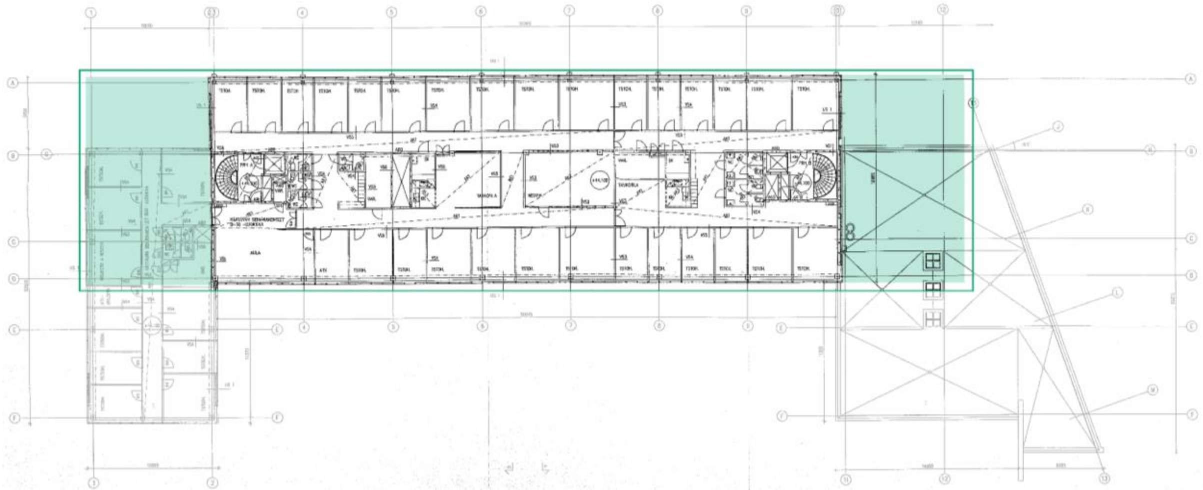

Figure 1. First floor plan of the case building in its original state with the demonstrator area encircled. Shaded areas indicate parts where the original plan was simplified to focus on the double corridor part recurring in many buildings of the era. Here, the structure was assumed to repeat as it is in the existing center part. Original image from the building inspection archives of the City of Vantaa.

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Figure 2. Floor plan of the case building after conversion into housing. Drawing: Malin Moisio.

3. Objective

The aim of the project is to demonstrate whether it is more climate-friendly and cost-efficient to convert an existing office building into housing or to demolish the existing building and construct a new block of flats of an equal size.

The conversion alternative comprises the changes illustrated in Figures 2 and 3. To extend the generalizability of the case, some simplifications to the initial situation were made, so that the layout corresponds better with the main layout commonly found in buildings of the examined cohort. Design decisions for the conversion, both technical and spatial, were made by the research team in accordance with typical current practice in Finland.

The replacement alternative comprises the demolition of the existing building and new construction of an equal volume on the same site. The structural and spatial solutions for the new construction were adapted from a recently constructed block of flats in Vantaa.

4. Technical analysis

4.1 Challenges

The existing double corridor layout of the building would be highly inefficient for housing unless the windowless spaces along the middle of the building frame could be utilized for auxiliary functions such as storage. Since these exist on all floors, the share of such spaces would end up exceeding the amount required by a typical residential building. Therefore, efficient utilization of the building requires significant changes to the existing layout. As walls between flats have very different requirements in terms of e.g. sound and fire insulation than walls between offices, the walls would have to be renewed regardless. Therefore, changes to spatial structure does not *per se* increase material use in the conversion.

The original building did not have any balconies. While balconies are not strictly required for housing, they do have a significant impact on the quality of living for the residents and on the desirability of the apartments. Adding balconies supported from the ground, on new foundations, could be costly due to the extensive construction works involved. The amount of materials required for the foundations and supporting structures might also comprise a notable amount of embodied emissions.

The original ventilation system of the building was mechanical exhaust only. Compared to more modern solutions, such a system is energy inefficient as there is no heat recovery. It is also uncertain whether the original system, even if in good shape, would be sufficient for the new use case. Furthermore, due to the changes in the layout of the building, ductwork would have to have been largely replaced regardless. Similarly, elevators, water and drain lines, and electrical systems needed repairs or replacement due to both their age and placement (except for the elevators).

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4.2 Solutions

The original double corridor layout is replaced with a central corridor, which allows more efficient utilization of floor area for housing. Furthermore, the new corridor is designed not to span the entire distance from one stairwell to another, thus leaving even more floor area for the flats. As the building has no load-bearing interior walls, this is structurally a relatively simple adjustment.

A balcony is added for each apartment, supported from the existing floor slabs. This option, although containing some labour-intensive steps, avoids extensive digging and concrete pouring at the building perimeter.

The existing mechanical exhaust only ventilation system is replaced with a mechanical intake-exhaust system with heat recovery, placed into a new equipment room on the roof of the building. Elevators are replaced, using the existing shafts. Water and drain lines are refurbished and electrical systems are replaced.

4.3 Lessons learnt

The post and beam structure of the building, typical to the cohort, is highly flexible when it comes to changing the interior spatial arrangements. On the other hand, buildings with interior load-bearing walls would typically have the bearing wall located on the interior side of one of the main corridors, still enabling a similar arrangement within the existing structure.

In comparison to the straightforward nature of the spatial adaptation, structural considerations are more challenging, as separations between units (flats) have higher requirements for e.g. noise and fire insulation, than those between offices. Feasible structural solutions are available, although on some technical aspects they may fall short of the present best-practice standard for new construction.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the performance has been compared to a base case without circular construction objectives. For this project, the base case is demolition of the existing building and replacement with a newly constructed block of flats of equal gross floor area.

5.2 Environmental performance indicators

Environmental performance has been primarily assessed through calculated whole-life carbon emissions. The life cycle assessment (LCA) calculations were made Using One Click LCA, following the Finnish Ministry of the Environment's method[3], which itself is based on the Level(s) framework developed by the European Commission. The emissions coefficients for construction materials used are based on the Finnish national generic database CO2data.fi, which has been commissioned by the Ministry of the Environment and is developed and

[3] Kuittinen, M. (2019). Method for the whole life carbon assessment of buildings. http://urn.fi/URN:ISBN:978-952-361-030-9

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maintained by the Finnish Environment Institute SYKE. In addition to the LCA, figures are presented on the amount of material use avoided when taking the circular approach(es) as opposed to demolition and replacement new construction.

Environmental performance has been assessed against the indicators selected for this project, shown in Table 1, which represent different aspects of circular construction.

Table 7. Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
Tonnes of materials used	Tonnes of materials used in the building
Whole life carbon emissions	kgCO2e

5.3 Environmental performance results

Overall, the circular intervention, i.e. conversion instead of replacement, improved the performance of the project on all the indicators considered.

The biggest improvement was in the amount of materials used, which was 58% lower due to the vastly smaller amount of construction required. Comparing the conversion alternative to the replacement alternative, it is estimated that 2,246 tonnes of material and 756,461 kg of CO2e will be saved (see Table 2 and Figures 3). Most of the reduction in emissions in the conversion alternative comes from the product stage of construction materials.

The LCA calculation assumes that the building will be demolished after the 50-year assessment period. It is important to note that this does not imply that demolition at that point should automatically happen in practice—on the contrary, further life span extension should be striven for.

Table 8. Environmental performance results.

	Conversion	Replacement
% of material not used	58%	–
Tonnes of materials used	1,600	3,846
Whole life carbon emissions (over 50 year period), kgCO2e	3,325,069	4,081,530

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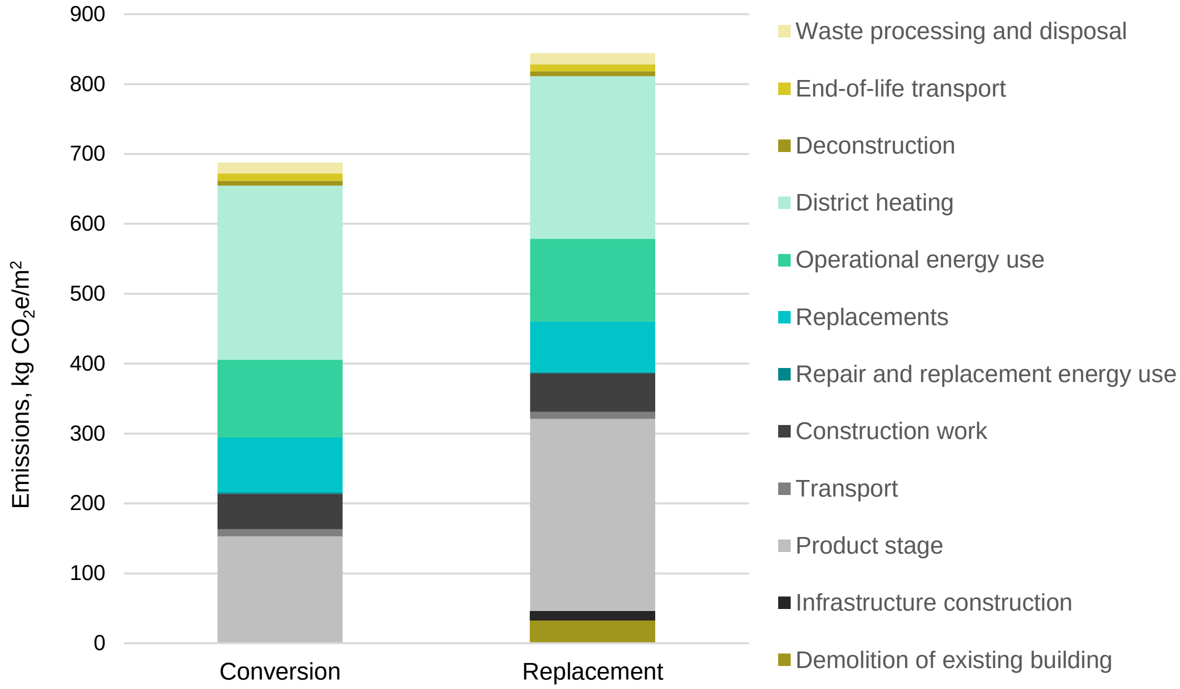

Figure 3. Distribution of emissions in the conversion and replacement alternatives after 50 years. Adapted from Moisio et al. (2023)[4]

6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to a base case. The base case is described in section 5.1.

6.2 Economic analysis indicators

For the life cycle costs, as with the environmental impacts through emissions, a 50-year period has been assessed. The life cycle costing has been carried out in accordance with the standard EN 15643-4 Sustainability of Construction Works - Assessment of Buildings - Part 4: Framework for the assessment of economic performance. Of the life cycle stages of a building, the assessment includes stages A0–A5 (initial construction), B1–B7 (operation and maintenance), and C1–C4 (end-of-life including disposal). The discount rate used is 3% and yearly energy price increase has been set at 2%.

6.3 Economic analysis results

The analysis found that in comparison to the base case, the circular construction (conversion) alternative resulted in 36.9% lower accumulated costs at the end of the 50-year assessment period due to its much lower construction costs (see Table 3 and Figures 4 and 5). After the initial construction (and demolition) works, both of the alternatives accumulated costs at virtually identical rates, the main difference arising from the conversion alternative's slightly

[4] Moisio, M., Räsänen, A., Kaasalainen, T., Huuhka, S. & Lahdensivu. J. (2023). Is adaptive reuse more low carbon than new build? Findings from a office-to-housing conversion case study. (Unpublished manuscript of a scientific article).

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higher operational energy use compared to the replacement alternative. The difference in cost between the two options is so substantial that no changes in construction costs, energy price increase or discount rate will change their mutual order.

Table 3. Distribution of life cycle costs in the conversion alternative and the replacement alternative after a 50-year period. The percentage under 'Difference' indicates the costs of the conversion alternative in relation to the replacement alternative.

	Conversion	Replacement	Difference
Product stage and construction	€8,718,710	€18,256,186	-52,2%
Use of products	€136,722	€137,332	-0,4%
Maintenance	€1,503,943	€1,510,647	-0,4%
Repair	€410,166	€411,995	-0,4%
Replacement	€273,444	€274,663	-0,4%
Refurbishment	€2,425,967	€2,424,020	0,1%
Operational energy use	€1,827,774	€1,798,458	1,6%
Operational water use	€715,279	€718,468	-0,4%
End-of-life	€242,422	€243,502	-0,4%
Total	€16,254,427	€25,775,271	-36,9%

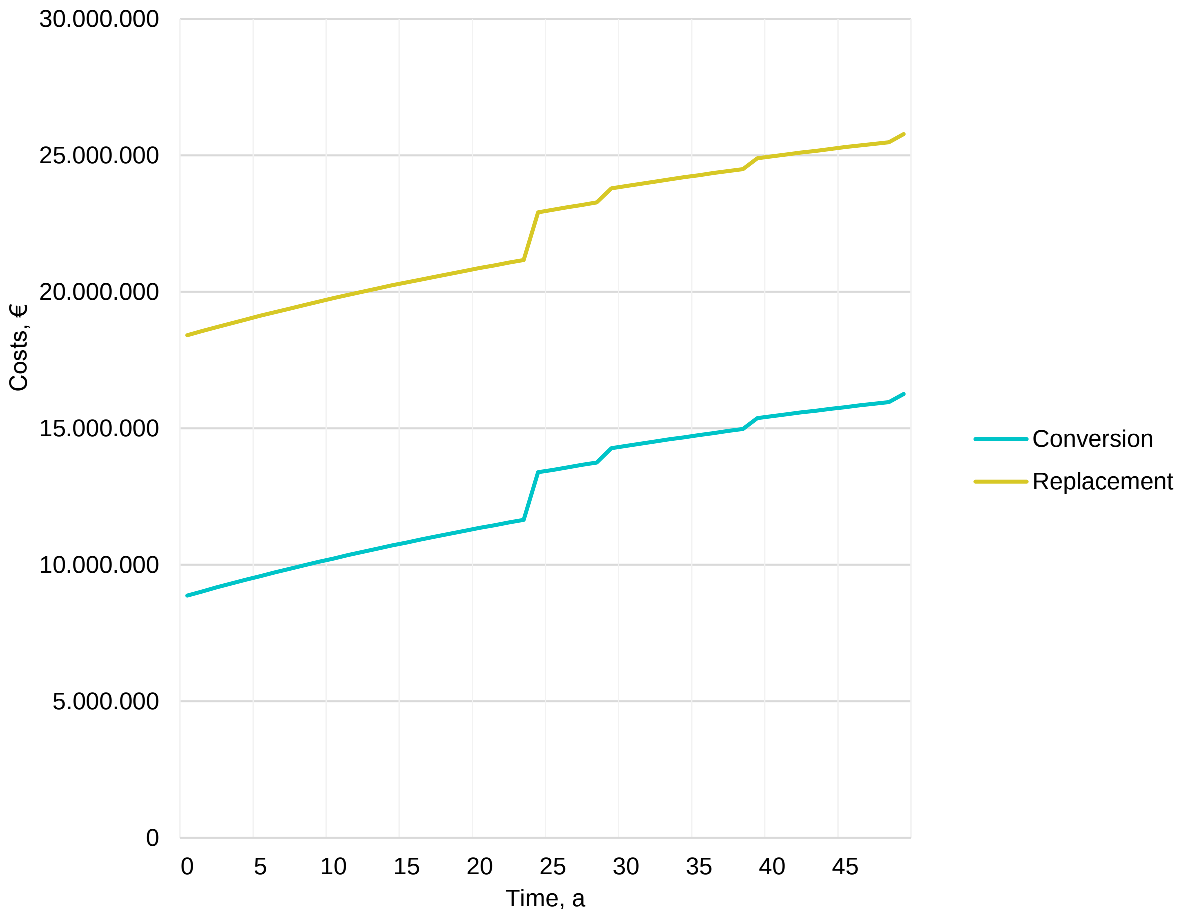

Figure 6. Accumulation of costs in the conversion and the replacement alternatives during a 50-year period.

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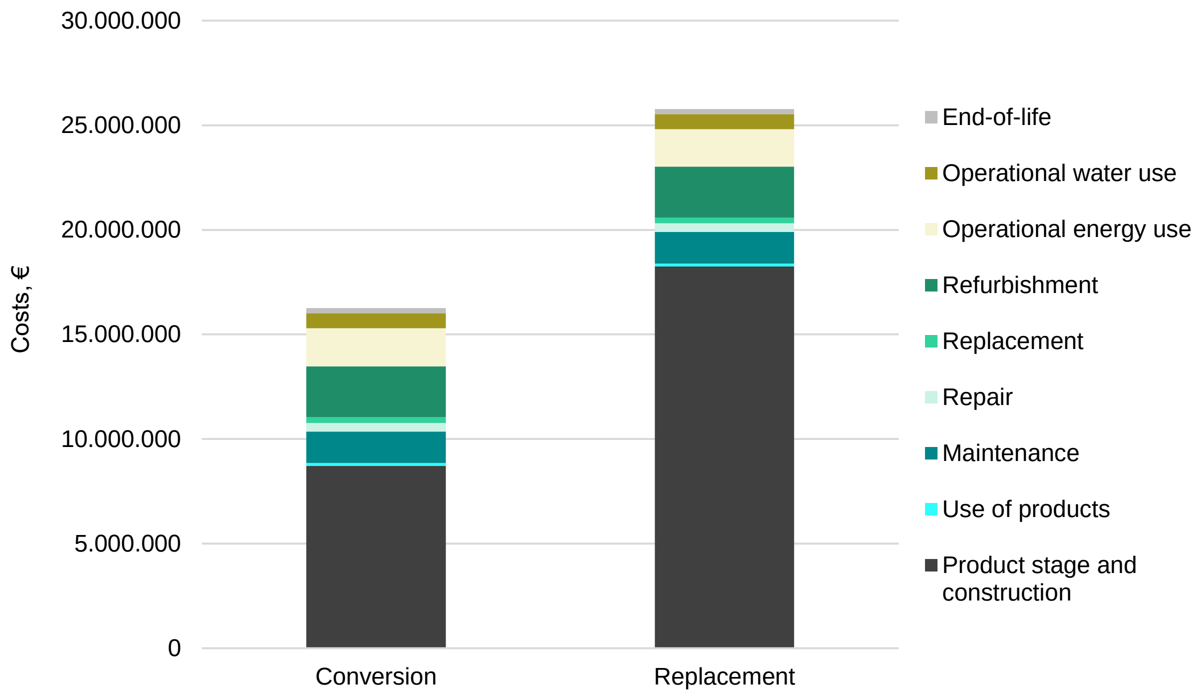

Figure 7. Distribution of life cycle costs in the conversion and replacement alternatives after a 50-year period.

7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across most of the structurally and spatially (in terms of both the buildings and their locations, i.e. suitable for housing) corresponding building stock in Vantaa. Based on 2018 data, the office building stock in Vantaa from the 1970s to 1990s comprises approximately 529,597 m² of gross floor area in 113 buildings. Applying the results of the demonstrator's conversion scenario to all these buildings, the amount of life cycle CO2 emissions avoided in comparison to the corresponding baseline demolition and replacement scenario would be 82,841,083 kgCO2e.

However, this figure is highly theoretical more so than in the other Vantaa business cases for building life-cycle extension. Office buildings in Vantaa are typically located in traffic junctions, where they often have been placed between a motorway or a railway and housing, with the purpose of shielding housing from the noise of the traffic. Therefore, the sites of these buildings will be more decisive for the viability of the conversion than perhaps the structural and spatial characteristics of the buildings.

Depending on their location, buildings outside of the time period from the 1970s to 1990s might also be viable candidates. Regardless of the specific extent of the suitable stock, it is clear that the potential impacts are significant. However, implementation requires particular attention on the specific site, potential context-specific hindering factors (such as noise) and the possibility for mitigation measures (e.g. directing balconies away from the traffic, improving noise insulation of windows, using noise barriers on plot boundaries towards traffic, etc).

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7.2 Realising the potential

As noted earlier, often the life cycle of a building comes to and end for reasons other than technical performance. When there's a lack of use for a building in its current form, with its current (or immediate past) function, adaptive reuse must be considered. Ideally, options for the future are assessed well in advance of expected obsolescence, proactively instead of reactively. Furthermore, a prerequisite for the conversion from one function to another is that the local detailed plan allows the new function. This is, as a rule, not the case. On the city level and in the stock of properties controlled by the city, the steps listed below should be applied to relevant buildings, i.e. those that are nearing the end of their current life cycle for any reason. For privately owned properties, the respective owners should do the same.

1. Study the physical condition of the building and devise repair scenarios. *By whom: building surveyor (condition investigation), structural engineer (repair scenarios).*
2. Study the spatial structure of the building and innovate novel functions for the building. *By whom: architect (spatial analysis, novel functions), owner (novel functions), potential new users (novel functions).*
3. Explore most potential new functions in more depth. *By whom: architect (spatial plan).*
4. Quantify environmental, economic and socio-cultural impacts of the alternatives. *By whom: environmental engineer or architect (environmental impacts), quantity surveyor (economic impacts), socio-cultural evaluator e.g. architect and/or social scientist (socio-cultural impacts, depending on the selection of studied impact categories).*
5. Select the preferred approach and engage in further measures, such as the renewal of the local detailed plan and the adaptive reuse of the building. *By whom: owner, together with other relevant parties such as planners, renovation contractors, etc.*

Generally, it can be said that in the past, urban planners have been reluctant to allow the change of function from office to housing. The potential environmental savings, which have been showcased here to be of significant magnitude, are a good reason for reconsidering that attitude. Of course, such a land use change requires that the context is suitable for housing, i.e. that adverse context-specific factors are not present or can be mitigated.

When it comes to the business aspects, it is often argued that a conversion is more costly than new build. This argument was also heard in the course of the demonstrator. However, the cost assessment concludes that this is not the case. It can be speculated that more than with actual costs, this argument has more to do with established processes and practices, or the lack thereof. Businesses that are accustomed to building new may find converting existing buildings to be more complicated and risky, as it is a more case-specific approach as opposed to the process-oriented approach they are so well used to. Assuming that cities will find conversion as desirable due to the environmental benefits, policy-makers should find ways to encourage businesses to increasingly engage with conversion. Land-use policies, where e.g. additional building rights (in m2) are granted for new build alongside the conversion, could be one way to implement such policy support.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Demonstrator	**D5: Life cycle extension alternatives for a listed school building, Vantaa**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Tapio Kaasalainen and Satu Huuhka (TAU). With contributions by: Malin Moisio, Emmi Salmio, Jukka Lahdensivu and Mario Kolkwitz (TAU), and Kimmo Nekkula (CoV).

1. Mission statement, background and political decisions

Public buildings are one of the building type categories demolished in the largest quantities, both in Vantaa and in Finland in general. Older school buildings have been identified as particularly prone to demolition due to centralization tendencies (combining small units to larger ones), indoor air quality concerns, and changes in pedagogy.

This project demonstrates the emissions and cost impacts of different kinds of refurbishment options aimed at extending the life cycle of the existing building, in comparison to new construction of the same volume. Extending the life span of a building supports a transition to a circular economy by avoiding unnecessary demolition and construction.

This project demonstrates how different degrees of refurbishment can be used to extend the technical lifespan of a mid-20th century school building and how those measures affect the life cycle CO_2 emissions and costs of the building.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Figure 2: Korso school in January 2022. Photo by Kimmo Nekkula.

2. Project details

The project comprises the oldest part of Korso school in Vantaa. The building was completed in 1959–1961 as a junior high school, in which function it operated until the end of 2021, first as a private school until 1977 and then as a public school. The school activities were relocated to a new building in a different location in Jan 2022 and the building was vacated.

The building is made out of concrete structures, though not yet prefabricated as in the decades to come, but cast in situ, and is structurally a typical representative of its kind for the era. The spatial structure – with a central corridor at one end of the building and a side corridor at the other end – is similarly typical. One of these corridor types appears widely in other buildings, even if not usually together. The building has repair needs, which have been documented by a professional building surveyor. The degradation is repairable and the building is nevertheless structurally sound, which was confirmed with the help of a site visit.

The refurbishment and new build alternatives' environmental and economic performance are assessed through calculations based on theoretical changes to the current situation. The presented construction alternatives' design and LCA calculations were conducted by

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researchers at Tampere University. LCC calculations were conducted by FCG Finnish Consulting Group Oy as commissioned by the City of Vantaa.

3. Objective

The aim of the project is to demonstrate a) whether it is more climate friendly and cost efficient to renovate or to demolish and build new; b) how the level of renovation influences environmental impacts and costs of the renovation, between renovation options and in comparison to replacement.

The renovation as well as demolition and replacement alternatives included are as follows:

- R1) Light refurbishment
- R2) Extensive refurbishment
- R3) Extensive energy refurbishment
- N1) Demolition followed by replacement new construction of equal heated net floor area using a concrete frame
- N2) Demolition followed by replacement new construction of equal heated net floor area using a wooden frame

Since conducting all the measures described above for the same building is not physically possible, the project is based on theoretical designs and corresponding Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) calculations. In other words, it is a virtual demonstrator.

4. Technical analysis

4.1 Challenges

Matters such as funds available at the decision-making moment or the environmental performance goals of the building owner may affect the selection of the degree of refurbishment. Thus, a solution that is theoretically optimal for building performance might not be feasible or desirable in practice. Typically, more extensive refurbishment has a higher up-front cost but may yield benefits on a long-time frame through e.g. reduced operating costs, better usability, or reduced or postponed need for further measures.

The building, along with the other buildings on the same site, is classified as modern built heritage site (class A). Therefore, architectural values are a consideration that affects the selection of suitable renovation measures, particularly when those measures would affect the exterior of the building. In this demonstrator, adding façade insulation would have a notable impact on the exterior architecture of the building due to the increased thickness of the walls.

4.2 Solutions

To address different needs and capabilities for refurbishment, three refurbishment scenarios were devised and examined: R1) light refurbishment, R2) extensive refurbishment, and R3) extensive energy refurbishment. The first of these only improves the air tightness of the building envelope and consequently, indoor air quality, shifting more extensive renovation (or demolition) into the future. The other two scenarios are longer lasting solutions.

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To examine a renovation alternative that extends the life span of the building and improves its environmental (and via reduced heating need, financial) performance while preserving the look of the building, a version of the extensive energy refurbishment alternative (R3) omitting added façade insulation was included (R3b).

4.3 Lessons learnt

Energy performance improvement measures can have a significant impact on a building's architecture. In this case, it was shown that even without adding insulation to the facades major improvements in energy efficiency were possible. In general, a building's case-specific values, such as heritage values, should always be considered when deciding on the appropriate technical repair approach.

As part of the refurbishment study, experimental architectural designs were drafted to examine the building's potential for adaptive reuse which could enable life span extension and the renovation measures presented even if there's no use for the building with its current function. These designs indicated the building frame to be highly flexible. Similarly, in cases where a building is under threat of demolition due to lack of use, the potential for adaptive reuse should be examined alongside technical repair needs and options.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the performance has been compared to a base case without circular construction objectives. For this project the base case is the demolition of the existing building and replacement new construction of equal volume. The baseline scenarios include two cases with different main construction materials for the replacement building, concrete (N1) and wood (N2).

5.2 Environmental performance indicators

Environmental performance has been primarily assessed through calculated whole life carbon emissions. The life cycle assessment (LCA) calculations were made Using One Click LCA, following the Finnish Ministry of the Environment's method[5], which itself is based on the Level(s) framework developed by the European Commission. The emissions coefficients for construction materials used are based on the Finnish national generic database CO2data.fi, which has been commissioned by the Ministry of the Environment and is developed and maintained by the Finnish Environment Institute SYKE. In addition to the LCA, figures are presented on the amount of material use avoided when taking the circular approach(es) as opposed to demolition and replacement new construction.

Environmental performance has been assessed against the indicators selected for this project, shown in Table 1, which represent different aspects of circular construction.

[5] Kuittinen, M. (2019). Method for the whole life carbon assessment of buildings. http://urn.fi/URN:ISBN:978-952-361-030-9

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Table 9. Environmental performance indicators.

Indicator name	Unit
Dematerialisation	% of material not used
Tonnes of materials used	Tonnes of materials used in the building
Whole life carbon emissions	kgCO2e

5.3 Environmental performance results

Overall, the circular intervention improved the performance of the project on all the indicators considered (see Table 2 and Figure 2). The LCA results show that at the end of the 50-year assessment period, all refurbishment alternatives except R1 had accumulated significantly fewer CO2 emissions than either of the baseline replacement cases (N1&2). Furthermore, it should be noted that even R1 outperformed both base cases for the first 15 years, i.e. until the postponed more extensive refurbishment, due to the lack of the initial carbon spike at year 0. This highlights the immediate emissions savings potential of refurbishment instead of replacement even when there is little to no improvement in a building's energy performance.

As a result of the intervention it is estimated that up to 4,744 tonnes of material (R2 versus N1) and 848,301 kg of CO2e (R3 versus N1) would be saved. Notably, by avoiding demolition and new construction the savings would be immediate.

The LCA calculation assumes that the building will be demolished after the 50-year assessment period. It is important to note that this does not imply that demolition at that point should automatically happen in practice—on the contrary, further life span extension should be striven for.

Table 10. Environmental performance results. For % of materials not used, refurbishment alternatives R1–3b as well as the wooden replacement alternative N2 are compared to N1. For tonnes of materials used, R3b having a higher amount than R3 despite the lack of additional insulation is due to a difference in the thickness of façade surface rendering used.

	Refurbishment				**Replacement (base cases)**	
	R1 Light	**R2 Extensive**	**R3 Extensive energy**	**R3b Extensive energy (no added façade insulation)**	**N1 Concrete**	**N2 Wood**
% of material not used	86%	86%	85%	84%	–	29%
Tonnes of materials used	772	766	835	867	5425	3,860
Whole life carbon emissions (kgCO2e)	2,615,150	2,094,243	1,663,701	1,865,103	2,512,002	2,305,776

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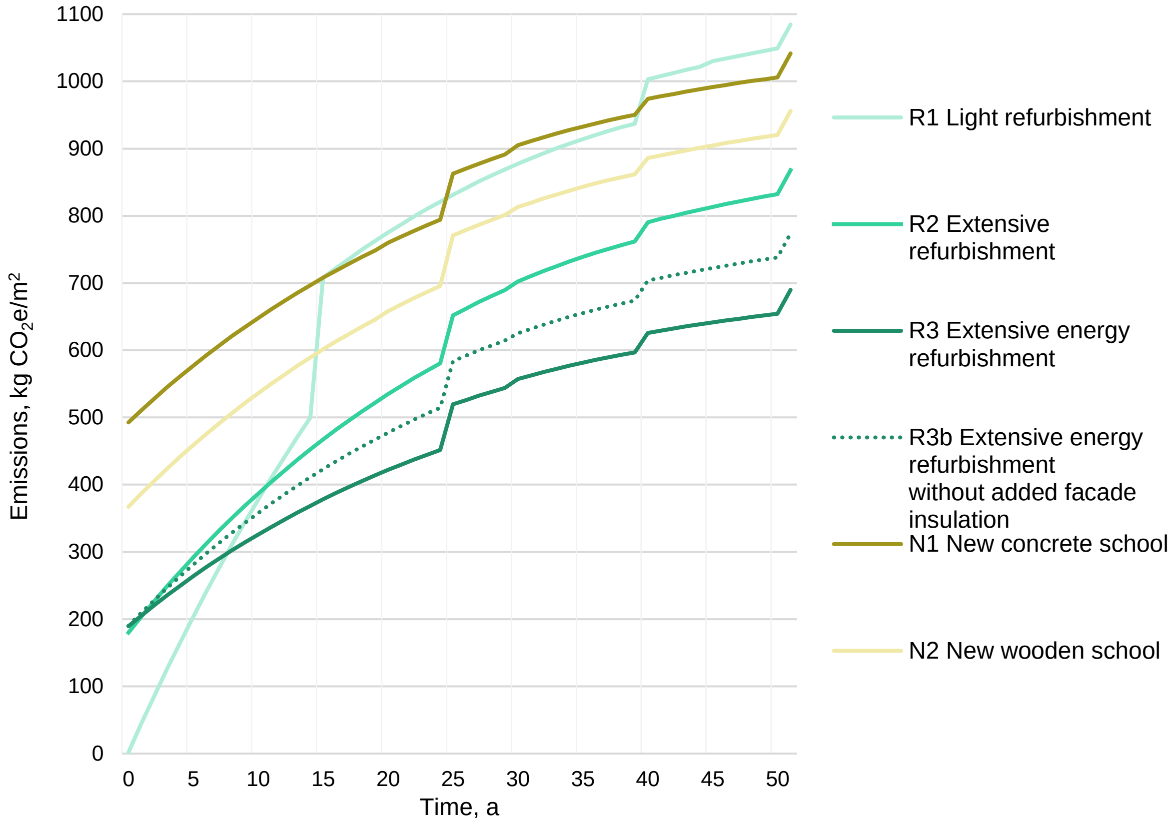

Figure 3. Accumulation of emissions in refurbishment alternatives R1–3(b) and replacement alternatives N1–2 during a 50 year period. Adapted from Moisio et al. (In review).[6]

The biggest improvement was in the amount of materials used, or correspondingly in the percentage of material not used: R1 and R2 used 86% less materials than N1. This was because utilizing the existing building required, even with considerable renovations, much less new materials than new construction.

6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to two base cases. The base cases are described in section 5.1.

6.2 Economic analysis indicators

For the life cycle costs, as with the environmental impacts, a 50-year period has been assessed. The life cycle costing has been carried out in accordance with the standard EN 15643-4 Sustainability of Construction Works - Assessment of Buildings - Part 4: Framework for the assessment of economic performance. Of the life cycle stages of a building, the assessment includes stages A0–A5 (initial construction), B1–B7 (operation and maintenance),

[6] Moisio, M., Huuhka, S., Salmio, E., Kaasalainen, T. & Lahdensivu, J. (In review). Climate change mitigation potential in building preservation: Comparing the CO2 performance of four refurbishment alternatives to new construction. (Unpublished manuscript of a scientific article).

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and C1–C4 (end-of-life and disposal). The discount rate used is 3% and yearly energy price increase has been set at 2%.

6.3 Economic analysis results

This analysis found that in comparison to the base case, the circular construction intervention resulted in up to a 5,501,201 € (40.5%) reduction in life cycle costs between the baseline case of demolition followed by replacement new construction using wood and the light refurbishment option. As shown in Table 3 and Figures 3–4, all refurbishment options resulted in significantly lower total costs during the 50-year assessment period, the reduction ranging between 26.6% and 36.3% when compared to the concrete baseline case and between 31.5% and 40.5% when compared to the wooden baseline case. As can be seen, a clear majority of the costs arises from construction works either at the beginning of the period (R2–3, N1–2) or during major refurbishments (R1). Of the refurbishment alternatives, the economic upfront investment is greater in R2 and R3 than in R1. However, R1 accumulates energy costs more quickly than the more energy-efficient alternatives and still requires the extensive renovation at a later point in time to last for the assessed 50-year period.

Table 11. Life cycle costs of base cases (N1–N2) and main refurbishment alternatives (R1–R3) after a 50 year period. "Construction" covers costs at the beginning of the 50 year period, while the other rows cover costs during and at the end of the period. Unit: €

	Refurbishment			**Replacement (base cases)**	
	R1 Light	**R2 Extensive**	**R3 Extensive energy**	**N1 Concrete**	**N2 Wood**
Construction	262,140	4,101,720	4,186,530	8,457,870	9,131,210
Use of products	204,328	204,328	204,328	204,328	204,328
Maintenance	1,566,513	1,566,513	1,566,513	1,362,185	1,362,185
Repair	340,546	204,328	204,328	204,328	204,328
Replacement	272,437	272,437	272,437	272,437	408,656
Refurbishments	3,271,717	1,171,719	1,171,719	752,588	752,588
Operational energy use	1,845,247	1,463,974	1,009,597	1,130,513	1,219,978
Operational water use	205,905	205,905	205,905	186,761	186,761
End-of-life	120,764	120,764	120,764	120,764	120,764
Total	**8,089,597**	**9,311,687**	**8,942,120**	**12,691,775**	**13,590,798**

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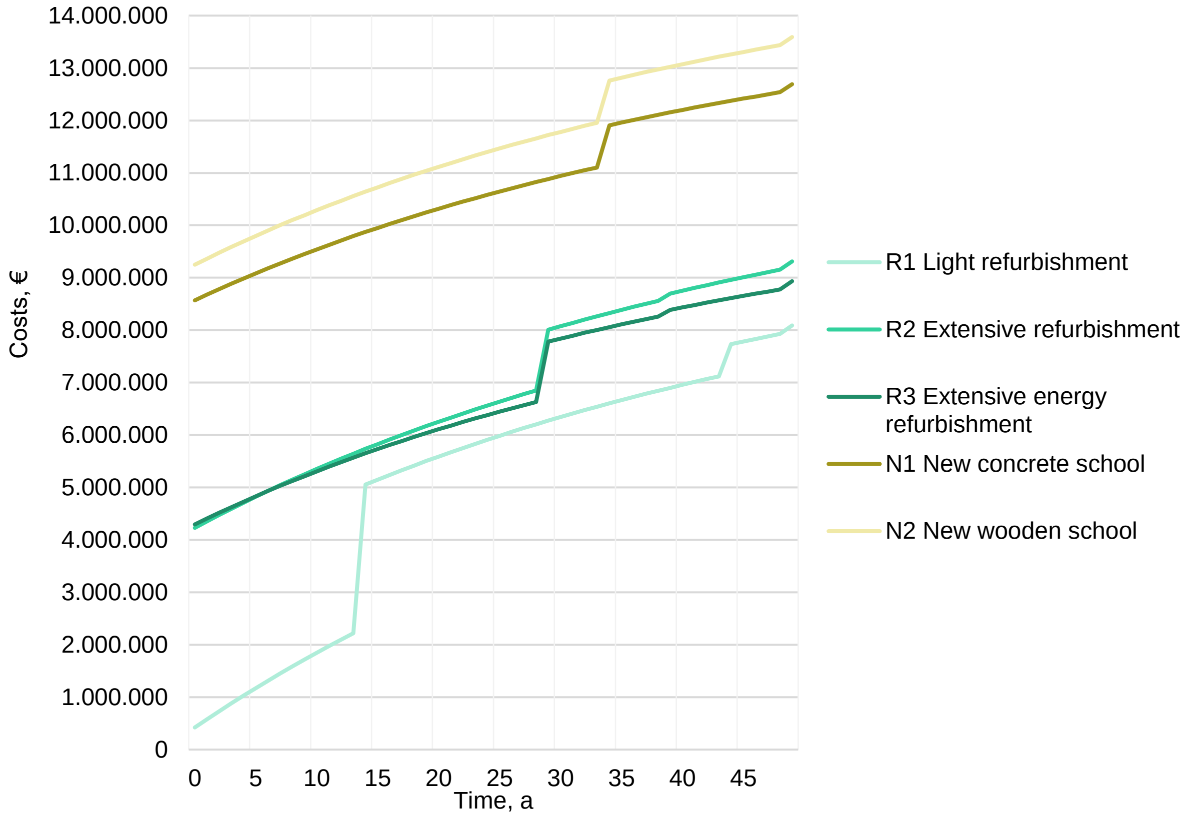

Figure 3. Accumulation of costs in refurbishment alternatives R1–3 and replacement alternatives N1–2 during a 50-year period.

Sensitivity analyses were conducted to see whether the order of the scenarios would change if the assumptions were altered. The only such switch might take place between R1 and R3. R3 will become the most affordable alternative if:

- the energy price increase goes up from 2% to 6%
- the discount rate decreases from 3% to 1.3%
- the price of heating energy increases from 80€/MWh to 155€/MWh
- the cost of refurbishment works in R1 increases from 102 €/m2/a to 400 €/m2/a

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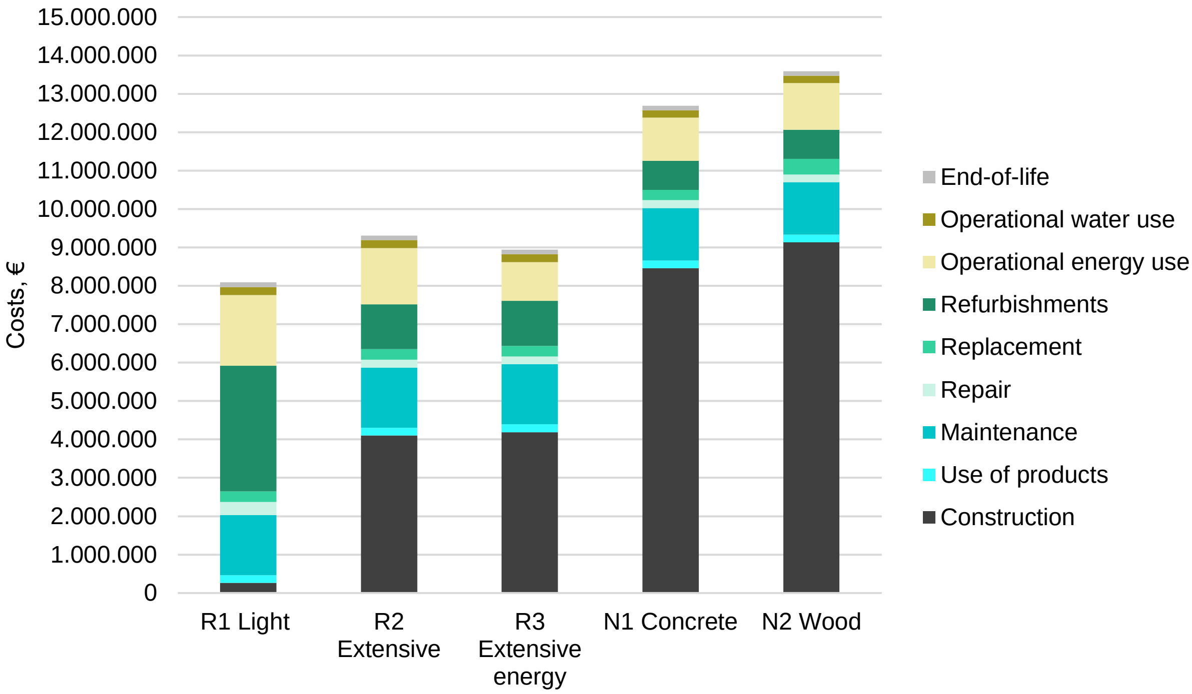

Figure 4. Distribution of life cycle costs of refurbishment alternatives R1–3 and replacement alternatives N1–2 after a 50-year period.

7. Scaling the impact and assessment of needs

7.1 City-level potential

This business case could potentially be replicated across most of the structurally and architecturally corresponding building stock in Vantaa. Based on 2018 data, the school building stock in Vantaa from the 1950s and 1960s comprises approximately 86,850 m² of gross floor area (GFA) in 25 buildings. Applying the results of the demonstrator's refurbishment scenarios to all these buildings through floor area, the amount of life cycle CO2 emissions avoided in comparison to the corresponding baseline demolition and replacement scenarios could be up to 30,545,167 kgCO2e (when comparing extensive energy refurbishment R3 and new concrete school N1). Obviously, not every building in this stock would be a viable candidate for these measures, but it is clear that the potential impacts are significant.

7.2 Realising the potential

As noted earlier, often the life cycle of a building comes to and end for reasons other than technical performance. When there is a lack of use for a building in its current form, with its current (or immediate past) function, adaptive reuse must be considered. Ideally, options for the future are assessed well in advance of expected obsolescence, proactively instead of reactively. Furthermore, a prerequisite for the conversion from one function to another is that the local detailed plan allows the new function. This is, as a rule, not the case. On the city level and in the portfolio of properties controlled by the city, the steps listed below should be applied to relevant buildings, i.e. those that are nearing the end of their current life cycle for any reason. For privately owned properties, the respective owners should do the same.

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6. Study the physical condition of the building and devise repair scenarios. *By whom: building surveyor (condition investigation), structural engineer (repair scenarios).*
7. Study the spatial structure of the building and innovate novel functions for the building. *By whom: architect (spatial analysis, novel functions), owner (novel functions), potential new users (novel functions).*
8. Explore most potential new functions in more depth. *By whom: architect (spatial plan).*
9. Quantify environmental, economic and socio-cultural impacts of the alternatives. *By whom: environmental engineer or architect (environmental impacts), quantity surveyor (economic impacts), socio-cultural evaluator e.g. architect and/or social scientist (socio-cultural impacts, depending on the selection of studied impact categories).*
10. Select the preferred approach and engage in further measures, such as the renewal of the local detailed plan and the adaptive reuse of the building. *By whom: owner, together with other relevant parties such as planners, renovation contractors, etc.*

Of the refurbishment alternatives, the economic and environmental upfront investment is greater in R2 and R3 than in R1. However, R1 accumulates energy costs and associated emissions more quickly than the more energy-efficient alternatives and still requires the extensive renovation at a later point in time to last for the assessed 50-year period. The selection of the 'correct' alternative depends in each situation on the building's physical condition and heritage value, the owner's aspirations for the use and lifetime, and the available economic resources. An exception to this is the lightest refurbishment alternative, which is not recommendable with adaptive reuse, as the operable lifetime it produces remains too short vis-à-vis the long-term nature of adaptive reuse—instead it would make sense to conduct a more extensive renovation immediately.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Demonstrator	**D6: Renovation and extension of 1970–80s public rental housing, Vantaa**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Tapio Kaasalainen and Satu Huuhka (TAU). With contributions by: Malin Moisio, Emmi Salmio, Aapo Räsänen, Jukka Lahdensivu, Minna Leppänen, Pirjo Kuuloa and Mario Kolkwitz (TAU), and Tiina Haaspuro (HSY).

1. Mission statement, background and political decisions

There is pressure to demolish existing housing in the Finnish capital region, a part of which the City of Vantaa is, and in other Finnish cities. The threat of demolition is often connected to a nexus of factors, which can, depending on the context, include: physical degradation and repair needs of buildings; lack of accessibility; socio-economic environment with precarious groups such as immigrants and marginalized populations; vacancy issues; a city's policy targets for urban densification and social mix/gentrification; the potential value of the plot with a renewed urban plan with substantially increased building rights (in m^2). Rental housing is particularly prone to demolition due to having one owner, but the phenomenon is increasingly identified in owner-occupied multi-family housing too.

This project demonstrates the emissions and cost impacts of different kinds of building extension and renovation options in comparison to demolition and new construction of the same volume. The target volume for extension is determined based on a typical Vantaa new construction project on a similarly sized plot. Extending the lifespan of a building supports a transition to a circular economy by avoiding unnecessary demolition and construction. Furthermore, (vertical) extension of a building minimizes the amount of construction needed to achieve the increase in usable floor area.

2. Project details

The project originally comprises a 2,859 m^2 plot on which there are two blocks of flats from the year 1979. The total gross floor area (GFA) of the existing buildings is 3,784 m^2, of which Building 1 (Figure 1) has 1,419 m^2 on 3 floors and Building 2 has 2,365 m^2 on 5 floors.

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Figure 4: Building 1 in January 2022. Photo by Kimmo Nekkula (CoV).

The original buildings are made from prefabricated concrete panels using structural and spatial solutions typical to the era. Both buildings are presently owned by VAV Group, the municipal housing company owned by the City of Vantaa. The buildings are in use and occupied by households of renting residents.

The renovation and new build alternatives' environmental and economic performance are assessed through calculations based on theoretical changes to the current situation. The presented construction alternatives' design and LCA calculations were conducted by researchers at Tampere University. LCC calculations were conducted by AFRY Buildings Finland as commissioned by HSY.

3. Objective

The aim of the project is to demonstrate a) whether it is more climate friendly and cost efficient to renovate and extend or to demolish and build new; b) if only part of the densification target can be achieved through the extension and some new construction must be placed elsewhere, what the impact is on climate and cost performance.

The extension and renovation as well as corresponding demolition and replacement alternatives included are as follows:

- RE1) renovation and vertical extension of both existing buildings, new civil defence shelter, total GFA 5,600 m²
- RE2) renovation and vertical extension of both existing buildings, new civil defence shelter, and complementary greenfield new construction elsewhere, total GFA 8,018 m²

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– DE1) demolition of both existing buildings and replacement new construction on site equal to the final volume in RE1, total GFA 5,600 m^2
– DE2) demolition of both existing buildings and replacement new construction on site equal to the final volume in RE2, total GFA 8,018 m^2

Additionally, RE2 is divided into two, REa and REb. In RE2a, infrastructure construction for complementary construction is considered only for the respective site, while in RE2b, supporting infrastructure construction for the wider area is also included.

Of these, RE1 and RE2 are the circular construction practice demonstrators, and DE1 and DE2 are the corresponding 'business as usual' baselines for comparison. The plot efficiency (the ratio of GFA to plot size) is 2.1 in RE1, RE2 and DE1, which makes them approximately equal to the average for recent greenfield construction in Vantaa. However, the plot efficiency of DE2, 3.0, is clearly higher than average but still within the commonly occurring range. This plot efficiency was selected based on a recently developed plot nearby in the same district, which was used as a reference.

Since conducting all the measures described above for a single plot is not realistic, the project is based on theoretical designs and corresponding Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) calculations. In other words, it is a virtual demonstrator.

Figure 2. The vertical extension of the existing buildings and the added civil defence shelter. Drawing: M. Moisio.

4. Technical analysis

4.1 Challenges

The original project plot does not have enough space to reach plot efficiencies (ratio of buildings' GFA to plot area) towards the higher end of the range found in new construction while preserving the original buildings, even when they are extended vertically, without significantly compromising the functionality of the plot. Correspondingly, there might be a need for more GFA than can be reached via renovation and extension of existing buildings alone.

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The practicality of vertical extension depends on the existing load-bearing structures' capacity to support additional floors. Reinforcements to load-bearing structures, including the foundations, can have a significant effect on the cost and complexity of the construction.

The civil defence shelter for the existing buildings will not be sufficiently large after the planned vertical extensions, unless an exemption can be granted, sufficient shelter space is available nearby, or new can be built. Due to the heavily reinforced concrete structures involved, it is not feasible to extend the shelter within the existing building envelope.

4.2 Solutions

To form a design alternative that incorporates renovation and extension of the original buildings while still resulting in a higher amount of GFA than those alone can reach, RE2 includes greenfield new construction outside the original plot.

To minimize the burden on existing load-bearing structures caused by the vertical extension, the additional floors were designed to be made out of wood. A common rule of thumb in Finland is that a typical building of the studied kind can support up to two additional lightweight floors (i.e. ones using a wood or steel frame) without much if any need for reinforcing existing structures. To ascertain the validity of this assumption for the studied buildings, calculations were made based on the existing buildings' design documents. The results showed that they would indeed be able to support the two additional floors planned. However, the reader should note that these calculations were performed on a level sufficient for the virtual demonstrator. For an actual implementation, they should be double-checked.

To account for the increased need in civil defence shelter after the vertical extensions, additional shelter space was planned as a separate building and included in the calculations.

4.3 Lessons learnt

The demonstrator showed utilizing existing buildings to be environmentally preferable to full scale replacement even if some supplementary new construction is still required. Correspondingly, the environmental benefits are proportional to the amount of demolition and new construction avoided. Through refurbishment, the operational emissions of an existing building can be brought to the level of those of a newly constructed building, or even below. Furthermore, the emission savings achieved through renovation instead of replacement are immediate.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the performance has been compared to baseline cases without circular construction objectives. For this project the baseline case scenario is demolition and new construction equal to the volume that could be achieved via extension and renovation. Two base cases are included: one corresponding to the volume achievable by vertically extending the existing buildings

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(DE1), and one corresponding to the volume achievable by adding greenfield construction to match the higher ranges of typical new construction plot efficiency in Vantaa (DE2).

5.2 Environmental performance indicators

Environmental performance has been primarily assessed through calculated whole life carbon emissions. The life cycle assessment (LCA) calculations were made Using One Click LCA, following the Finnish Ministry of the Environment's method[7], which itself is based on the Level(s) framework developed by the European Commission. The emissions coefficients for construction materials used are based on the Finnish national generic database CO2data.fi, which has been commissioned by the Ministry of the Environment and is developed and maintained by the Finnish Environment Institute SYKE. In addition to the LCA, figures are presented on the amount of material use avoided when taking the circular approach(es) as opposed to demolition and replacement new construction.

Environmental performance has been assessed against the indicators selected for this project, shown in Table 1, which represent different aspects of circular construction.

Table 12. Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
Tonnes of materials used	Tonnes of materials used in the building
Whole life carbon emissions	kgCO2e

5.3 Environmental performance results

Overall, the circular intervention improved the performance of the project on all the indicators considered, in all of the studied cases (see Table 2 and Figure 3). In renovation alternative RE2b the whole life carbon emissions are, however, virtually equal to those of the corresponding demolition and replacement alternative DE2 due to the wider area infrastructure construction involved.

It is estimated that by prioritizing a circular, retention approach, in the first comparison pair where renovation and vertical extension (RE1) is compared to demolition and replacement new construction (DE1), 3,846 tonnes of construction material use would be avoided. In the second comparison pair, where renovation and vertical extension with complementary greenfield construction elsewhere (RE2) is compared to demolition and larger new construction on site (DE2), 5,539 tonnes would be avoided. Expressed another way, in the comparison pair with 5,600 m² resulting GFA (RE1 and DE1) the material use of the renovation option (RE1) is 28% of the replacement option (DE1). In the comparison pair with 8,018 m² resulting GFA (RE2 and DE2) the material use of the renovation option (with complementary greenfield construction) is 53% of the replacement option (RE2). It should be noted, however, that the figures above do not include any material masses used on site outside the buildings themselves and their foundations, such as paths or exterior sewer or water lines. Over the 50-year assessment period, RE1 is estimated to produce 475,561 kgCO2e (10.4%) less

[7] Kuittinen, M. (2019). Method for the whole life carbon assessment of buildings. http://urn.fi/URN:ISBN:978-952-361-030-9

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emissions than the corresponding replacement alternative DE1. Correspondingly, RE2a is estimated to produce 237,316 kgCO2e (3.8%) less and RE2b 7,879 kgCO2e (0.1%) less emissions than the corresponding replacement alternative DE2.

The LCA calculation assumes that the building will be demolished after the 50-year period. It is important to note that this does not imply that demolition at that point should automatically happen in practice—on the contrary, further life span extension should be striven for.

Table 13. Environmental performance results. For % of material not used, RE1 is compared to DE1 and RE2 to DE2. For carbon emissions, RE2a is a version of the where infrastructure construction for complementary construction is considered only for the respective site, while in RE2b supporting infrastructure construction for the wider area is also included.

	Renovation and extension		Replacement (base cases)	
	RE1	**RE2**	**DE1**	**DE2**
% of material not used	72%	47%	–	–
Tonnes of materials used	2,432	6,278	8,622	11,817
Whole life carbon emissions (over 50 year period), kgCO2e	4,105,196	a: 6,064,604 b: 6,294,049	4,580,757	6,301,920

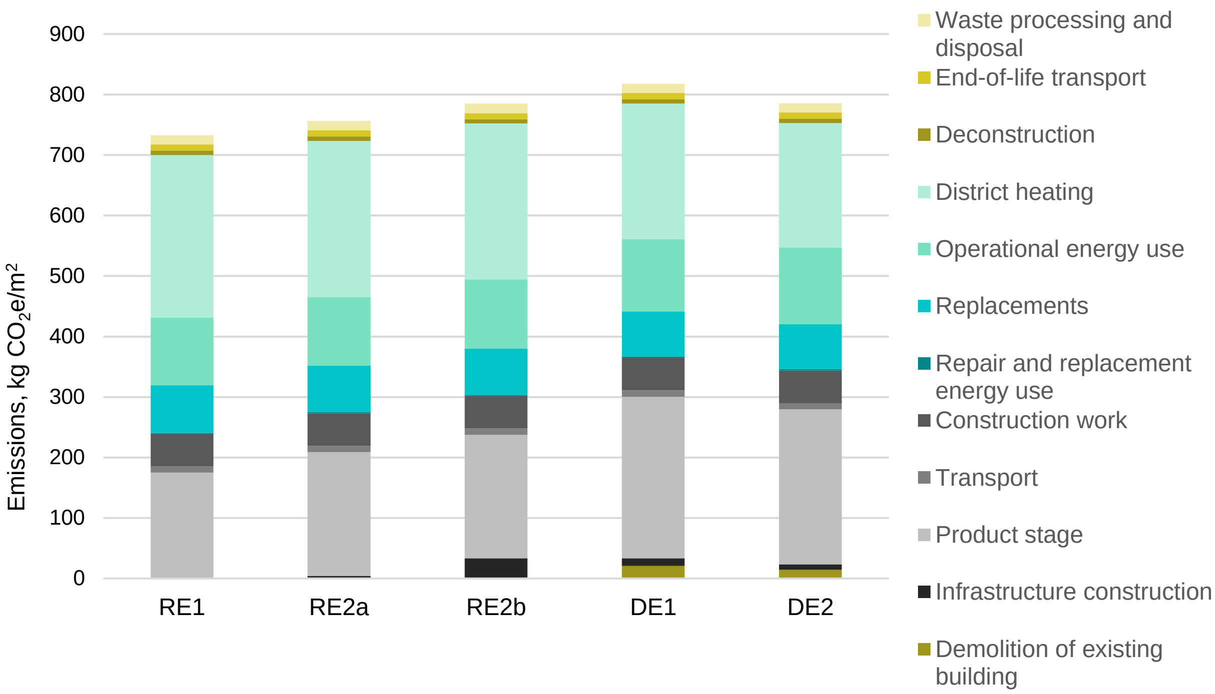

Figure 3. Distribution of emissions in extension and renovation alternatives RE1–2 as well as demolition and replacement alternatives RE1–2 after 50 years. RE2a is a version of the where infrastructure construction for complementary construction is considered only for the respective site, while in RE2b supporting infrastructure construction for the wider area is also included. Adapted from Moisio et al. (2023).[8]

[8] Moisio, M., Salmio, E., Kaasalainen, T., Huuhka, S., Räsänen, A., Lahdensivu, J., Leppänen, M. & Kuula, P. (2023). Towards Consequential Replacement LCA for the built environment: Comparing the CO2 performance of infill, greenfield, and replacement-based densification. (Unpublished manuscript of a scientific article).

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6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to base cases. The base cases are described in section 5.1.

6.2 Economic analysis indicators

For the life cycle costs, as with the environmental impacts through emissions, a 50-year period has been assessed. The life cycle costing has been carried out in accordance with the standard EN 15643-4 Sustainability of Construction Works - Assessment of Buildings - Part 4: Framework for the assessment of economic performance. Of the life cycle stages of a building, the assessment includes stages A0–A5 (initial construction), B1–B7 (operation and maintenance), and C1–C4 (end-of-life and disposal). Results are presented using current costs as well as different scenarios for the future development of costs (see Table 3).

Table 14. Costs change scenarios used in LCC.

	Discount rate	Construction and maintenance costs index	Yearly increase in energy costs
Costs scenario 1	2.0%	4.0%	6.0%
Costs scenario 2	3.0%	3.0%	4.6%
Costs scenario 3	5.0%	2.0%	1.5%

6.3 Economic analysis results

This analysis found that in comparison to the demolition and replacement base cases DE1 and DE2, the circular construction alternatives RE1 and RE2 resulted in costs ranging as follows: between 76.1–120.1% in RE1, between 102.3–120.7% in RE2 (see Figure 6).

In all costs scenarios—including current costs—the order of the refurbishment and replacement alternatives stayed constant throughout the 50-year assessment period, as shown in Figure 5. RE1 accumulated less costs than the corresponding replacement alternative DE1 in all scenarios except in Cost scenario 1. Conversely, RE2a/b remained more costly than DE2 in all scenarios. In all alternatives initial construction costs, including demolition if relevant, formed the majority of total costs (see Figure 7).

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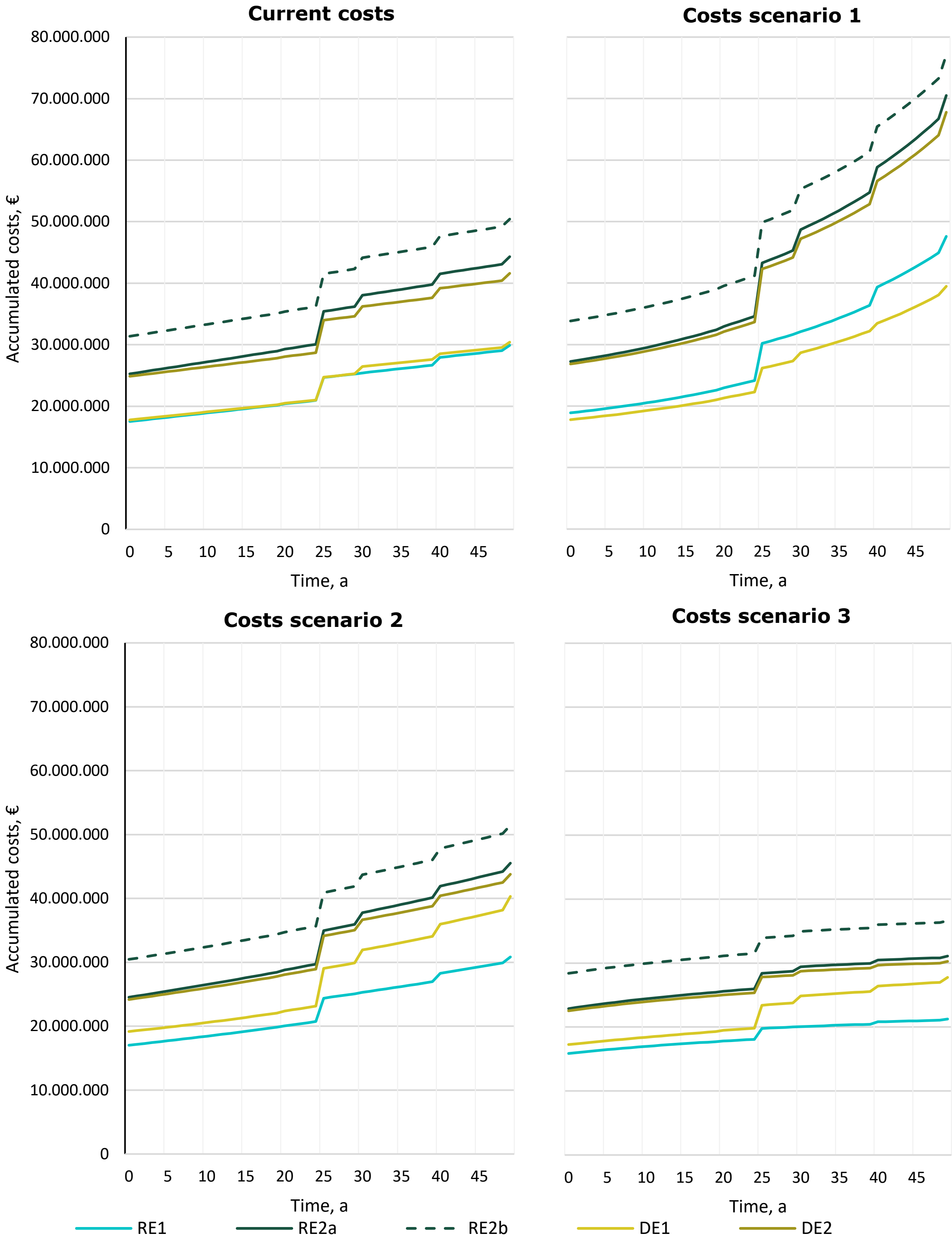

Figure 5. Accumulation of costs in refurbishment alternatives RE1–2 and replacement alternatives DE1–2 during a 50 year period. RE2a is a version of the where infrastructure construction for complementary construction is considered only for the respective site, while in RE2b supporting infrastructure construction for the wider area is also included. For a description of the costs scenarios see Table 3.

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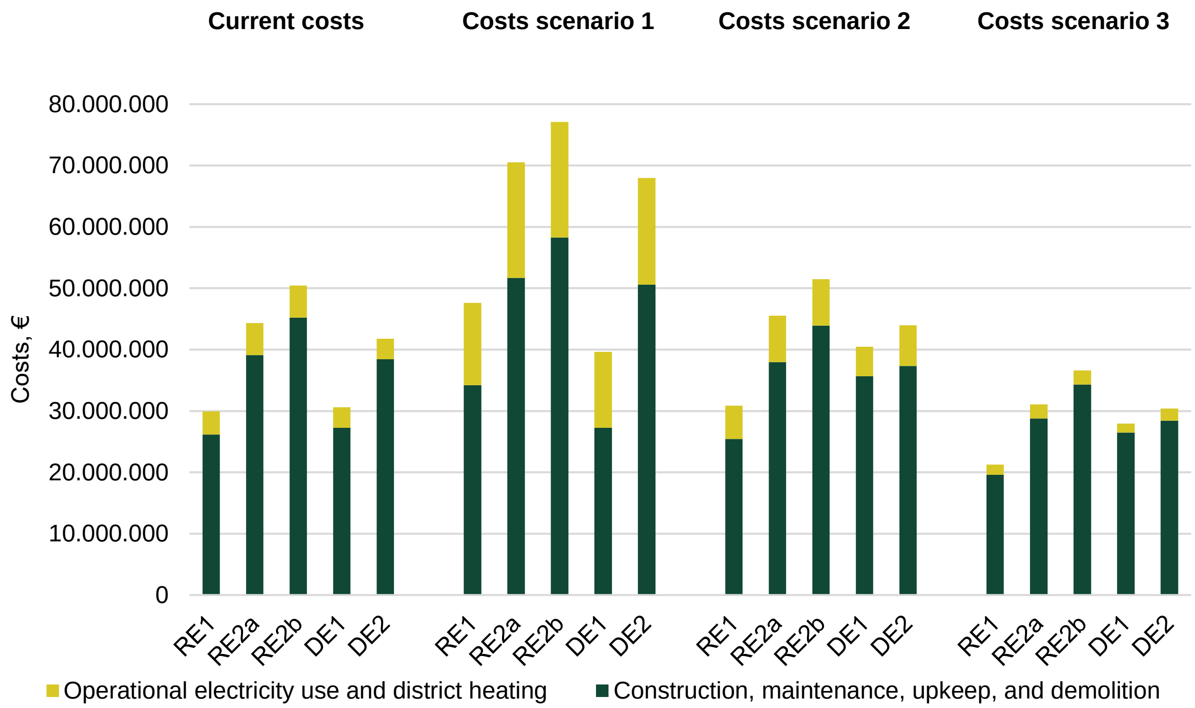

Figure 6. Life cycle costs of refurbishment alternatives RE1–2 and replacement alternatives DE1–2 after a 50-year period using current costs and in costs scenarios 1–3. RE2a is a version of the where infrastructure construction for complementary construction is considered only for the respective site, while in RE2b supporting infrastructure construction for the wider area is also included. For a description of the cost scenarios see Table 3.

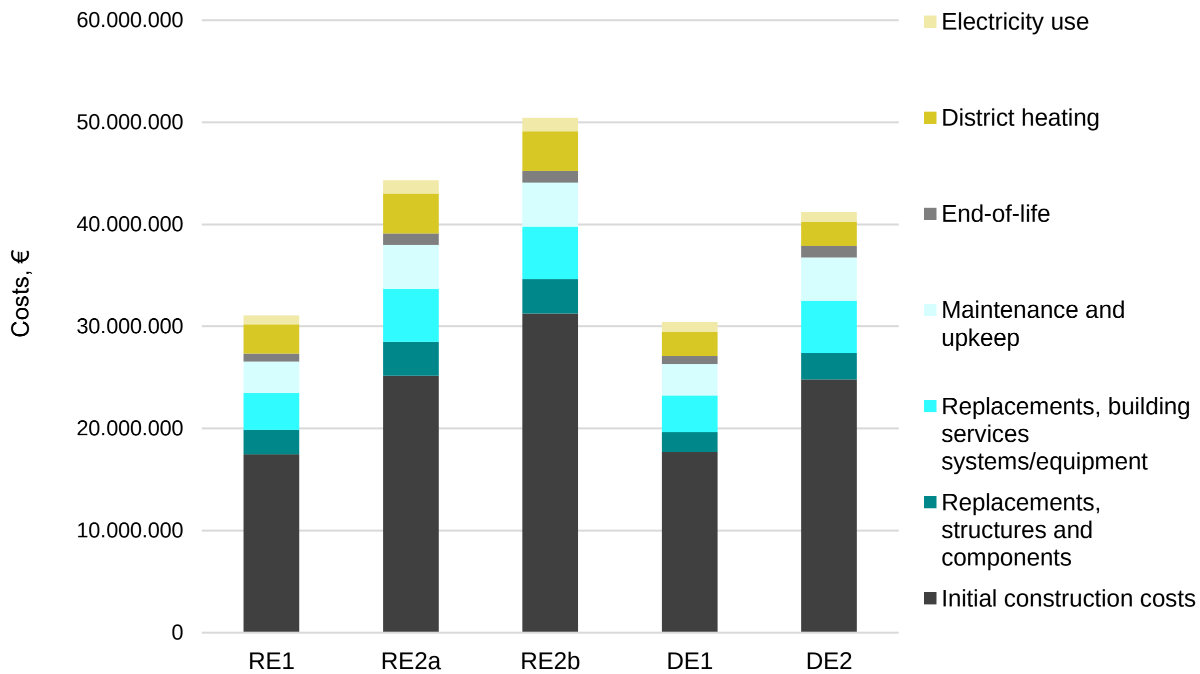

Figure 7. Life cycle costs of refurbishment alternatives RE1–2 and replacement alternatives DE1–2 after a 50-year period using current costs. RE2a is a version of the where infrastructure construction for complementary construction is considered only for the respective site, while in RE2b supporting infrastructure construction for the wider area is also included.

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7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across most of the structurally and spatially (in terms of both the buildings and their locations, i.e. suitable for housing) corresponding building stock in Vantaa. Based on 2018 data, the block of flats stock in Vantaa from the 1970s and 1980s comprises approximately 2,389,141 m² of gross floor area in 1,067 buildings. Applying the results of the demonstrator's renovation and extension scenario (RE1) to all these buildings, the amount of life cycle CO2 emissions avoided in comparison to the corresponding demolition and replacement scenario (DE1) would be 1,751,409,299 kgCO2e. It should be noted that not all buildings in the entire stock would be viable candidates for these measures, nor will there likely be such a massive need for dwellings as the extension would imply. On the other hand, buildings outside the aforementioned period might also be viable candidates. Regardless of the specific extent of the suitable stock, it is clear that the potential impacts are significant.

7.2 Realising the potential

Future public policy, and zoning and building regulation should acknowledge circular economy values in life cycle extension, the potential of which can be measured in saved virgin materials and avoided waste and CO2 emissions. This material and emission aspect should be promoted as a focal decision-making point, equal to heritage value and socio-economic considerations.

When there is no need to increase the density of the plot (RE1 and DE1 scenarios), emissions savings most likely go hand-in-hand with cost savings (apart for Cost scenario 1, where replacement is more affordable). However, when there is a need to house more people, the costs of the retention alternative (RE2) are higher than those of the replacement alternative (DE2), even if the emissions of the retention alternative are lower than those of the replacement. This forms a major implementation challenge.

Therefore, it would be highly recommendable to clarify the rules at play in building extensions, such as if and when the construction of an additional air-raid shelter or parking spaces are required. In practice, such requirements may raise the complexity and costs of a transformation project in a fashion that inadvertently encourages demolition and new build. These regulations are typically neither publicly available or explicitly stated; they vary between cities and may be negotiable to a degree.

Cities wishing to support life cycle extensions as a form of circular economy should devise enabling policies, publicize them openly and promote their adoption. On the city level and in the stock of properties controlled by the city, the following steps should be applied to relevant buildings. For privately owned properties, the respective owners should do the same.

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11. Study the physical condition of the building and devise a feasible repair scenario. *By whom: building surveyor (condition investigation), structural engineer (structural repair scenario), architect (architectural consequences of the repair scenario).*
12. Study the building's structural and practical potential for vertical extension, in particular the load-bearing capacity of the foundations and the need to add air-raid shelter and/or parking space. *By whom: structural engineer (foundations), architect (requirements from building codes and affordances for air-raid shelter and parking spaces).*
13. Set the targets for the vertical extension and design its layout and structures. *By whom: owner (targeted flat size distribution and other non-technical and technical targets), architect (spatial plan and architectural expression), structural engineer (structures).*
14. Study a replacement (demolition and new build) scenario as an alternative to the life cycle extension. *By whom: owner (targets for the new build), architect (spatial plan and architectural expression), structural engineer (structures).*
15. Quantify environmental, economic and socio-cultural impacts of both alternatives (life cycle extension vs. replacement). *By whom: environmental engineer or architect (environmental impacts), quantity surveyor (economic impacts), socio-cultural evaluator e.g. architect and/or social scientist (socio-cultural impacts, depending on the selection of studied impact categories).*
16. Select the more low-carbon and circular approach. Engage in further measures, such as the renewal of the local detailed plan to increase building rights for the additional floors or denser new build. Proceed to implementation with necessary measures, such as more detailed design, tendering, etc. *By whom: owner, together with other relevant parties such as planners, designers, contractors, etc.*

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Demonstrator	**D7: Transformation and densification on plot with a listed 1954 building, Hamburg**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Maike Hora (e-hoch-3) Johannes Braun (e-hoch-3) Miriam Akou (e-hoch-3) Shirin Gomez (e-hoch-3)

1. Mission statement, background and political decisions

The Godewindpark demonstration is an example of the preservation and transformation of a heritage listed building. The building was transformed from a car dealership to a gym with holiday apartments.

In Europe and Germany, there are many heritage buildings. When heritage buildings are left as they are, there is a risk of high vacancy and wasted resources including space and building materials. Through transformation, these heritage buildings find new, mixed or extended uses, which is why it is important to consider the potential of this type of building stock. However, it must also be considered that in the case of listed buildings, renovations of the exiting building energy envelope are often limited. This must be taken into account when considering ecological aspects.

This demonstration shows that increased costs of preservation efforts are often worth the effort, because in addition to the materials saved, there are also social and urban scale benefits. In this case, the potential of the site given its location and size made transformation worthwhile.

From a technical point of view, the demonstration also shows that there are opportunities to improve structural deficiencies of existing buildings to increase density.

The demonstration shows that economic efficiency should not always be the decisive factor.

From a development perspective, construction criteria and location are often important factors for consideration.

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Figure 5: Godewindpark façade

2. Project details

The existing building was erected in 1954 as a car dealership and extended several times between 1958 and 1966. Among other things, the workshop and offices were added during the 1960s. The building never had any other use prior to the conversion and was briefly vacant during the planning and project development phase.

Parts of the structure (the sales area) were heritage listed in the early 2000s because of the curved glass façade.

This project is located at Fahrenberg 4, 23570 Lübeck-Travemünde. The area is an attractive and very popular location on the Baltic coast of Schleswig-Holstein, about 85km north-east from Hamburg city centre.

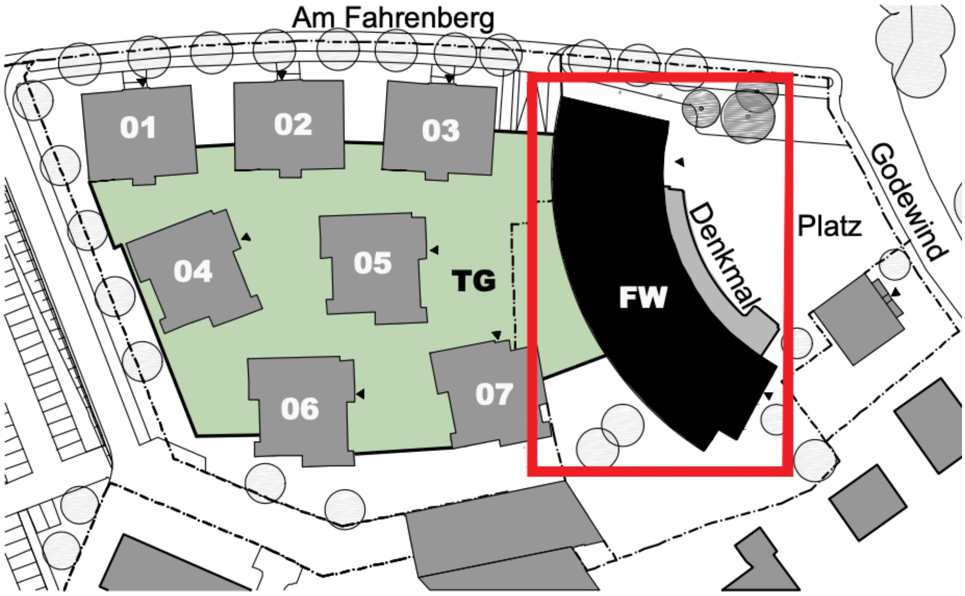

Figure 6: Location of Godewindpark

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The Godewindpark project, developed and built by the company Otto Wulff, involved the conversion of a one storey car dealership into a gym. Three additional floors were added above the existing heritage listed building for vacation apartments, comprising 119 vacation and condominium apartments.

Since significant areas and the façade of the car dealership is a listed building, this part of the building was integrated into the new construction. The workshop at the rear, on the other hand, was demolished and replaced by a new space.

Figure 7: East view of Godewindpark

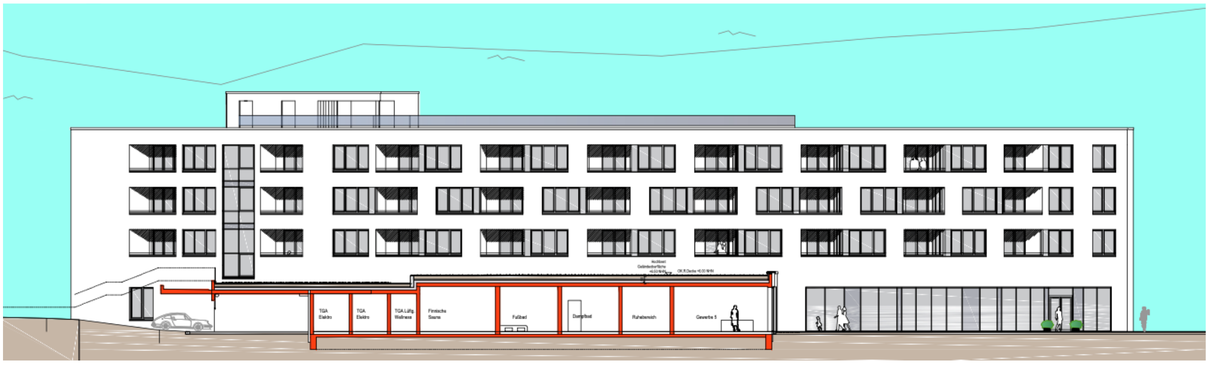

Figure 8: West view of Godewindpark

The entire project was completed in 2020, approximately 65 years after the construction of the original building and has now a net floor space of 5.440 m^2.

	2015	2016	2017	10/18	11/18	07/18	09/18	11/18	01/29	03/19	05/19	07/19	09/19	11/19	01/20	03/20	04/20
Concept design	■	■	■														
Commissioning of general contractor				■													
Demolition (where applicable)					■												
Construction						■	■	■	■	■	■	■	■	■	■	■	
Completion																	■

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3. Objective

The objective of the project was to retain the structure of the listed building and to transform it from a car dealership and workshop into a fitness room with holiday apartments, to demonstrate the benefits of looking at heritage listed buildings as potential building stocks.

Building components that were preserved included the following:

- Cornice beam east (above the glass façade)
- The load-bearing structure of the 1-storey building
- 2 rectangular steel/wood mullioned windows in the "Fahrenberg" wing including the historic window sills
- The rear wall of the curved structure including cornice
- The grid and muntin division of the window mullions in the defining curved glass façade east
- The profile dimensions of the isolated historic wooden mullions and the sills in the formative, curved glass façade east
- Textured rendering of the rear wall on remaining wall surfaces

The new building components included the following:

- Tiles and floor structures (incl. screed)
- Metal suspended ceiling incl. all lighting equipment
- Cladding of the subsequently installed steel reinforcement
- Electrical, heating and sanitary installations
- Technical installations
- Doors and gates
- Aluminium window-door element of the rear entrance
- The curved glass façade east of non-historic building elements (glazing, mullions, glass elements) Components (glazing, mullions, glazing bars, sills (dating from 2000))
- Wall cladding and ceiling cladding (wallpaper and plaster)

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- Roof sealing as well as parapet and cornice sheets
- Non-load-bearing walls
- Reinforcement of the concrete floor

4. Technical analysis

4.1 Challenges

What was considered unfavourable as a starting point was the limited load-bearing capacity of the foundation. The single storey building was in no way designed for the load of the three additional stories above. In addition, the floor of the building had eroded.

The preservation of the glass façade also presented some challenges, both from a visual and energy perspective. During the construction process, it was discovered that much of the heritage facade did not date from the original building construction date. This was unexpected.

The heritage requirements were not the only decisive factor for the preservation of the building fabric, since not all components were in their original condition. For the remaining building components, decisions were made based on condition and suitability to achieve the required quality. The focus here was on the common interest of preserving this building in its special form and leaving it usable. At the same time, these goals then had to be understood by the architects and transferred into the building planning, so that a functioning product could be created.

4.2 Solutions

To solve the issue of the limited load-bearing capacity of the foundation, additional piles were inserted in the existing structure. The eroded building floor was replaced. The effort involved was considerable, extending the construction time and cost. This was however necessary for the transformation.

In consultation with the authorities responsible for heritage protection and after an extensive survey, the façade was rebuilt and installed true to the original. The façade was thus adapted to current energy requirements in accordance with the state of the art. Cooperation with the heritage protection authority was of particular importance. First, it was necessary to define the exact building components that were heritage protected. This was followed by an as-built analysis of the condition of these components and then a joint determination of what may and must be renovated and in what form.

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4.3 Lessons learnt

Key lessons learnt for future projects include ensuring, early in the design process, that the heritage protection listing matches what is actually present onsite, and that collaboration is crucial for several reasons:

- Collaboration with the heritage authorities to clarify uncertainties, areas that must be preserved, areas that can be modified and to what extent.
- Collaboration with the architects to integrate both the modern high-quality standards of new buildings with the heritage look of the existing building, without standing out in a negative way.

This project included many opportunities, but also many challenges that made the implementation of such a project something special. The knowledge gained from this project could be applied to the densification of other existing heritage listed structures. This was a project with many unique conditions including its heritage status, the facade detailing, the need to strengthen the foundations and load bearing walls, the integration of the building within a quarter with multiple proposed buildings and its location close to the sea. Increased density and a new future-oriented use was achieved through revised room layouts and structural strengthening to enable three new floors above. The overall heritage character of the building created other design opportunities in non-heritage listed areas of the building. For example, different finishes to highlight where there were previously doors to celebrate the buildings changing function and history. In addition, the development of multiple buildings as one integrated precinct enabled views of and from the heritage facade to be preserved and celebrated.

Cooperation with the heritage protection authorities was key to the success of this project and should be incorporated in the early project planning design phase of similar projects to achieve the best outcomes.

5. Performance measures

5.1 Baseline

The performance of the project has been assessed over a completely new life cycle i. e. approximately 80 to 100 years. For context, the performance has been compared to a base case without circular construction objectives. The base case scenario for this project is the complete demolition of the listed building and construction of a new building, of the same size of the fitness centre with holiday apartments, without retaining any of the existing building components.

The analysis was conducted for steel and concrete materials only.

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5.2 Environmental performance indicators

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 15 Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
~~**Design for secondary material compatibility**~~	~~% of secondary materials used in the building at design stage~~
~~**Design for disassembly**~~	~~% of the building that can be disassembled~~
Design for adaptability (transformation capacity)	% of the building that can be adapted at end of life
~~**Renewable content**~~	~~% renewable content~~
Reused content	% reused content
~~**Recycled content**~~	~~% recycled content~~
~~**Reuse potential**~~	~~% by mass of products that can be reused~~
~~**Recycling potential**~~	~~% by mass of products that can be recycled~~
~~**% building products covered by Extended Producer Responsibility schemes**~~	~~% building products covered by an extended producer responsibility scheme (e.g. a take-back scheme)~~
~~**Intensiveness of use**~~	~~% hours actually occupied versus potential~~
Total material arisings (whole life)	Tonnes of waste arising
% reused, remanufactured, recycled	% reused, remanufactured, recycled
Whole life carbon emissions	kgCO2e

5.3 Environmental performance results

The environmental performance was exclusively measured by the amount of demolished and used reinforced concrete.

Overall, the circular intervention improved the performance of the project on all 6 of the indicators considered. The biggest improvement was in the whole life carbon emissions which was improved by 7 %, which was due to volume of the existing listed building structure/ components that were kept.

As a result of the intervention, it was estimated that 321 tonnes of material, 186 tonnes of waste and 74.231 kg of CO2e was saved. Compared to the new net floor space of the building, the carbon emission saving was 14 kgCO2e/m^2.

Table 16 Environmental performance results

	Base case	Intervention
% of material not used	100 %	14 %
% of the building that can be adapted at end of life	0 %	86 %
% reused content	0 %	86 %*
Tonnes of materials used	5.367 tonnes	5.046 tonnes
Tonnes of waste arising	216 tonnes	30 tonnes

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Whole life carbon emissions (kgCO2e)	1.183.226 kgCO2e	1.108.995 kgCO2e
- Life carbon emissions of demolition process (kgCO2e)	1.671 kgCO2e	232 kgCO2e
- Life carbon emissions of construction process (kgCO2e)	1.181.555 kgCO2e	1.108.763 kgCO2e
***216t demolition base case - 30t demolition intervention = 186t —> 86%**		

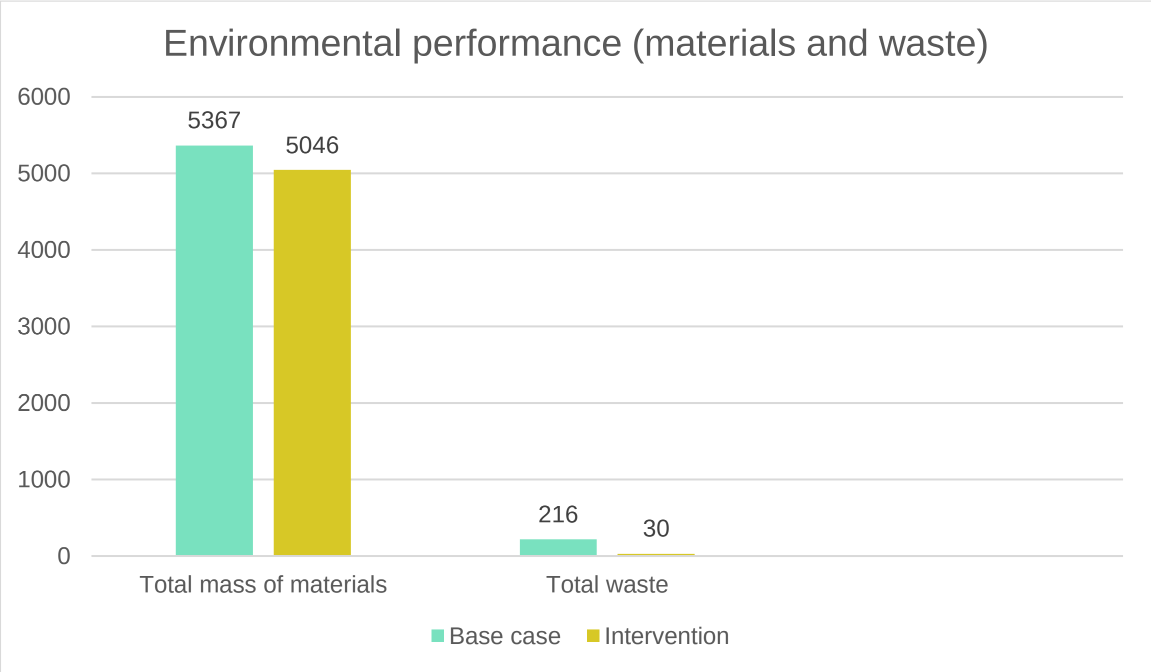

Figure 9 Environmental performance comparison (materials and waste)

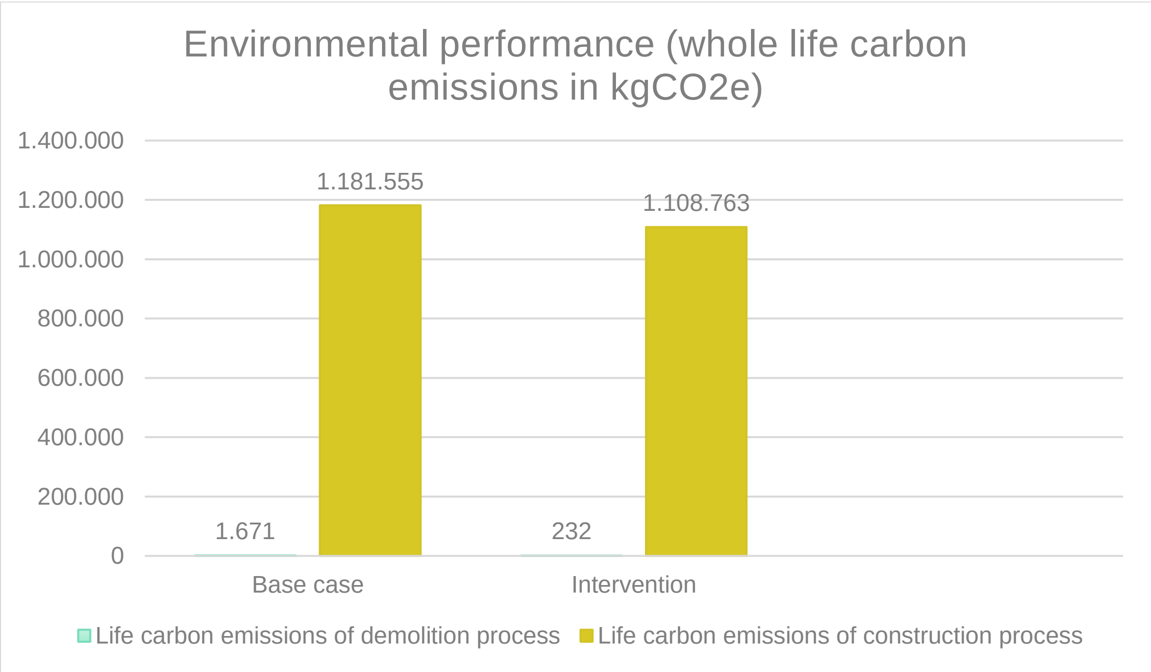

Figure 10: Environmental performance comparison (whole life carbon emissions)

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6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to a base case. The base case is described in section 5.1.

6.2 Economic analysis indicators

The economic analysis has been considered in relation to the four components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing; construction costs and end-of-life costs (of the existing building), along with the relevant components of whole life cost.

For the economic analysis the total net value costs have been considered for the demolition, refurbishment and construction processes. Operation, maintenance and end-of-life cost (of the new building) are excluded from the calculation as the costs would be nearly identical in both scenarios.

6.3 Economic analysis results

This analysis found that in comparison to the base case, the circular construction intervention resulted in a decrease in the total demolition and construction by 4,2 %.

Table 17 Economic analysis

	Base case	Intervention	Difference
Total demolition and construction costs	€ 9.420.000	€ 9.024.000	4,2 %
- End-of-life costs (demolition of existing building)	€ 91.000	€ 49.158	46 %
- Construction costs (incl. refurbishment)	€ 9.329.000	€ 8.974.842	3,8 %

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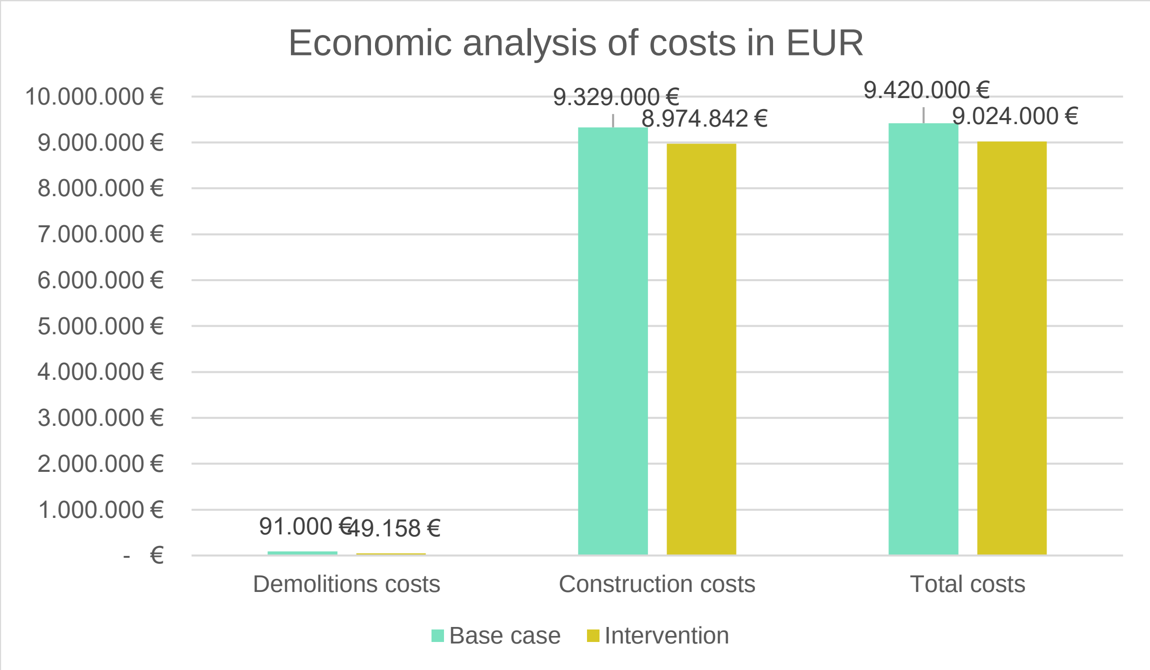

Figure 11 Economic analysis comparison

Regarding the state of the art, the building naturally has weaknesses in its existing components compared to the energy efficiency of a new building. However, for this project, the building services were renovated and as such there is no difference to a new building. For example, air conditioning and ventilation were integrated to make the most of the existing potential.

This demonstration shows that increased costs of preservation efforts are often worth it, because in addition to the materials saved, there are also social and urban scale benefits. In this case, the potential of the site given its location and size made transformation worthwhile.

7. Social results

The building is located within a residential area next to a small park with a pond. The promenade and the beach of Travemünde are about 500 m walking distance. In addition, the train station of Travemünde is about 300 m away. Various supermarkets, as well as basic medical care are located within a radius of 1.0 km.

For the social analysis 25 selected indicators have been assessed by a group of experts from the involved partners for two different scenarios:

- Do nothing: no intervention of the building
- Partial demolition: a partial demolition and transformation process with the existing building

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

The indicators were weighted and scored from 1 to 10, meaning 1 the lowest rate and 10 the highest rate. The scores and indicators were then grouped together to obtain eight criteria which are presented in the table belllow and visualised in figure 7.

Table 18: Weighting and scoring od social criteria of Godewind Park

CRITERIA	WEIGHT	Norm. weight.	DO NOTHING		TRANSFORMATION	
			norm. weighted score	**weighted score**	norm. weighted score	**weighted score**
Affordability	9,3	0,13	0,25	**2,0**	0,59	**4,6**
Freedom of choice	9,2	0,13	0,00	**0,0**	0,98	**7,8**
Safety/Security	9,5	0,13	0,00	**0,0**	0,00	**0,0**
Urban connection	9,2	0,13	0,32	**2,5**	1,15	**9,2**
Services/job	10,0	0,14	0,20	**1,5**	1,02	**7,5**
Public image	6,5	0,09	0,34	**3,8**	0,27	**3,1**
Social diversity	9,5	0,13	0,00	**0,0**	0,65	**5,0**
Social networks	10,0	0,14	0,00	**0,0**	0,68	**5,0**
Total	73,2	1,00	1,11	**9,8**	5,35	**42,2**

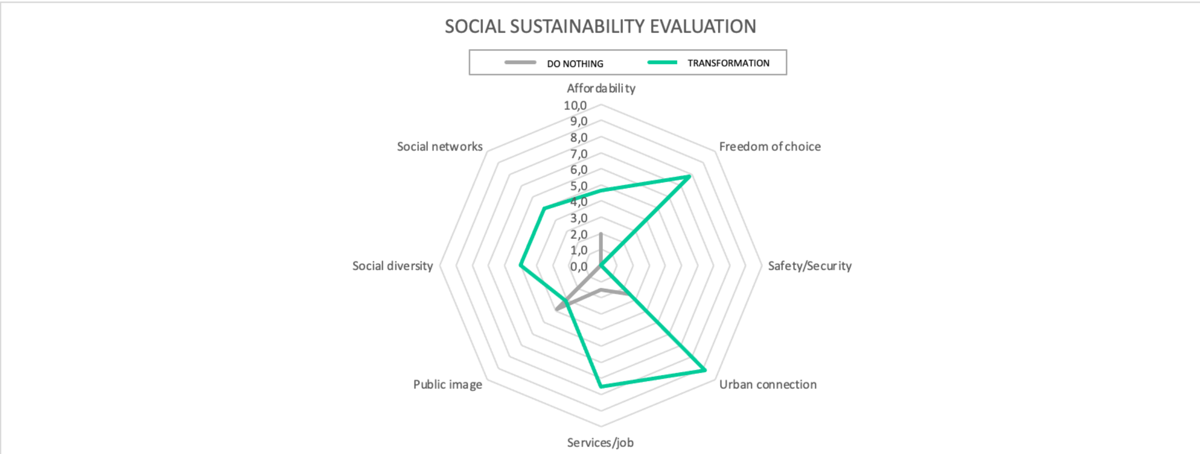

Figure 12:Diagram of social scoring of different scenarios of Godewind Park

Compared to the scenario where no actions are initiated, the social criteria may be improved by 328 % with a partial demolition and transformation process. A third scenario where the existing building would be completely demolished and rebuilt is not considered, as the social results would be the same than for the transformation scenario.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Demonstrator	**D8: Housing block renovation for 1960s housing typology, Hamburg**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Maike Hora (e-hoch-3) Johannes Braun (e-hoch-3) Miriam Akou (e-hoch-3) Shirin Gomez (e-hoch-3)

1. Mission statement, background and political decisions

This project demonstrates how the modernisation of an apartment building can be applied to extend the building life cycle and avoid demolitions. This will reduce the need of virgin construction materials and avoid demolition waste.

The base line scenario will be the complete demolition of an existing building and the development of a new construction as shown in figure 1.

Figure 13: New construction of the building

2. Project details

After the demolition of an existing three-storey building with a parking lot, the construction of a new residential building is planned. The new building will have maximum dimensions of approx. 49,4 m x 12 m and will be equipped with a basement, a ground floor, three upper

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floors and an attic. A new car park with ten parking spaces will be built to the east of the development and will be accessed from the street.

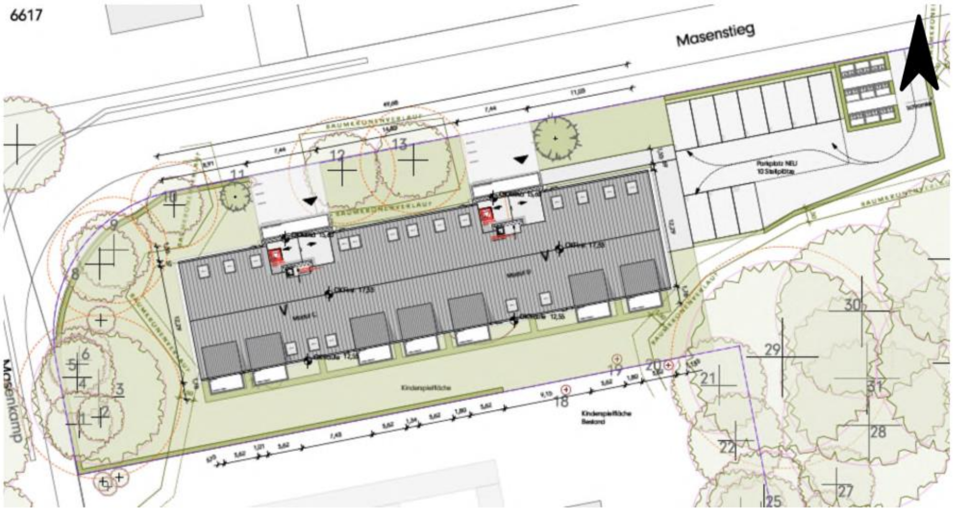

Figure 14: Site plan new building

The original building was constructed in 1963 for social housing purposes. The total living space is 1.120 m² with 15 one-room apartments and 9 two-rooms apartments. 37 parking spaces are available.

Figure 15: Existing building

The new building will also be used for social housing. The building will have four floors and an attic. A living space of 2.209 m² is planned, with 35 apartments of two to four rooms. The average apartment size will be 63 m². Ten parking spaces will be available.

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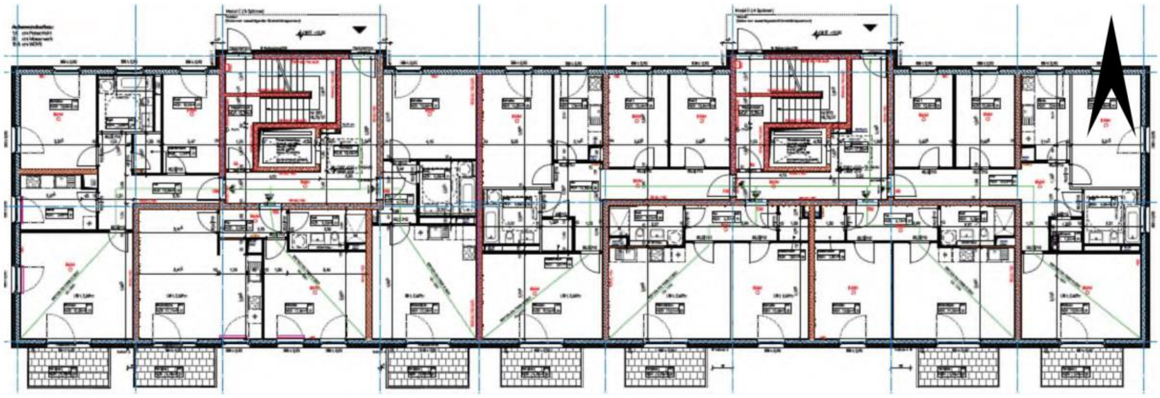

Figure 16: Ground plan of ground floor (new building)

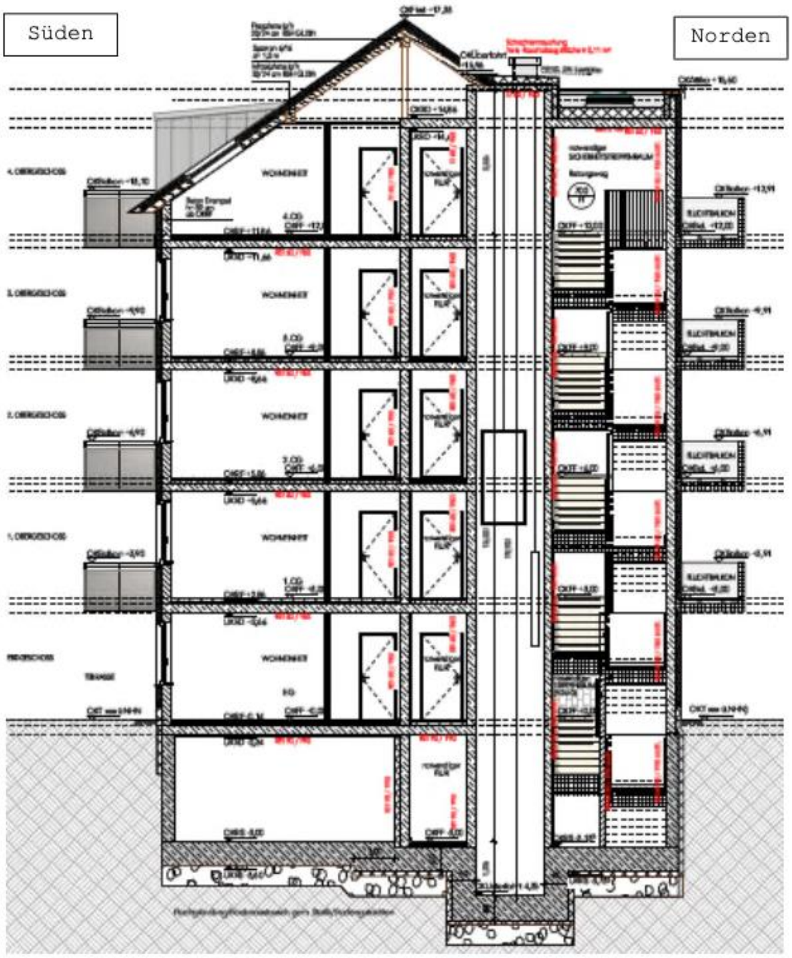

Figure 17: Cut view of new building

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

3. Objective

This project serves as a baseline for the development of a tool that allows to compare the CO2 emissions from a scenario where a building is demolished and a new building is constructed versus a modernisation concept of an existing building. The objective is to help the decision makers to consider other options besides demolition on behalf of a circular construction.

4. Performance measures

4.1 Baseline

Performance of the project has been assessed over a period of 50 years. For context, the performance has been compared to a base case without circular construction objectives. For this project the base case is a demolition of the original building and the new construction.

The intervention consists in a modernisation process of the exciting building, e.g. new windows, composite thermal insulation system, new bath rooms.

4.2 Environmental performance indicators

As the living space is different of the two scenarios, the environmental indicators are compared to the 1 m² living space.

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 19 Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
~~**Design for secondary material compatibility**~~	~~% of secondary materials used in the building at design stage~~
~~**Design for disassembly**~~	~~% of the building that can be disassembled~~
~~**Design for adaptability (transformation capacity)**~~	~~% of the building that can be adapted at end of life~~
~~**Renewable content**~~	~~% renewable content~~
~~**Reused content**~~	~~% reused content~~
~~**Recycled content**~~	~~% recycled content~~
~~**Reuse potential**~~	~~% by mass of products that can be reused~~
~~**Recycling potential**~~	~~% by mass of products that can be recycled~~
~~**% building products covered by Extended Producer Responsibility schemes**~~	~~% building products covered by an extended producer responsibility scheme (e.g. a take-back scheme)~~
~~**Intensiveness of use**~~	~~% hours actually occupied versus potential~~
Total material arisings (whole life)	Tonnes of waste arising
~~**% reused, remanufactured, recycled**~~	~~% reused, remanufactured, recycled~~
Whole life carbon emissions	kgCO2e

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

4.3 Environmental performance results

Overall, the circular intervention improved the performance of the project on three out of the three indicators considered.

The biggest improvement was in whole life carbon emissions which was improved by 99 %. This was because of the reuse of existing building structure.

As a result of the intervention it is estimated that 1,98 tonnes of material per m² living space, 0,03 tonnes of waste per m² living space and 4,5 kg of CO2e per m² living space will be saved.

Table 20 Environmental performance results

	Base case	Intervention
% of material not used per m² living space	100 %	1,5 %
Tonnes of materials used per m² living space	2,28 tonnes/m²	0,30 tonnes/m²
Tonnes of waste arising	3.697 tonnes	28 tonnes
Tonnes of waste arising per m² living space	1,67 t/m²	0,03 t/m²
Whole life carbon emissions (kgCO2e per m² living space)	56,51 kgCO2e/m²	7,29 kgCO2e/m²
- Demolition carbon emissions (kgCO2e per m² living space)	42,82 kgCO2e/m²	0,80 kgCO2e/m²
- Transportation of demolished materials carbon emissions (kgCO2e per m² living space)	2,76 kgCO2e/m²	0,04 kgCO2e/m²
- Construction/ Modernisation	10,93 kgCO2e/m²	6,45 kgCO2e/m²

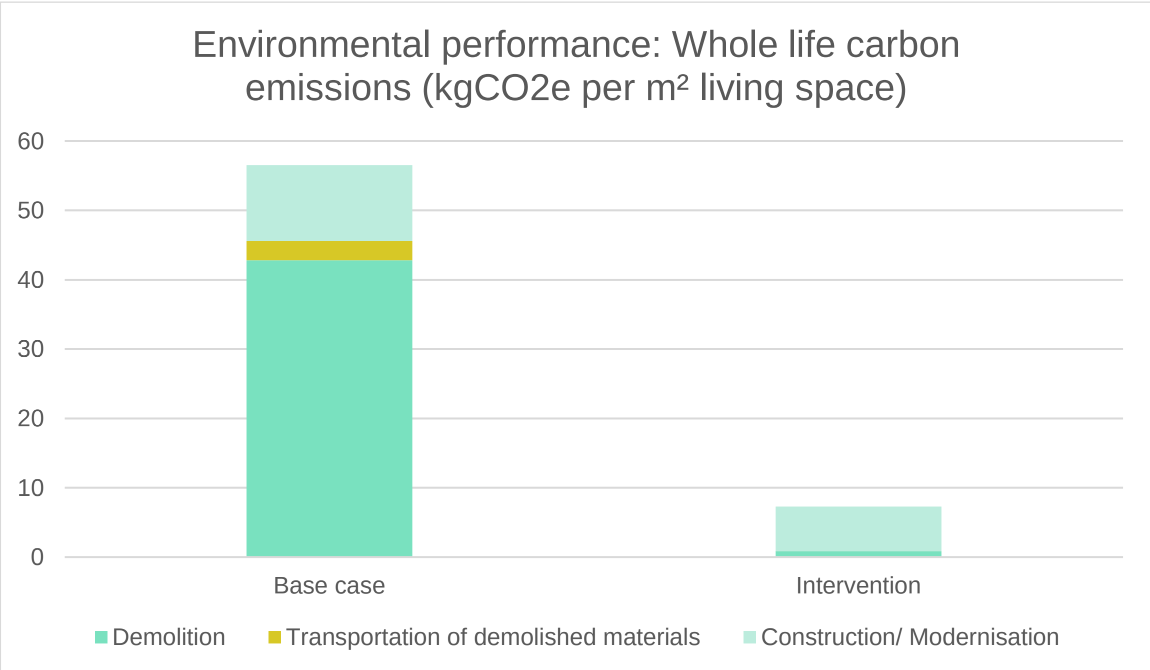

Figure 18 Environmental performance comparison

The following assumptions have been taken for the calculation of the carbon emissions:

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- The data of the masses are based on the demolition specification for the demolitions process of the base case.
- For the intervention it is assumed, that only the following materials will be demolished:
  - Building materials containing asbestos
  - Artificial mineral fibre
  - Tiles and ceramics of the bathroom
  - Glass
  - PCB-containing joints
- The demolished materials will be transported to the Eggers recycling site.
- The Ecoinvent process "Hazadous material for underground disposal" for the asbestos abatement has been modified to exclude the amount of needed steel (because these materials are not stored in metallic barrels).
- Evacuated earth of 400 m3 for the new construction.
- The roof trusses do not contain a wooden floor.
- Operation and use phase are excluded, as they are assumed equivalent for both scenarios.
- Furniture in excluded from the analysis.
- The data for the new budling is based on the costing of the project. For the intervention it is assumed that components like windows and insulation systems are renewed based on the data of the new building.
- Specific assumptions for the stairs and windows have been made to complete the calculation.
- Roof structure remains in the intervention as the wood is not assumed to be contaminated.
- The concrete framework is excluded for the new construction, as it is often reused.

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5. Economic analysis

5.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to a base case. The base case is described in section 5.1.

The cost calculation on the base case (new construction) is based on the actual demolition specifications and costing of the project. As the project has not been finished yet, the costs may change during the implementation. Additionally, the 20 % cost reduction for the housing company is not included.
The cost calculation of the intervention (modernisation) is based on four other comparable modernisation projects of the same housing company.

5.2 Economic analysis indicators

The economic analysis has been considered in relation to the four components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing; construction costs (without operation costs, maintenance costs and end-of-life costs of the new/modernised building), along with the relevant components of whole life cost. The demolition costs of the original building have also been considered.

5.3 Economic analysis results

This analysis found that in comparison to the base case, the circular construction intervention resulted in decreased total net costs (demolition and construction) of 7,4 % per m² living space.

Table 21 Economic analysis

	Base case	Intervention	Difference
Total net costs per m² living space (demolition and construction/refurbishment)	€ 2.695	€ 2.133	20,9 %

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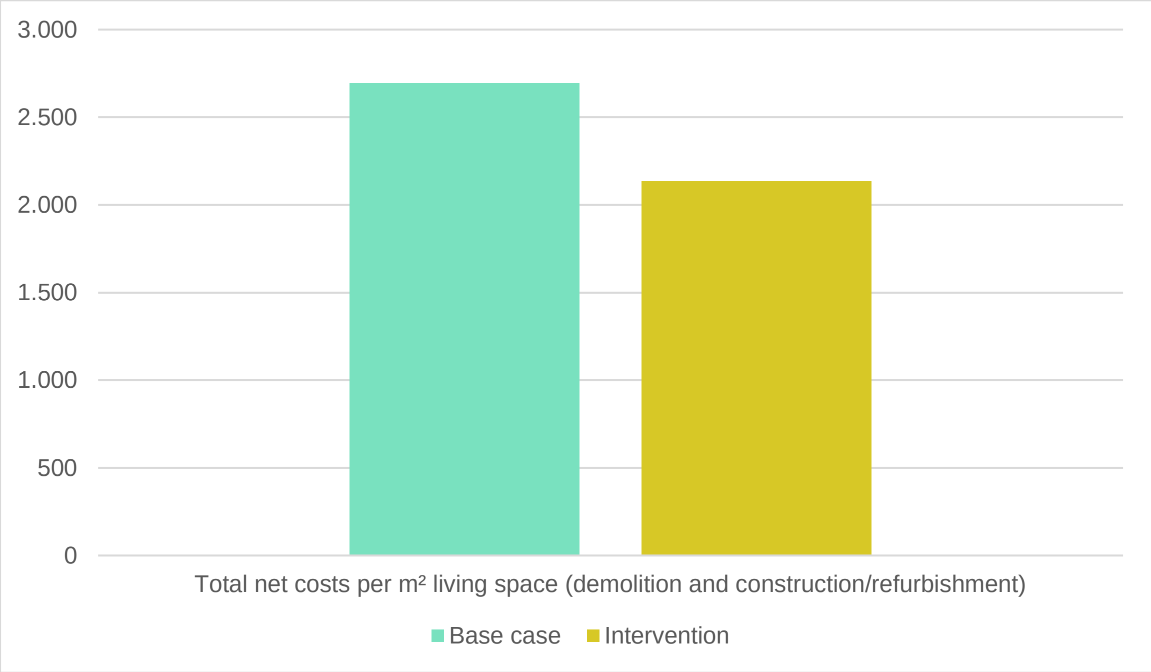

Figure 19 Economic analysis comparison

The asbestos abatement has been excluded from the calculation because it is necessary for both scenarios.

The following assumptions have been made for the costs calculation:

- The costs of the modernisation projects are assumed to be in net value.
- Additional construction costs (Baunebenkosten) of 17 % have been assumed.

6. Social Analysis

For the social analysis 25 selected indicators have been assessed by a group of experts from the involved partners for three different scenarios:

- Do nothing: no intervention of the building is planned.
- Transformation: a modernisation and transformation process with the existing building is planned.
- Built completely new: the existing building will be demolished, and a new building will be constructed.

The indicators were weighted and scored from 1 to 10, meaning 1 the lowest rate and 10 the highest rate. The scores and indicators were then grouped together to obtain eight criteria which are presented in the diagram.

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CRITERIA	WEIGHT	Norm. weight.	DO NOTHING		TRANSFORMATION		BUILT COMPLETELY NEW	
			norm. weighted score	weighted score	norm. weighted score	weighted score	norm. weighted score	weighted score
Affordability	9,3	0,13	0,42	**3,3**	0,68	**5,4**	0,73	**5,7**
Freedom of choice	9,2	0,13	0,59	**4,7**	0,72	**5,7**	1,04	**8,3**
Safety/Security	9,5	0,13	0,85	**6,5**	0,97	**7,5**	1,09	**8,4**
Urban connection	9,2	0,13	0,66	**5,3**	0,70	**5,6**	0,79	**6,3**
Services/job	10,0	0,14	0,00	**0,0**	0,00	**0,0**	0,00	**0,0**
Public image	6,5	0,09	0,55	**6,2**	0,68	**7,7**	0,82	**9,2**
Social diversity	9,5	0,13	0,90	**6,9**	0,61	**4,7**	0,61	**4,7**
Social networks	10,0	0,14	0,00	**0,0**	0,00	**0,0**	0,00	**0,0**
Total	73,2	1,00	3,96	**32,9**	4,37	**36,6**	5,08	**42,6**

Figure 20: Weighting and scoring of social criteria

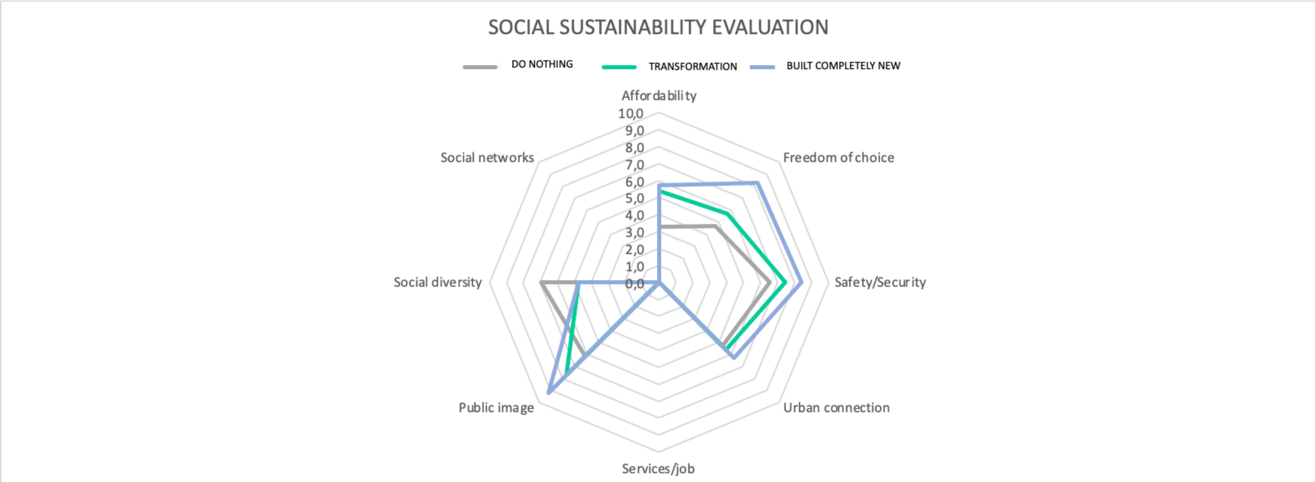

Figure 21: Diagram of social scoring of different scenarios

Compared to the scenario where no actions are initiated, the social criteria may be improved by 11.3 % with a transformation process and by 29.7 % with the construction of a new building. It means that after a demolition the new building achieves a 17.0 % higher score than the modernised building.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Demonstrator	**D9: Transformation of a multi-story parking garage from 1963, Hamburg**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Maike Hora (e-hoch-3) Johannes Braun (e-hoch-3) Miriam Akou (e-hoch-3) Shirin Gomez (e-hoch-3)

1. Mission statement, background and political decisions

This project demonstrates how strategic tools for transformation of the built environment across building and neighborhood scales reduces raw material waste and extend building life cycles. This project will facilitate transformative development, involving key stakeholders to develop and contextualize regenerative design strategies, principles and visualization.

Figure 22: Perspective of proposed Gröninger Hof transformation by Duplex Architekten

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Figure 23: Section of proposed Gröninger Hof transformation by Duplex Architekten

2. Project details

The Gröninger Hof project is led by the Genossenschaft Gröninger Hof eG (Gröninger Hof Cooperative).

Gröninger Hof multi-level car park building is located at Neue Gröningerstraße 12, 20457 Hamburg (Altstadt), which is considered the city's commercial heart. The building was built in 1963. The use of the building as a car park ceased in 2020. The proposed project is currently in the planning phase.

The site is approximately 2.000 m^2. The total existing building floor area is approximately 10.300 m^2 consisting of 8 floors and approximately 650 car parking spaces. In the new design 70-84 flats, cafes, workshops, offices and co-working spaces are proposed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Figure 24: Gröninger Hof (front view)

Figure 25: Gröninger Hof (inside view)

3. Objective

The Gröninger Hof demonstration is an example of the transformation of a typical multi-level concrete car park building into a mixed-use (predominantly residential) building. The transformation aims to create affordable, high quality and sustainable inner-city housing for diverse tenants and includes community uses. The conversion of a multi-level car park building to a future-oriented use is a contemporary expression of social and ecological change. A partial reuse of the building shall reduce the raw material needs and construction waste.

4. Technical analysis

4.1 Challenges

During an inspection of the building, chloride contamination was detected. Due to a missing sealing layer to protect the concrete, de-icing salt contaminated the materials making the columns and walls on several stories unusable for the new building. Furthermore, this concrete will need to be disposed of as special waste.

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Another challenge is the height of the existing walls, which do not meet the standards for housing for new apartments.

4.2 Solutions

The contaminated concrete structures will need to be demolished and replaced, with the exception of almost only the car park foundation, which remained uncontaminated.

The new building will be rebuilt according to the original plans by incorporating an intelligent design for the proposed future apartments that allows for generous living spaces while keeping the original height of the walls from the car park building.

4.3 Lessons learnt

The proposed project is currently still in the planning phase, but one key lesson learnt is the necessity to review/ inspect the integrity of load-bearing construction components. This includes especially the corrosion of steel and concrete material and potential presence of harmful substances.

5. Performance measures

5.1 Baseline

For context, the performance has been compared to a base case without circular construction objectives. For this project the base case is an existing car park building which is demolished completely and will be rebuilt for the second building. The analysis is based on steel and concrete materials only.

5.2 Environmental performance indicators

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 22. Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
Reused content	% reused content
Reuse potential	% by mass of products that can be reused
Total material arisings (whole life)	Tonnes of waste arising
% reused, remanufactured, recycled	% reused, remanufactured, recycled
Whole life carbon emissions	kgCO2e

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

5.3 Environmental performance results

Overall, the circular intervention can improve the performance of the project on all six of the indicators considered.

The biggest improvement is in used materials which was improved by 47 %. This was due to the intention of retaining foundations and additional walls and soles from the existing building.

As a result of the intervention it is estimated that 2.613 tonnes of material, 2.613 tonnes of waste and 573.809 kg of CO_2e will be saved.

Table 23. Environmental performance results

	Base case	Intervention
% of material not used	100 %	84,5 %
% reused content	0 %	15,5 %
% by mass of products that can be reused	0 %	15,5 %
Tonnes of materials used	5.548 tonnes	2.936 tonnes
Tonnes of waste arising	16.860 tonnes	14.247 tonnes
Whole life carbon emissions (kgCO2e)	1.347.010 kgCO2e	773.201 kgCO2e
- Carbon emissions for demolition process	168.780 kgCO2e	142.627 kgCO2e
- Carbon emissions for construction process	1.178.230 kgCO2e	630.574 kgCO2e

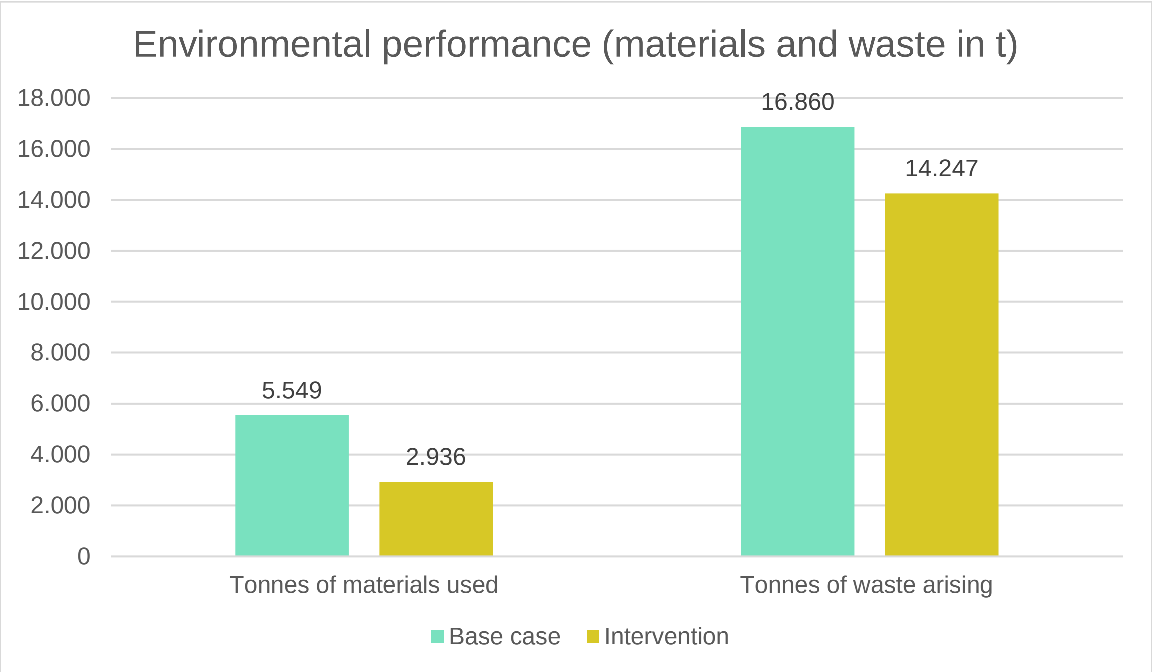

Figure 26: Environmental performance comparison (materials and waste)

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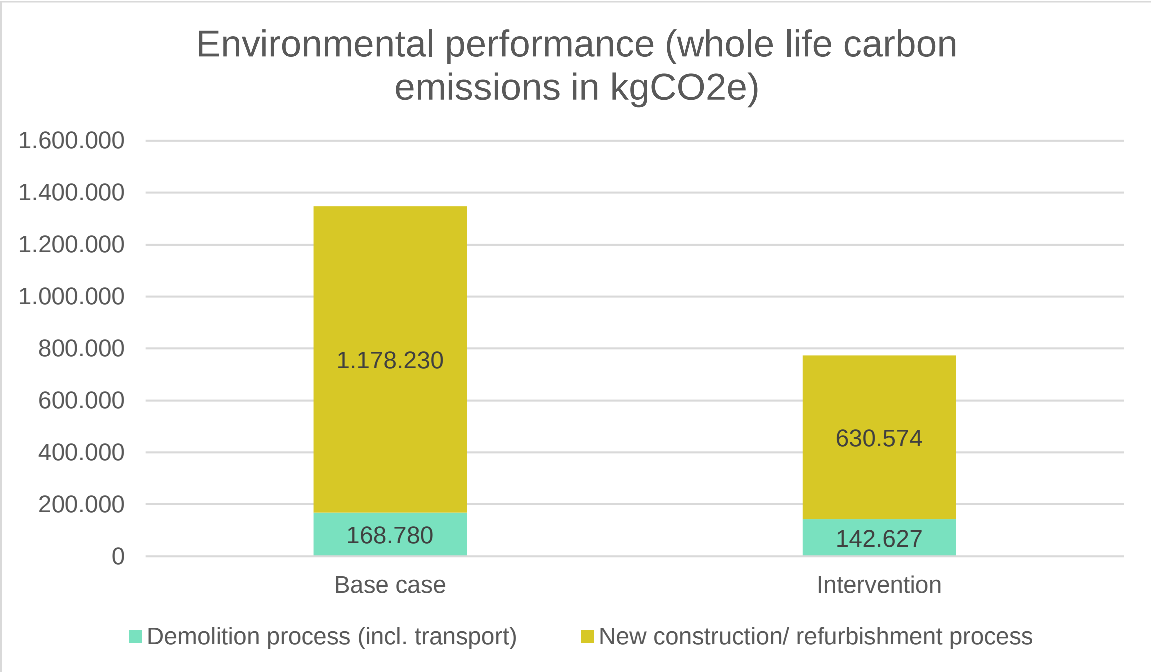

Figure 27: Environmental performance comparison (whole life carbon emissions)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been done in comparison to a base case. The base case is described in section 5.1.

The cost calculation for the demolition has taken into consideration costs for landfill class 0 (inert landfill for mineral waste with low pollutant content) and landfill class 2 (landfill for polluted but non-hazardous waste) to account for the contaminated concrete. This is assumed to be an exception and not the base case for the upscaling potential.

6.2 Economic analysis indicators

The economic analysis has been considered in relation to the four components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing; construction costs and end-of-life costs (of the existing building), along with the relevant components of whole life cost.

6.3 Economic analysis results

This analysis found that in comparison to the base case, the circular construction intervention resulted in decreased demolition costs of about 15 % and a total cost reduction of about 4 %.

Table 24. Economic analysis

	Base case	Intervention	Difference
Total costs (with landfill class 0)	€ 20.508.394	€ 19.793.891	3,5 %
Total costs (with landfill class 2)	€ 20.763.333	€ 20.009.311	3,6 %
- Demolition costs (landfill class 0)	€ 457.394	€ 387.891	15,2 %
- Demolition costs (landfill class 2)	€ 712.333	€ 603.311	15,3 %
- Construction costs	€ 20.051.000	€ 19.406.000	3,2 %

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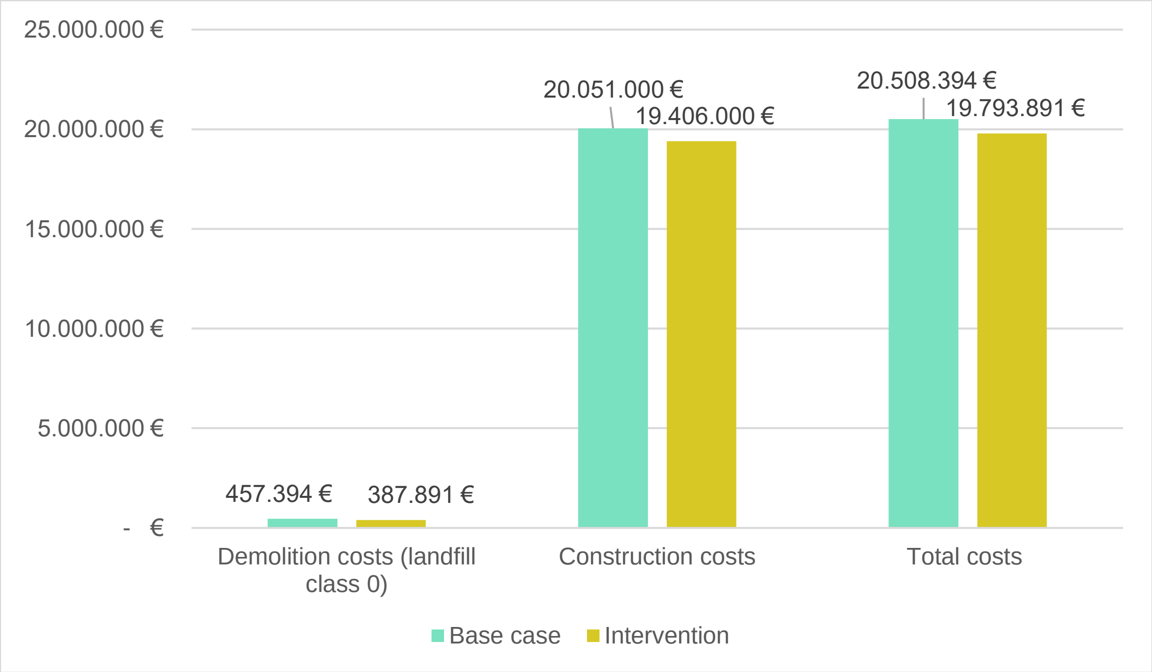

Figure 28. Economic analysis comparison

The following elements have been considered for the calculation of the demolition costs:

- Above-ground demolition would take approx. 60 working days / 3 months.
- Foundation excavation would take approx. 3 weeks extra.
- The road would probably have to be fully closed, the costs for this are not included, but are not expected to be significant.
- The building would have to be installed with scaffolding on three sides (major cost).
- The footpath would need to be protected by a drop bed (rubber matting), which is a weekly cost, 3 weeks have been assumed to take down the frontage.
- If the foundations are crushed, vibration monitoring will be required due to the nearby historic church.
- Equipment used would be a 35 t excavator and a long front excavator.
- To recycle concrete, one LAGA construction waste analysis per 1000 t is needed, which makes 10 analyses for disposal.

The following were not included in the cost estimates:

- The remediation of the hazardous waste (because this would also be done for a rebuild).
- The remediation of the workshop (here hydrocarbon contamination of building materials is to be expected).
- The remediation of the façade panels.
- The construction of an underpinning in the case of foundation excavation (technically very complex, the cost would have to be enquired about with a specialist civil engineering firm).

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The following elements have been considered for the calculation of the construction costs:

- The indication refers to cost group 300+400 (i.e. building costs) from DIN 276
- This does not include cost group 200 (preparatory measures), i.e. development, demolition work, disposal of contaminated materials, etc.).
- All necessary inspections, approvals, neighborhood permits, permits and fees are to be arranged by the client and any resulting measures and costs are to be borne by him.
- The commercial units are considered as a closed shell, i.e. without finishings and building services. The limits are the commercial entrance doors and tenant transfer boxes from the installation which must be arranged by the trader himself). Pricing commercial units is usually very difficult in this case, as the materials of different components are not known. Therefore, the calculation is based on assumptions.
- Cost group 500 (outside facilities), cost group 600 (fittings (including kitchens) and cost group 700 (all planning etc.) and of course also land and financing costs (cost group 100 + 800) are not included in the above price.
- Prices are current price assumptions, i.e. corresponding construction cost adjustments are to be made for the possible execution time.

7. Social Analysis

For the social analysis 25 selected indicators have been assessed by a group of experts from the involved partners for two different scenarios:

- Do nothing: no intervention of the building is planned.
- Partial demolition: a partial demolition and transformation process with the existing building is planned.

The indicators were weighted and scored from 1 to 10, meaning 1 the lowest rate and 10 the highest rate. The scores and indicators were then grouped together to obtain eight criteria which are presented in the diagram.

CRITERIA	WEIGHT	Norm. weight.	DO NOTHING		PARTIAL DEMOLITION	
			norm. weighted score	weighted score	norm. weighted score	weighted score
Affordability	9,3	0,13	0,00	**0,0**	0,87	**6,8**
Freedom of choice	9,2	0,13	0,00	**0,0**	1,19	**9,5**
Safety/Security	9,5	0,13	0,46	**3,5**	1,23	**9,5**
Urban connection	9,2	0,13	0,48	**3,8**	1,02	**8,1**
Services/job	10,0	0,14	0,00	**0,0**	0,41	**3,0**
Public image	6,5	0,09	0,00	**0,0**	0,24	**2,7**
Social diversity	9,5	0,13	1,11	**8,5**	1,30	**10,0**
Social networks	10,0	0,14	0,96	**7,0**	1,37	**10,0**
Total	73,2	1,00	3,00	**22,9**	7,61	**59,5**

Figure 29: Weighting and scoring od social criteria of Gröninger Hof

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

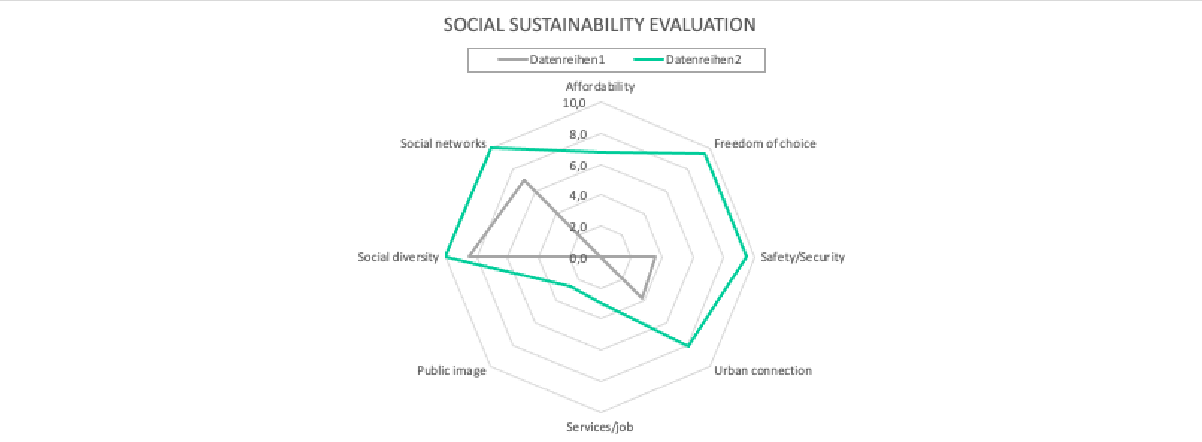

Figure 30: Diagram of social scoring of different scenarios of Gröninger Hof

Compared to the scenario where no actions are initiated, the social criteria may be improved by 160 % with a partial demolition and transformation process. A third scenario where the existing building would be demolished completely and rebuilt is not considered, as the social results would be the same as for the transformation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201

Demonstrator	**D10: Life cycle extension alternatives for 1960s commercial building, London**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Peter Swallow (Grimshaw) & Colin Rose (ReLondon)

1. Mission statement, background and political decisions

Many light industrial buildings across London are being demolished to make way for redevelopment. This project demonstrates methods to retain and transform this typology in the short/medium term as meanwhile space and longer term as an integral components of future redevelopment proposals.

Figure 31: Existing building – former textiles warehouse (google street view)

2. Project details

Block F is located within a peri urban/post-industrial Meridian Water area to the east of the London Borough of Enfield – See fig. 1-2. As part of their advisory role on the integration of

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circular principles within the wider Meridian Water master plan, Net Positive Solutions [NPS] were commissioned to undertake a feasibility study to partially retain Block F.

Figure 32: Existing building aerial site plan (google maps)

Step 01: Demolition 2022

Assumptions

- 50% minimum demolition scope
- New stairs, MEP, lift and WC's

Figure 33: Site plan of existing building

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	06/20	07/20	08/20	09/20	10/20	11/20	12/20	01/21	02/21	03/21	04/21	05/21	06/21	07/21	08/21	09/21	10/21	11/21	12/21
Concept design	■	■	■	■															
Detailed design					■	■	■	■	■										
Demolition (where applicable)									■	■	■								
Construction											■	■	■	■	■	■	■	■	
Completion																			■

Figure 34: Project timeline

Location: Block-F, Meridian Water Development, Enfield, Greater London
Stakeholders: Enfield Council (Land owner/Developer), Stace (Cost manager), Net Positive Solutions (Circularity consultant).
Building typology: Two story light industrial building
Program: Meanwhile use offices and light industrial
Year of completion: 1950s
Style : Post-war industrial
Size : 1,100sqm [Over 2 floors]

3. Objective

This demonstration provided valuable information about the development and application of triple bottom line (TBL) decision making to evaluate the transformation potential of an existing building. The project explored technically replicable and scalable solutions for retaining systems and structures of similar building typologies constructed in the same period.

4. Technical analysis

4.1 Challenges

In general, light industrial buildings from this period are considered of low quality. They are built from sub-standard materials and require significant levels of upgrades to meet modern energy efficiency standards and building regulations more generally. They are often considered of low architectural merit and therefore lacking in cultural value.

In relation to the project, the first phase of the Meridian Water masterplan development earmarked Block F for demolition to make way for the new road network to serve future development plots. Whilst the new road layout didn't require the entire building to be demolished, this was initially deemed to be the most likely outcome by the council until NPS, supported by CIRCuIT's London partners, proposed to evaluate the viability of saving 50% of the building to be transformed into a meanwhile use space.

The transformed building's expected extended life span was limited to 10-15 years. This was driven by the need to clear the site to make way for the future residential development plans for the site. This is one of the major issues affecting the business case for the building re-use.

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Climate change adaptation wasn't specifically considered as part of the scenarios explored. However, the cost plan for the retained option studies assumed upgrades to the envelope and HVAC systems to meet local building regulations.

The structural grid and floor to ceiling heights provided a lot of scope for transformation to residential or office accommodate over the building's 15-year projected life span. Given more time it is likely that options to retain and integrate the building as part of the wider development plans for the site could have been drawn up; however, this wasn't considered as part of the evaluation criteria set out as part of the TBL business case undertaken.

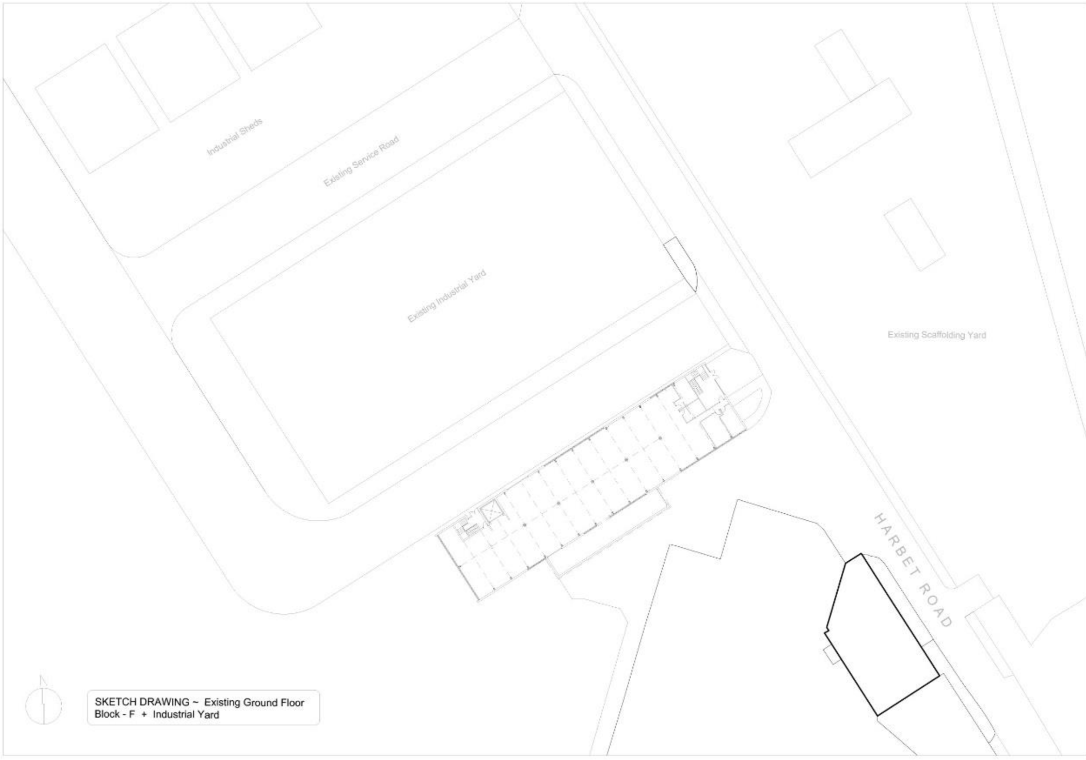

Figure 35: Existing floor plan

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Figure 36: 50% retained floor plan options

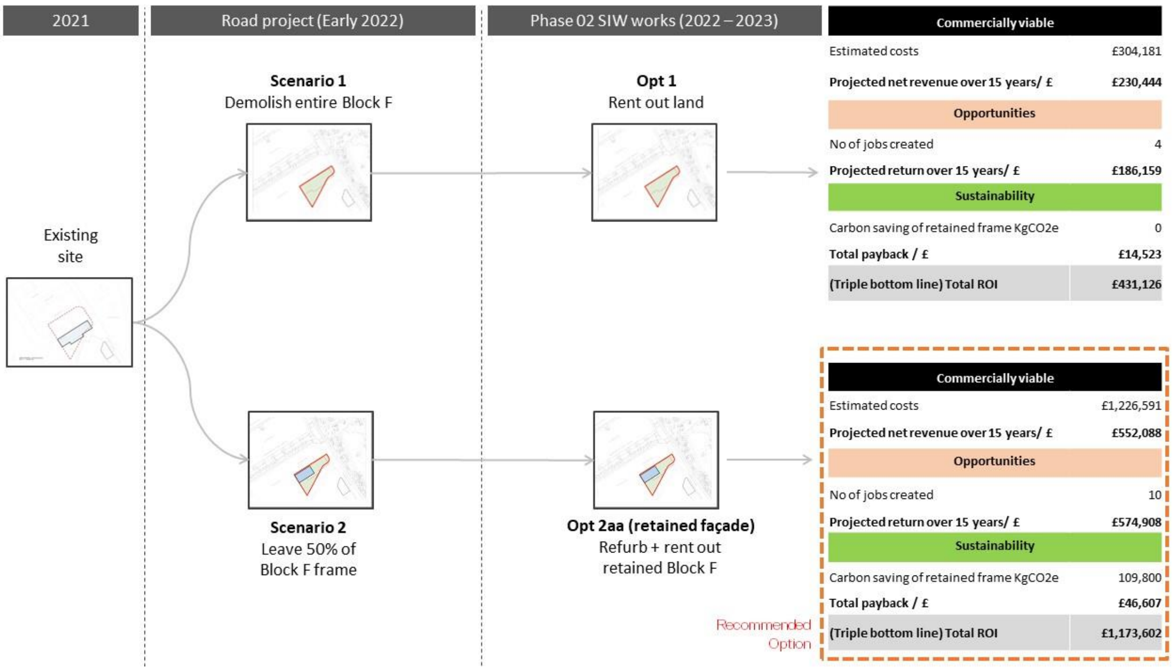

Figure 37: Preferred phasing route

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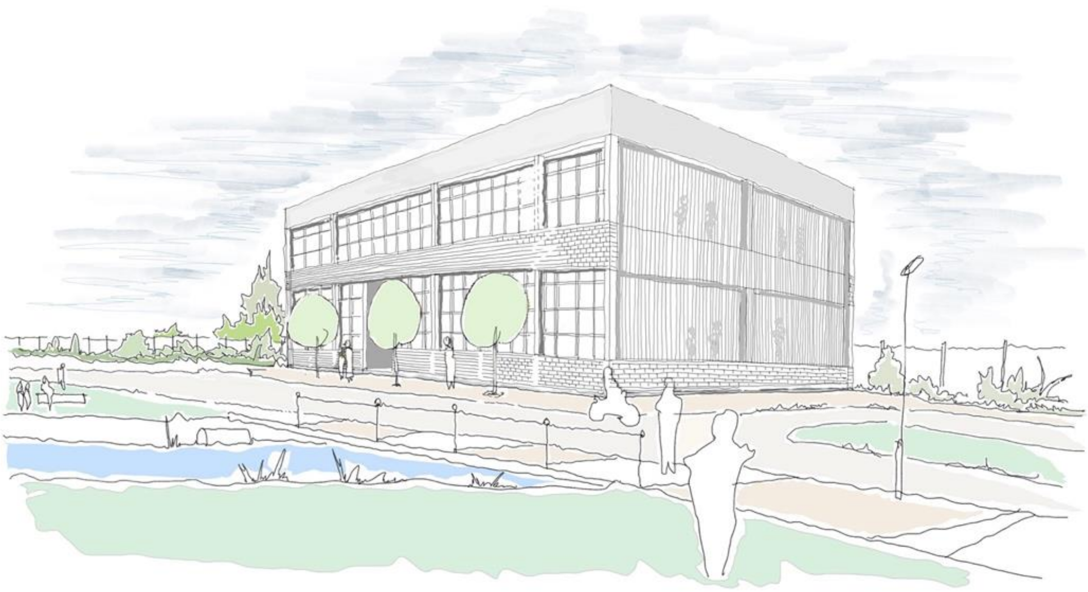

Figure 38: Option 2aa – retain 50% of frame, refurbish façade

4.2 Solutions

Material and structural reuse: The challenges arising from the primary structure's condition and subsequent partial demolition, were the main technical issues to resolve. Remedial works needed to be undertaken to ensure the structural frame was capable of being reused. These works ranged from underpinning the foundations to stiffening up the exposed slab edges resulting from the demolition works to enable the frame to support a new façade. The existing envelope was also dilapidated, requiring work to fix damage to the brick upstands, replace broken glazing and repair the roof waterproofing. It was unknown at the time if any remedial works to the building would trigger the need to upgrade the existing cladding to meet current building code.

The structural grid and floor to ceiling heights provide a lot of options for transformation if the building was to stand for longer, but due to the limitations imposed by the wider masterplan, the most likely use if the building had been saved would be for it to continue to serve as a light industrial space.

Reconfiguration of old and new: Re-providing MEP utilities, HVAC and amenities were required for the partial demolition options which in turn added additional cost to the works.

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Figure 39: Building strip out and demolition

4.3 Lessons learnt

Whilst the partial retention and adaptive reuse of Block F was not given the go ahead, there are several lessons that can be taken from the design development and options appraisal process undertaken. The work done in establishing the building's adaptive re-use potential, and the comparative analysis undertaken to determine the best design strategy to take forward, has been generalised into set of principles that can be applied to other buildings to evaluate their own re-use potential. The following section gives an overview of the design considerations & assumptions specifically related to retaining existing light industrial buildings within a larger masterplan development.

Step 1 – Programme: Early consideration of a building is key to maximising the potential for a building's retention and integration into a new master plan.
Step 2 – Options evaluation: Options to be considered should be scoped out and agreed with the client as soon as possible. The criteria by which they are compared should consider economic, social and environmental value indicators. As a minimum, upfront cost, carbon and return on investment indicators should be considered.
Step 3 – Information required: If available, existing plans, 3D scans and survey info should be obtained for the building(s) being evaluated. Commissioning of pre-demolition audit and conditions report is advised to ensure a suitable level of information is available for a robust evaluation.
Step 4 – Scope of demolition and rectification works: Scope out demolition works required for each option being investigated and any rectification and remedial works required, including existing sub structure (underpinning etc.); super-structure (reinforcement, replacement etc.); façade repairs; vertical circulation; services.
Step 5 – Spatial reconfiguration: Develop layouts necessary to meet minimum regulatory, client and tenant specific requirements. Clearly identify new elements and finishes that will need to be included in the cost plan.
Step 6 - Envelope upgrades: Establish if the proposed works will necessitate performance enhancements to meet and/or exceed local building regulations.
Step 7 – MEP provision: Identify minimum regulatory, client and tenant specific requirements and develop strategies to meet them. Consider on-site renewables and avoidance of fossil fuel-based HVAC system to minimise carbon emissions.

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Step 8 – Risks and opportunities: Consider the following opportunities to maximise the projects life extension:
a) Ensure the building forms part of the long-term development plans
b) Identify risks to retaining the building as part of the wider development plans
c) Where the building is only being considered for short term/ meanwhile use, identify opportunities to reuse the materials at the end of life.
Step 9 – Measure: Ensure appropriate economic multipliers are used for each performance criteria. Carbon saved though retention should be priced based on appropriate rates set regionally or by global bodies such as the UN; Revenue estimates benchmarked against local data; Social value indicators based on national figures.
Step 10 – Evaluation and recommendation: As part of the final evaluation report, set out any assumptions made and areas of uncertainty for each of the options. Final recommendations should be supported primarily with quantitative data with qualitative data provide used to provide context.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 15 years. For context, the performance has been compared to a base case without circular construction objectives. For this project the base case is full demolition to the ground slab without material recovery and construction of a new meanwhile building providing the same floorspace that would have been provided by the 50% retention of the existing building.

5.2 Environmental performance indicators

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 25 Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used as a result of the retained frame compared to the baseline
Materials used	Tonnes of materials used in the building
Upfront embodied carbon emissions	kgCO2e

5.3 Environmental performance results

Overall the circular intervention would have improved the performance of the project on all of the environmental indicators considered.

The biggest improvement was in upfront embodied carbon emissions which was improved by 62%. This was because retaining half of the existing building could have avoided a large proportion of the emissions from a new meanwhile building.

If the intervention had been adopted, it is estimated that 1,176 tonnes of material, and 190,000 kg of CO2e could have been saved.

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Table 26 Environmental performance results

	Base case	Intervention	Savings
% of material not used	0%	60%	60%
Tonnes of materials used	1,962 tonnes	786 tonnes	1,176 tonnes
Upfront embodied carbon emissions A1-4	300,000 kgCO2e	109,800 kgCO2e	190,200 kgCO2e

Triple bottom line Evaluation

15 year development timeline

Baseline option for comparison

Recommended Options for Phase 01 and Phase 2

Scenarios	Option 4 Full demolition + newbuild of 50% F Block footprint		Option 2aa Partial demo (retained façade) + refurbishment	
Phase 01 - 2021/22 (Demolition material retention options)	**Baseline demo + 50% rebuild**		**Assumed Option ii**	
Demolition costs	£	177,450	£	239,870
Retained façade option (assumed further saving)			£	25,000
Phase 02 - 2023 (Dec) (up to completion of SIW)				
Construction costs/ £ (Light industrial)	£	970,000	£	872,788
Phase 03 - 2024/25 (Post SIW)				
Construction costs/ £				
Estimated professional fees (at 12% of construction costs)	£	116,400	£	104,735
Phase 04 - Operation				
marketing, management, security and maintenance costs	£	88,934	£	88,934
Revenue over 15 yrs/ £ (light industrial buildings)	£	1,416,727	£	1,416,727
Revenue over 15 yrs/ £ (Land)	£	361,952	£	361,952
Total revenue/ £	£	1,778,679	£	1,778,679
Projected revenue over 15 years/ £ (Commercially viable)		**£425,895**		**£472,353**
Indicators				
Total No of jobs created (gross direct employment)		10		10
Net Total addiitonal GVA	£	574,908	£	574,908
Projected return over 15 years/ £ (Opportunities)		**£574,908**		**£574,908**
Embodied carbon reduction				
Embodied carbon saved	£	-	£	26,901
-Circular payback				
Estimated money recouped from sale of residual assets	£	14,523	£	19,706
crushed masonry (Type 1) available for use in road project	No		yes	
F Block becomes a showcase of circular economy for future phases	No		Yes	
Contributes to Placemaking during Meanwhile masterplan phase	Yes		Yes	
Total payback / £ (Sustainability)		**£14,253**		**£46,607**
(Triple bottom line) Total ROI		**£1,015,326**		**£1,093,867**

Figure 40: Triple bottom line evaluation (Option 4 = base case; Option2aa = circular intervention)

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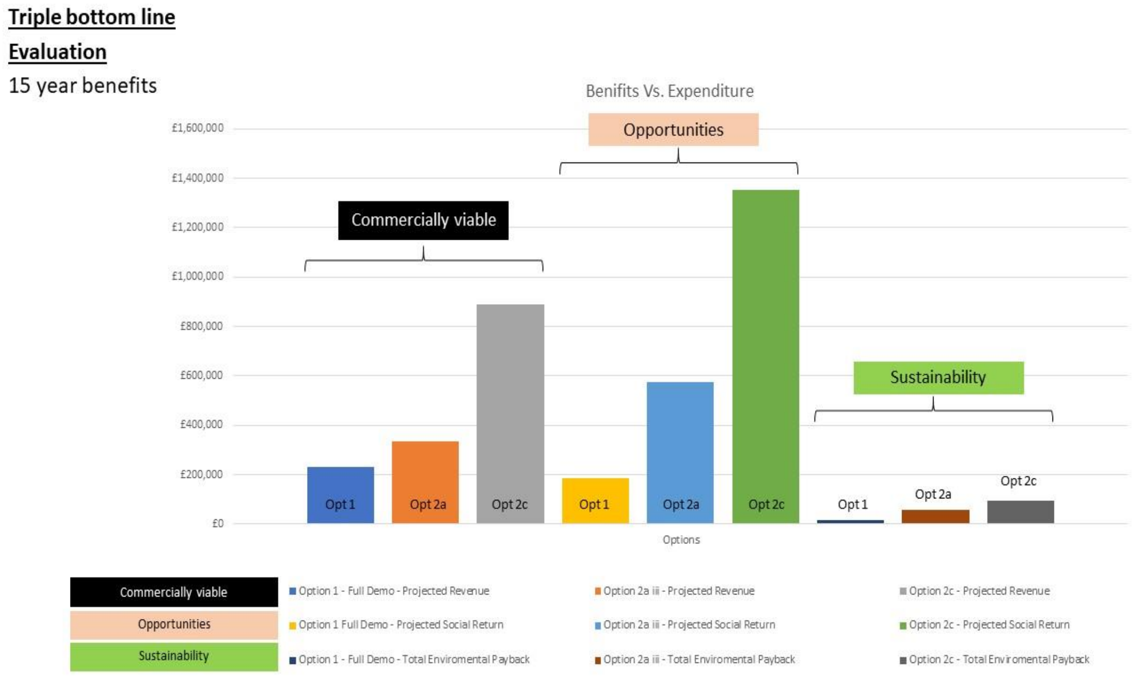

Figure 41: Triple bottom line cost benefit summary

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6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been made in comparison to a base case. The base case is described in section 5.1.

As with the environmental performance, the economic analysis has been undertaken in comparison to a 'baseline' scenario. For this 'Meanwhile Use' project at the Block F development site at Meridian Water, five options were initially considered to redevelop the site on the basis of usage as light industrial buildings. The existing site benefits from an existing building of 880 m2 floor area split equally over two floor levels.

Three of the five initial options considered the economic benefits of undertaking the works against an enlarged site development area (by taking into account the lease of adjacent open land), with two other options considered the costs and economic benefits costs against the smaller site, i.e. local to the existing building.

An enlarged site development area would need to be created by the extension of the site by the lease of open land to extend the site to activate a new High Street frontage.

For the purposes of this review Option 2a will be used, which generated the highest return on investment, without the need to spend over £1m on new buildings and which would not incur programme delays from the need for legal agreements to create the enlarged site area.

For Option 2a, 676 m2 GIA of the existing building is retained and refurbished, with a small extent of demolition to the existing building, and which is assessed against the development value of the smaller site area. Construction capital costs assume remedial works to frame, cladding and MEP systems, but exclude any provision of green roofs or the like.

In terms of the demolition work, four alternative options were considered as follows:-

- baseline : to clear the site (i.e. traditional BAU approach)
- option i : to crush brick, concrete and glass as 6F2 for re-use
- option ii : to recycle concrete to aggregates and glass, bricks to 6F2 material
- option iii : to separate and recover bricks for re-use

As the building is not located within an area of particular Planning interest, no allowance has been included for any enhancement beyond current typical industry standards. The provision of a 'shell only' warehouse has been assumed to a standard developer's base build specifications, with tenant Cat B office fit-out standards.

Costs only include for on-plot external works, and exclude any works off-site beyond the site red line boundary. Capital costs assume that the re-use of drainage connections and mains

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utility services will be sufficiently adequate, and therefore no allowance has been made for any off-site network reinforcement.

6.2 Economic analysis results

The economic analysis has been considered in relation to the components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life Cycle Costing and includes the following:

- initial construction costs
- maintenance and operating costs (assumes 5% of revenue for marketing, management, security & maintenance costs)

As well as these indicators being considered, they have also been combined with forecast revenue costs and residual values at the end of the 'Meanwhile Use' to reflect the overall financial performance of the demonstrator in terms of net projected revenue at present day values (NPV).

The revenue calculations have been based on light industrial usage of the building for 13 years for the existing building. The summary analysis for this project in Appendix B also includes projected revenue and projected social return over a 15 year period, with assessments of jobs created and the circular payback.

The above economic indicators were considered for the purpose of demonstrating that by designing and planning for transformation and refurbishment of existing structures, the return on investment for existing buildings can be significantly improved, whilst minimising initial capital expenditure.

The following life cycle components were not considered relevant for the purposes of this demonstrator and are therefore excluded from the analysis:

- externalities
- non-construction costs

For the life cycle costs and economic analysis of this 'Meanwhile Use', a 15-year period has been assessed. The LCC analysis excludes End of Life costs for demolition termination or replacement of the buildings at the end of the 15-year period.

6.3 Economic analysis results

This Lifecycle and return on investment analysis has established that by comparison to the baseline (BAU) demolition case, through spending relatively small additional sums, the circular construction intervention has resulted in increased returns on investment.

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For demolition Intervention Option i, the additional cost represents a 0.37% increase in capital costs, resulting in a 1.39% reduction to the projected revenue. However when social and particularly environmental paybacks are taken into account, this option has the effect of increasing Return On Investment by +0.25% in overall terms (to £955k).

For demolition Intervention Option ii, the additional cost represents a 0.94% increase in capital costs, resulting in a 3.57% reduction to the projected revenue. However when social and particularly environmental paybacks are taken into account, this option has the effect of increasing Return On Investment by +0.75% in overall terms (to £960k).

For demolition Intervention Option iii, the additional cost represents a 1.34% increase in capital costs, resulting in a 5.10% reduction to the projected revenue. However when social and particularly environmental paybacks are taken into account, this option has the effect of increasing Return On Investment by +1.25% in overall terms (to £964k).

Table 27 Economic analysis

OPTION 2a	Baseline	Intervention Option i	Intervention Option ii	Intervention Option iii
Construction costs	£1,338,670	£1,343,560	£1,351,200	£1,356,590
Renewal costs*	£0	£0	£0	£0
Operation costs*	£88,934	£88,934	£88,934	£88,934
Maintenance costs*	included	Included	Included	Included
Projected Net Revenue over 15 years (NPV)	£351,075	£346,185	£338,545	£333,155

Table 4. Return on Investment (ROI) analysis

OPTION 2a	Baseline	Intervention Option i	Intervention Option ii	Intervention Option iii
Projected Net Revenue over 15 years (NPV)	£351,075	£346,185	£338,545	£333,155
Projected Social Return over 15 years (NPV)	£574,908	£574,908	£574,908	£574,908
Projected Environmental Payback over 15 years (NPV)	£26,901	£34,163	£46,607	£56,758
Projected Return on Investment over 15 years (NPV)	£952,884	£955,255	£960,059	£964,821

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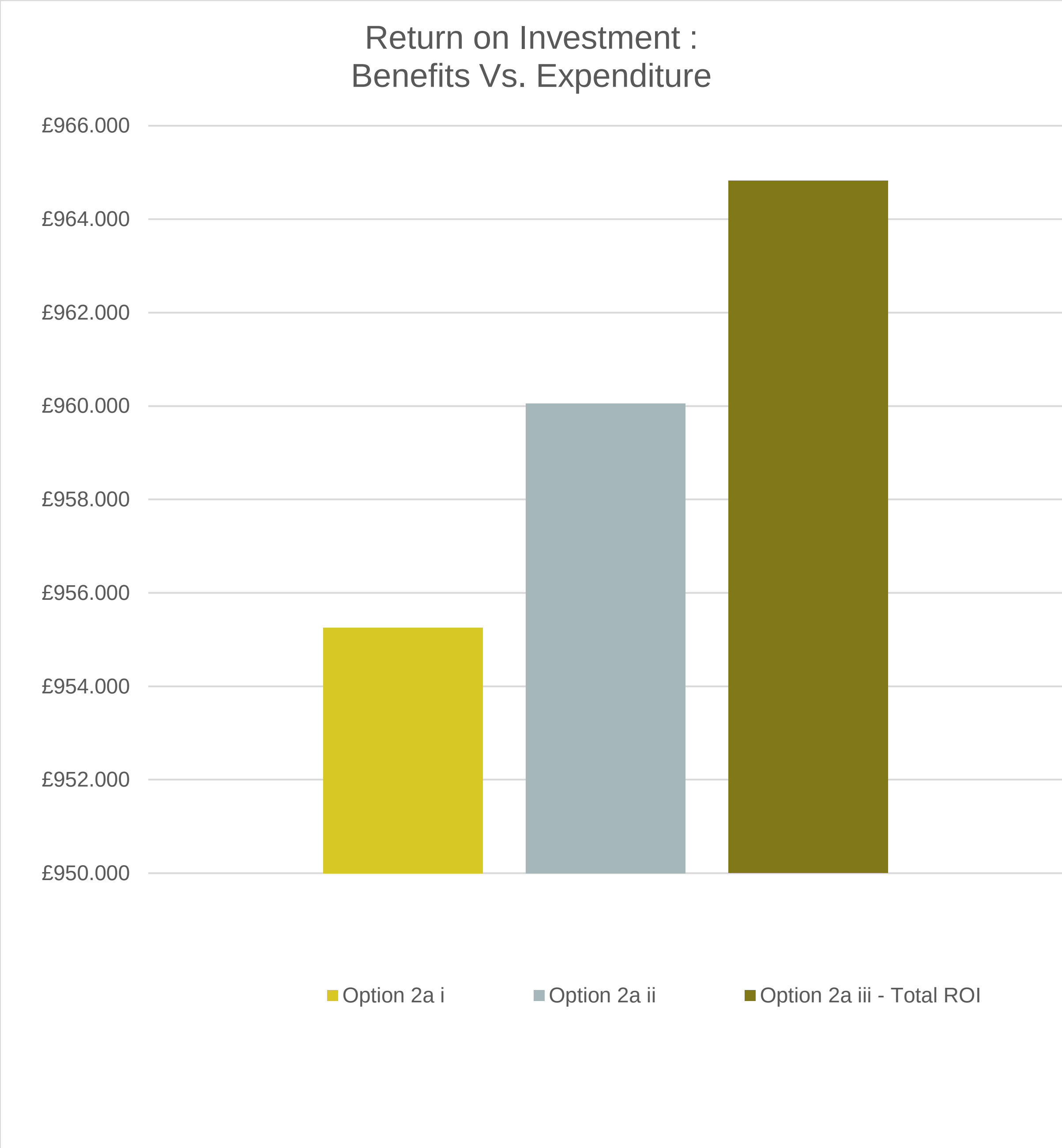

Figure 42. Return On Investment analysis comparison

7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across a proportion of the 820 other post-war light industrial buildings in Greater London.[9] If it is assumed that in the medium- to long-term, 10% of these buildings are subject to regeneration plans, in which existing occupants

[9] Based on Verisk UKLand database: industrial buildings in Greater London built from 1945-1980 with masonry wall construction = 821 results, total 1,155,085.6 sqm.

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are evicted in advance of the site's redevelopment and meanwhile buildings are provided, the replication of this business case could potentially result in 15,600,000 kgCO2e upfront embodied carbon savings across Greater London. This is equivalent to the annual emissions from 1,950 homes.

7.2 Realising the potential

- The assumption is that the rollout of the masterplan would lead to the building's demolition in 15 years, even if it had been partially retained: the need for new housing makes the case for retaining low-density light industrial buildings difficult to sustain. Nevertheless, the demonstrator indicates that meanwhile use of existing buildings during the years- or decades-long process of building out major regeneration projects can create significant benefits.
- Due to the post-industrial nature of site, and the amount of land already cleared for redevelopment, there was limited existing architectural narrative or cultural historic narrative. If the building had been partially retained and upgraded, there would have been some opportunity to create a new architectural narrative through the dialogue between new and existing elements.
- There was potential for the architecture of the building's regeneration to express the Council's meanwhile use agenda, which sought to generate a critical mass of activity to bring life to the site in advance of the main masterplan development.
- The building could have contributed to the sense of place and community that would have emerged from meanwhile use.
- The new road layout made the retention of the existing building as a whole impossible. Retaining the whole building would have likely been more financially viable as the renovation works would have been far simpler than the 50% retention option.
- This might have been achieved by setting out on the wider masterplan design and phasing strategy with adaptive reuse of existing buildings in mind – either for long-term retention or short-term retention during the masterplan rollout.
- TBL assessments like those reported in this business case should be undertaken and should exert influence over early masterplanning and phasing decisions.
- The Meridian Water project delivery team have expressed a desire to adopt a similar TBL evaluation methodology for other existing buildings within the Meridian Water development and elsewhere within Enfield.
- Ultimately the decision not to retain the building was made by the council on the basis that the ROI was limited, and the associated costs were likely to increase beyond the initial estimates.
- Meanwhile uses can be seen as a risk for landowners in terms of safety/logistical reasons or delays in getting vacant possession when the site is due to be developed.

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A building or site will not always be suitable for meanwhile uses, for instance if access impedes construction vehicle movements, but this can be considered in the early planning stages. Vacant possession can be ensured by establishing agreeing lease arrangements and maintaining clarity about the meanwhile use period.

- The value of sustainability issues such as carbon emissions avoided through reuse over new-build do not have a significant impact on the economic part of the TBL analysis. Under current economic norms, even applying the most optimistic value to the economic multipliers didn't change this. To address this there needs to be regulation for embodied carbon to incentivise the market to adopt a retrofit first approach to development.
- A new build equivalent 15 year scheme would have likely been more cost effective that the 50% retention approach. This can be rebalanced with incentives such as cutting VAT for refurb projects and taxing new build.
- Retention studies for existing buildings should be prioritised as part of any masterplan development, to mitigate real and perceived barriers to their reuse potential. These studies should include short, medium and long-term integration strategies to evaluate the ROI incentives across economic, social and environmental indicators.
- The real risk of demolition was posed by a lack of economic incentive to retain the existing building. This could have been mitigated by minimising the remedial or upgrade works to be carried out, whilst maximising the useful period over which the building will operate to ensure the ROI for developers is maximised.
- If these issues can be addressed for similar buildings facing demolition, they will stand a better chance of being selected for reuse instead.

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Demonstrator	**D11: Life cycle extension alternatives for historical mixed-use townhouses, London**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Peter Swallow (Grimshaw) & Colin Rose (ReLondon)

1. Mission statement, background and political decisions

The primary objective of this demonstration was to explore adaptive reuse strategies to maximise the retention of existing and underutilised buildings located on inner-city sites, comprised of varying structural systems, massing and volumetric constraints.

Figure 43: North Row street view

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2. Project details

31-34 North Row is located within the inner city as part of Grosvenor's North Mayfair district in the City of Westminster, London. The area was originally developed by the Grosvenor family in the 18th century as a new residential neighbourhood for occupation by the aristocracy and upper middle classes. Across the separate landholdings, development largely comprised high-quality, speculative development. By the mid-18th century, the area was given over primarily to houses.

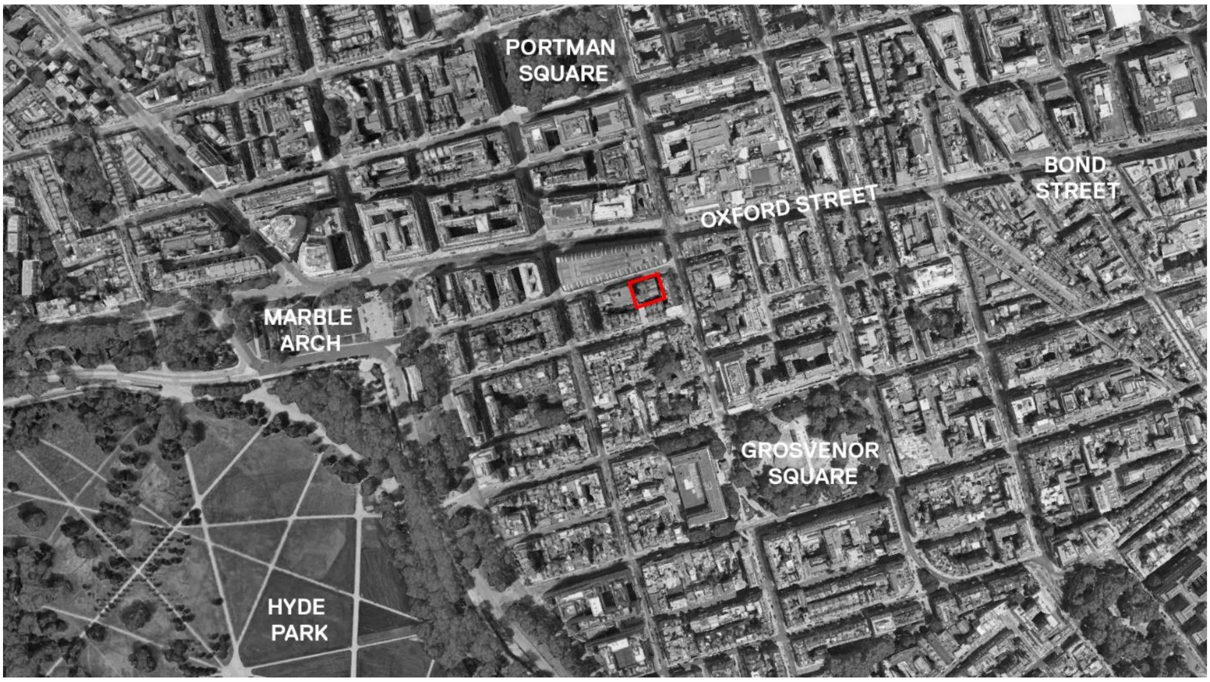

Figure 44: Site location plan (Google Earth)

North Row was originally developed as a mews street to the rear of properties facing on to Oxford Street. In the 18th century, the north side of North Row was largely taken up with the stables and other appendages of buildings in Oxford Street and Hereford Street. North Row was steadily rebuilt from 1871 until the end of the 19th century, mainly with blocks of artisans' dwellings, parochial buildings, and light industrial premises, including a large coach manufactory.

During the 20th century, North Row was impacted by bomb damage and subsequent infill development. This, along with large-scale commercial redevelopment on Oxford Street during the second half of the 20th century, means that North Row is now predominantly lined with commercial buildings of relatively recent date.

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Nos 31-33 is a group of three narrow, gabled, red-brick, modest, late-Victorian buildings constructed for light industrial purposes, with three identical principal elevations that appear largely unaltered since they were constructed in 1892.

No. 34 North Row was originally built in 1891-92 to the designs of Eustace Balfour and Thackeray Turner as a workshop. The building remained in light industrial use until the end of the 20th century, when it was converted to provide modern offices.

In 2020, Grosvenor commissioned Orms architects and Elliott Woods engineers, via competitive tender, to undertake an initial feasibility study to transform the buildings into modern commercial offices. As part of this initial study the team undertook an R&D study, led by Grosvenor, that explored the reuse potential of materials extracted from the existing buildings on site and maximising the use of sustainable materials as part of the redevelopment. Two design reports were produced outlining the main findings of the 'Re-use potential' workstream for the 'Most Sustainable Building' Materials Study. This work was carried out in parallel with three other workstreams: material passports, material sourcing and specification banding, during a three-month period from October 2020 to January 2021.

Following the study, Grosvenor determined that a commercial development wasn't financially viable for the site. Orms subsequently undertook a new study to assess the viability of developing the site as a residential complex involving the demolition of plots 31-33 and retention of plot 34.

The demonstration project sought to redevelop the series of adjoining building plots, housing a mix of residential accommodation and commercial office space, into a premium residential development, whilst retaining as much of the existing buildings as possible. The project also looked at maximising the recovery and reuse of materials from parts of the existing buildings earmarked for demolition, which is investigated further in the related WP4 timber reuse demonstrator.

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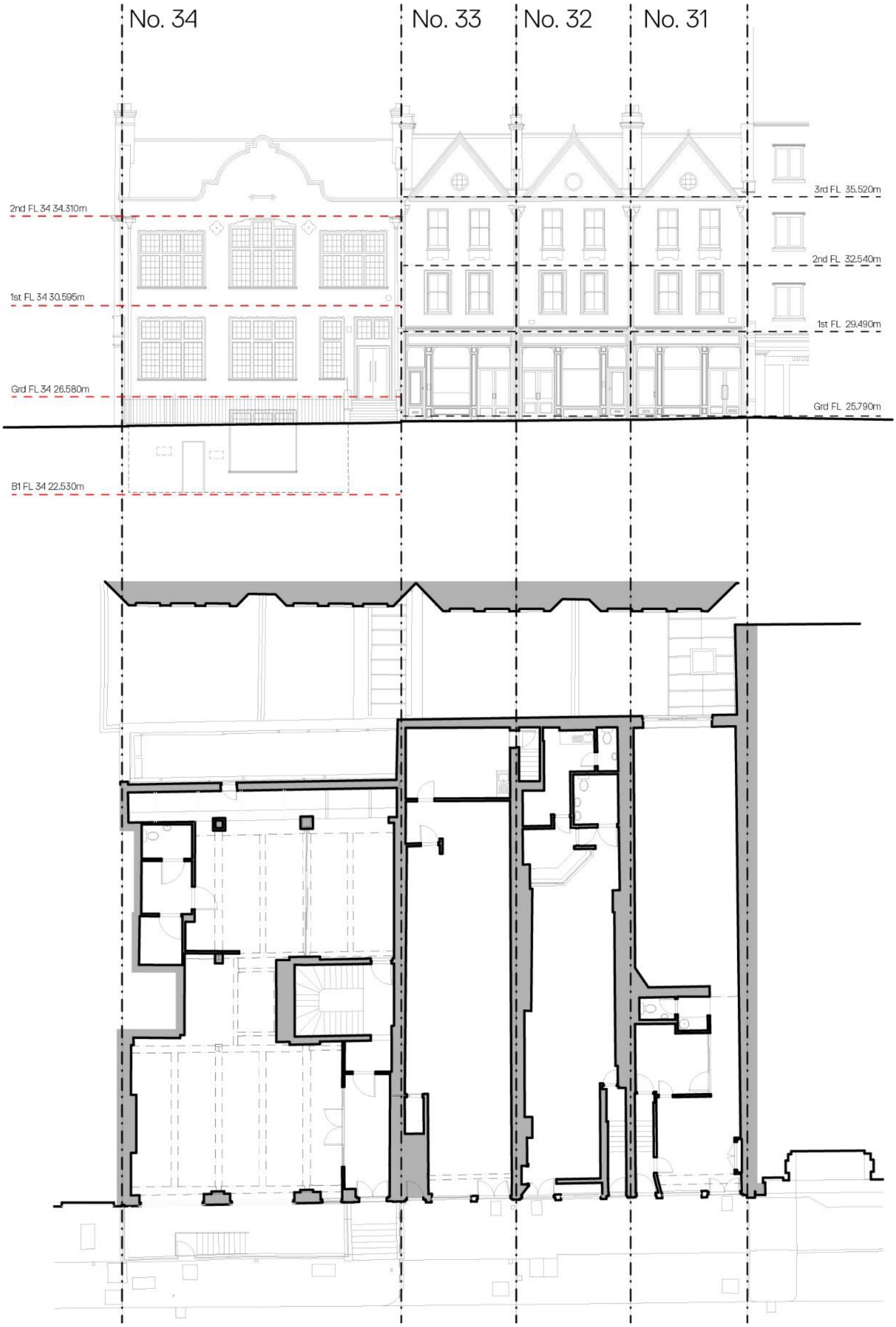

Figure 45: Nos. 31-34 Elevation + Survey Plans

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Figure 46: Project timeline

Location: 31-34 North Row, Mayfair, Central London
Stakeholders: Grosvenor [Owner/Developer], Orms [Architects], Elliot Wood [Structural Engineers]
Building typology: Light industrial + workshop
Program: Conversion to retail [basement + ground floor] + luxury apartments [First to fourth floor]
Year of completion: Original 2025 [Currently on hold]
Style: Late Victorian red brick [31-33] + Late Victorian painted red brick [34]
Size: 2250sqm (Over 4 plots and 6 floors)

3. Objective

This demonstration aims to retain as much of the buildings' fabric as possible. Strategies to achieve circular construction were devised throughout the site with the ambition of extending life for an additional 50/60 years. The project provided valuable information about the practical application of 'cut and carve' transformation strategies to existing buildings. The project explored technically replicable and scalable applications of this strategy to maximise the retention of existing building systems and structures from similar periods and typologies.

4. Technical analysis

4.1 Challenges

The existing buildings, as they currently stand, are deemed to be unsuited – in terms of floor to ceiling heights, proportion and internal access – to be retained as part of any proposed residential developments. Fig 5 illustrates the issue with regards to existing floor levels.

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Figure 47: Evaluations: Existing Floor Levels

The age and condition of the current amenities within the existing buildings are also below that expected for the local area, which is considered a premium location within London. The threat of demolition for this specific building typology is prevalent across London for similar reasons.

4.2 Solutions

Structural appraisals were considered to ensure the building provides maximum potential for flexibility and future adaptations. Retaining the existing party walls between the adjacent properties will allow the localised removal of floor slabs to facilitate a more generous floor to ceiling height.

The work done in establishing the buildings adaptive re-use potential, and the analysis undertaken to determine the best design strategy to take forward, have been generalised into set of activities for assessing the potential reuse of similar building typologies to the North Row scheme. The following provides an overview of these activities:

Activity A: Obtain available information (Existing drawings; 3D scans; 2D measured survey; Pre-demo Audit; condition report) Identify gaps and sources additional surveys / reports. Refine information to enable an informed design brief. Undertake historical assessment, analysing the design approach and historical merit.

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Activity B: Identify the scope of demolition (Rectification/remedial works required) Seek advice from demolition contractor / engineer to identify further challenges and opportunities

Activity C: Evaluate spatial & structural reconfigurations; define design methodology through assessment of the re-use potential of the building elements identified in the demolition audit, condition report, Intrusive structural investigation

Activity D: Options appraisal; determine the regulatory / design standard considerations to ensure that the residential accommodation delivered is of a high standard, including considerations for dual aspect dwellings, achieves minimum space standards, inclusive design, adequate storage and external spaces

Activity E: Whole life carbon analysis; In tandem with the development of the design options, consideration for material specifications and opportunities to reuse/recycle existing

Activity F: Mapping material reuse; Studies evaluating the re-use of existing material either onsite or offsite through the parameters of time; cost; legislation; available information/technologies

See fig 6. Demonstration activities workflow diagram summarising the above actions, their sequence and relationship to each other and other complimentary workflows that expand on some of these activities in more detail. (Those that address material reuse off-site are relate to the North Row WP4 timber reuse demonstrator.)

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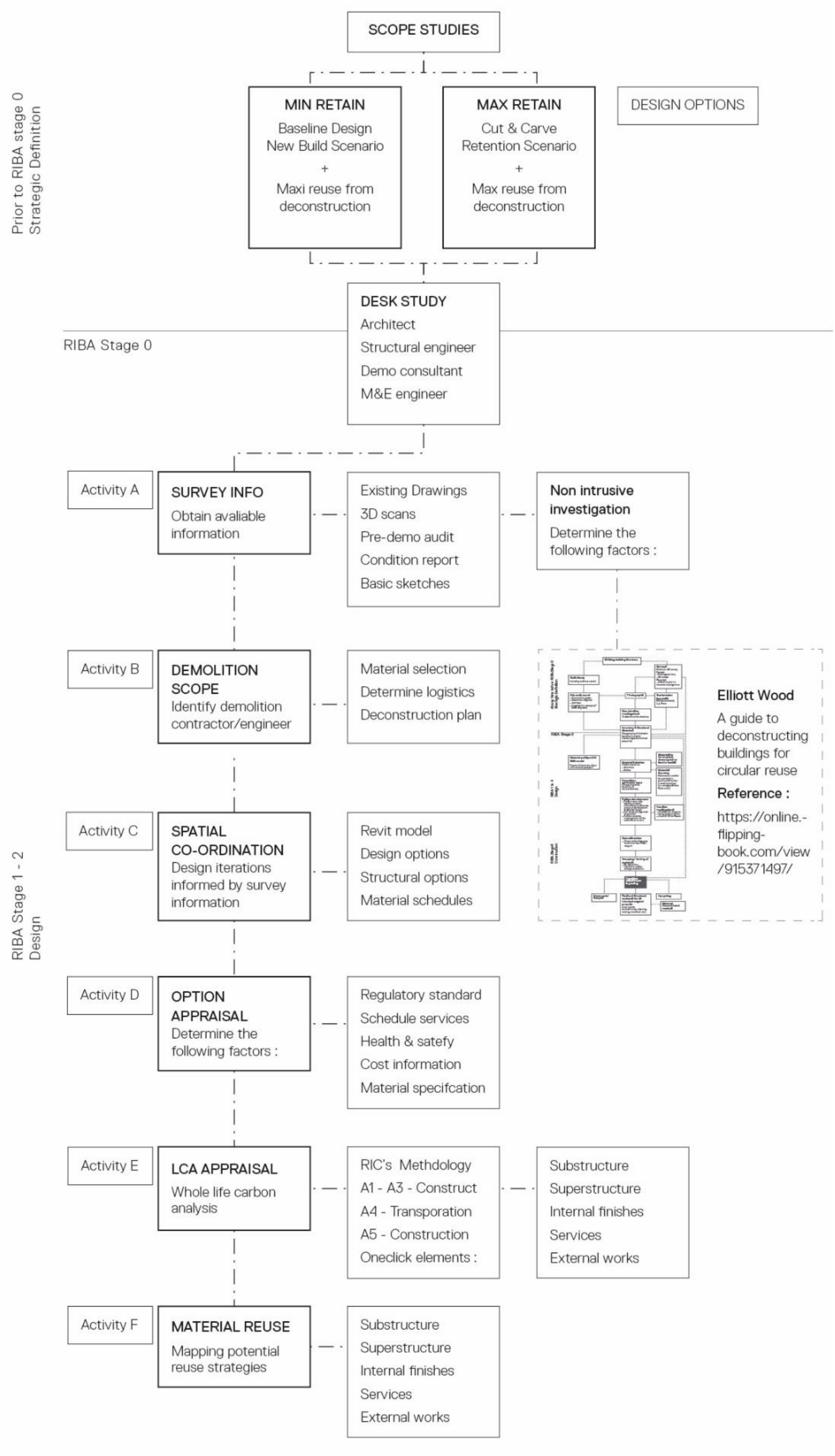

Figure 48: Demonstration Activities Workflow Diagram

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4.3 Lessons learnt

The workflow undertaken indicates the practical actions needed to establish the potential for and scope of building retention. This can be replicated on other projects in an inner city context that face multiple constraints. Lessons from the demonstrator include the necessity to carry out the identified studies at the earliest feasibility and design stages, as part of a 'retrofit first' approach.

Understanding which adaptive reuse strategies make the most sense economically, environmentally and socially to implement for an existing building such as North Row is a complex problem. That said, establishing a framework to systematically undertake a triple bottom line assessment can support this process and give the building client a clear understanding of the pros and cons for each option to support their decision making. The step-by-step design strategy outlined in this report provides a methodology for creating such a framework.

Before reaching the circular intervention investigated in this demonstrator, it was found that saving a maximum amount of the existing fabric led to larger cost and carbon impacts of the new structure required (due to underpinning foundations, reinforcing brick walls, and large steel transfer beams). Many of these findings are highly contextual, e.g., the floor level alignment between building no. 34 and no. 33 limited the scope to achieve a fully accessible luxury residential apartment, which in the Mayfair context will impact on re-sale value.

Internal layouts were revised to suit the existing fabric of the buildings whilst discussions regarding the basement design, room layouts, service strategies, accessibility and construction methods were considered. Thus the main transferable finding is not a single approach to existing buildings, but the need to assess a range of approaches to adaptive reuse and to continue to assess their merits holistically as part of the ongoing design development.

5. Performance measures

5.1 Baseline

The 'baseline' option (fig. 7) assumes the retention of only one building (34 North Row), whereas the "Cut and Carve" option (fig. 8) assumes retaining the North Row façade of all four buildings, 34 North Row as well a substantial part of 31-33. As the buildings are located within the Mayfair area of London, Orms have advised that it would be highly unlikely (in Planning terms) that any 'baseline' scenario could assume a complete demolition and rebuild scheme.

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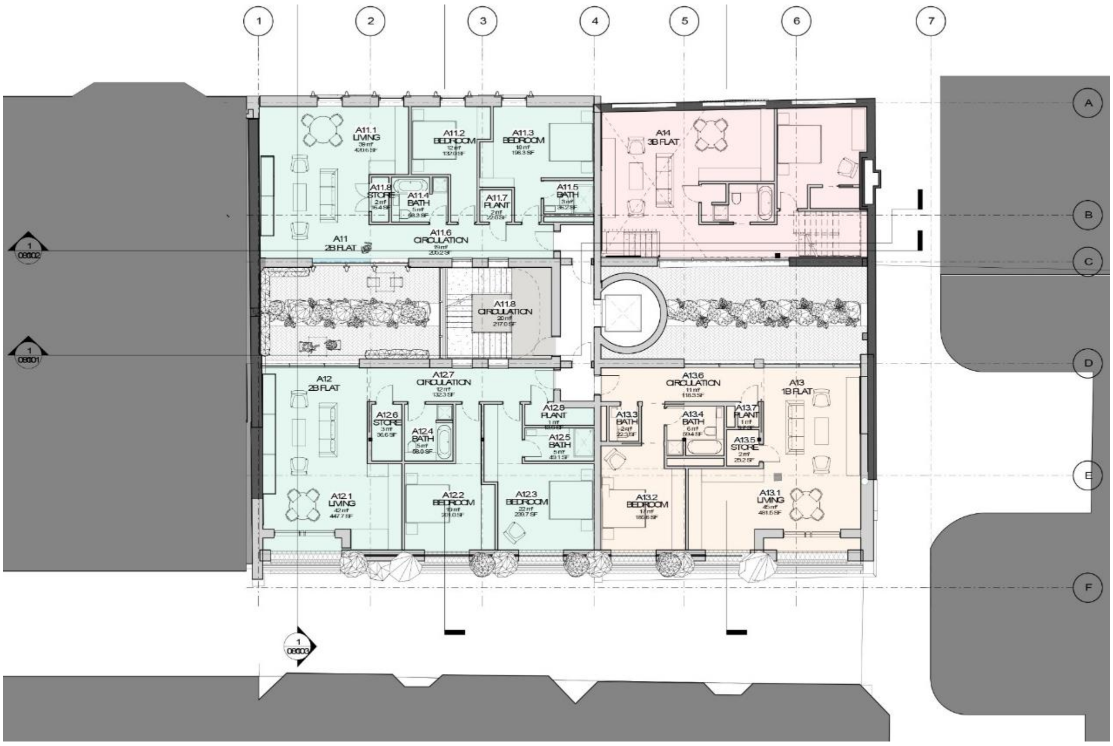

Figure 49: Baseline Option [Min building retention + max on-site material reclaim/re-use] - Typical Floor Layout

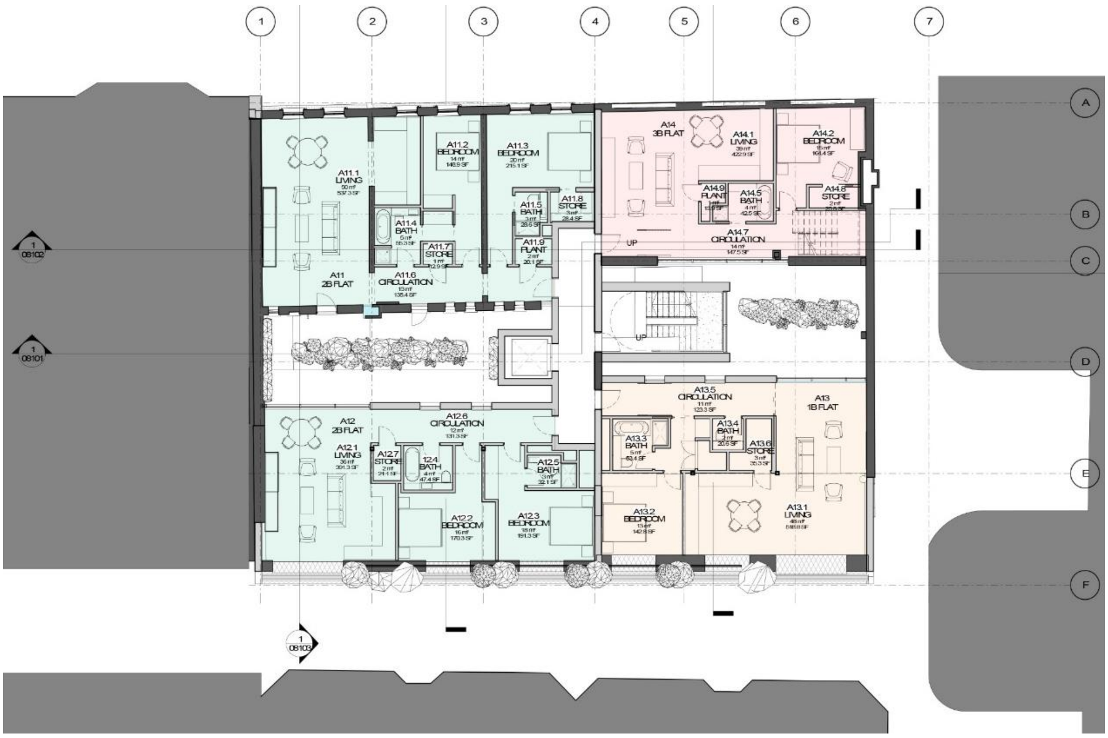

Figure 50: Cut & Carve Option [Max building retention + max on-site material reclaim/re-use] – Typical Floor Layout

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Both the baseline and cut and carve schemes have aimed to provide a high standard of internal living; quality of finishes; amenity requirements; provision of natural light; whilst staying focused to providing a sustainable approach.

Some additional reconfiguration is required to retain a greater extent of the existing building as part of the cut and carve option. This included the relocation of the courtyard, stairs and lift shafts to accommodate existing walls and additional stairs and ramp access to maintain the existing floor levels. For the retained buildings, it is assumed that no adjustments are required to change existing floor levels.

The baseline option includes for an increased basement construction in comparison to the cut & carve option which retains the original basement / building footprint.

5.2 Environmental performance indicators

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 28. Environmental performance indicators

Indicator name	Unit
Dematerialisation	% of material not used
Reused content	% reused content
Recycled content	% recycled content
Total material arisings (whole life)	Tonnes of waste arising
% reused, remanufactured, recycled	% reused, remanufactured, recycled
Whole life carbon emissions	kgCO2e

Delete the rows from the table that are not used for the project.

5.3 Environmental performance results

Table 29. Environmental performance results

Indicators	Base case	Intervention	Savings
Upfront embodied carbon emissions A1-4	512,695 kgCO2e	413,762 kgCO2e	98,933 kgCO2e

6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been undertaken in comparison to a 'base case / baseline' scenario. This 'baseline' is described in section 5.1.

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6.2 Economic analysis indicators

The economic analysis has been considered in relation to the components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life Cycle Costing and includes the following:

- initial construction costs
- renewal costs
- maintenance costs
- operating costs – utilities (energy & water), cleaning

As well as these indicators being considered in isolation, they have also been combined to reflect the overall financial performance of the demonstrator in terms of net present value (NPV). For this a discount rate of 3% has been assumed. Depreciation nor appreciation of the asset itself over time has not been included in the modelling.

The above economic indicators were considered for the purpose of demonstrating that by designing and planning for transformation and refurbishment of existing structures, life cycle expectancy for existing buildings can be extended significantly, and that it is also possible to achieve this whilst saving on the initial capital expenditure.

The following life cycle components were considered irrelevant for the purposes of this demonstrator and are therefore excluded from the analysis:

- end-of-life costs including residual values and terminal values
- externalities
- non-construction costs
- income
- occupancy costs
- return on investment

6.3 Economic analysis results

This LCC analysis has established that by comparison to the base case, the circular construction intervention has resulted in a 10% saving in the capital construction cost, has reduced operational costs by 6%, reduced maintenance cost by 6%, reduced renewal costs by 3% and reduced the Whole Life costs by 7%, all as set out in Table 3 below.

The 'cut & carve' option includes savings in the capital cost expenditure arising from the reduction in construction costs of the substructures, frame & upper floors, & external walls, however this scenario results in a Gross Internal Floor Area reduction of 255 m2, principally at basement floor level.

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For the 'cut & carve' option, the construction cost estimate does make allowance for additional preliminaries cost due to an extended construction period, because of additional temporary works, protection, structural strengthening, etc. to the retained structures.

It should be noted that the cost estimates for this demonstrator do not take into account, make any allowance, or make any adjustment for the potential to carefully salvage demolition material for re-use, such as reclaiming timber or its use as part of glulam beams or the like. This is subject to a separate demonstrator under WP4. The demolition costs included for this demonstrator in both scenarios assume conventional demolition techniques and programme durations and BAU waste management.

Table 30. Economic analysis

	Baseline	Intervention	Difference	Saving /Extra %
Construction costs	£6,192,772	£5,592,866	-£599,907	-10%
Renewal costs*	£8,393,360	£8,150,990	-£242,370	-3%
Operation costs*	£1,337,100	£1,251,660	-£85,440	-6%
Maintenance costs*	£3,073,260	£2,876,940	-£196,320	-6%
Net present value (NPV)	£13,158,153	£12,277,957	-£880,196	-7%

* These costs are discounted Net Present Values and take a 3% discount time-based factor into account.

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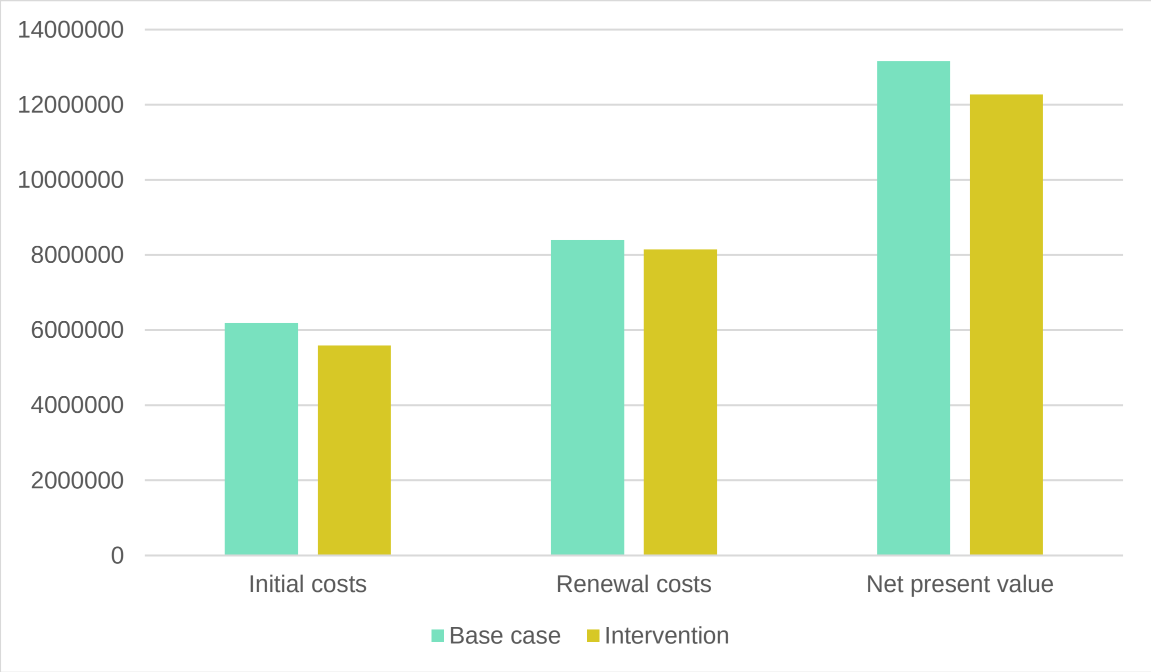

Figure 51. Economic analysis comparison

7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across a proportion of the nearly 23,000 tall terraced buildings of this era in Greater London.[10] If it is assumed that 5% of these are subject to regeneration plans as part of multi-property development sites in the medium- to long-term, the replication of this business case could potentially result in 113,000,000 kgCO2e upfront embodied carbon savings across Greater London. This is equivalent to the annual emissions from 14,000 homes.

7.2 Realising the potential

- Based on their experience, the North Row architects, Orms, suggest that planners should ask for carbon assessments more often and more forcefully. One London borough brought in an officer with carbon assessment experience, who was able to challenge RICS targets/methodology and ask searching questions of the developer. E.g., requesting that the developer submits embodied carbon assessment with and without adjustment for cement replacement, since that can't be guaranteed at planning stage. It is helpful to make carbon assessments 'pessimistic' so that developers have to plan for the worst case and work harder at savings. These approaches will tend to favour existing building retention.

[10] Based on Verisk UKBuildings database: 'tall terraces 3-4 storeys', with basement level(s), residential AND commercial/office/retail mixed use, in Greater London, built from 1837-1870 = 22,899 results, total 8,774,934.6 sqm.

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- Under current economic situation environmental issues, such as carbon avoided through reuse over new-build, have minimal material impact on the triple bottom line and return on investment analysis. Even applying the most optimistic economic multipliers to account for the true cost of carbon does little to affect this situation. To have a real impact, embodied carbon needs to be regulated and tax on refurbishment projects removed to incentivise the market to adopt a retrofit first approach to development.
- There is a lack of economic incentive to retain existing buildings. In some cases, this could be mitigated by minimising the remedial or upgrade works to be carried out to ensure the return on investment for developers is maximised. For the North Row development this wasn't possible due to the extent of the transformation and new build work required. If the incentive issue can be addressed for similar buildings facing demolition, they will stand a better chance of being selected for reuse instead.
- Adaptive re-use of similar building typologies without a change in legislation may not be affordable due to the high labour costs in the UK. Tax reforms such as ex-tax could potentially add more value to the natural resources incentivising the re-use of materials and thus enable the adaption of buildings.
- There is a collective responsibility for construction industry actors to advocate for tax reform to incentivise the use of renewable resources and disincentivise the use of non-renewable resources; if income tax was removed and levied on material purchase instead, financial analyses would favour maximum retention and reuse.

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Demonstrator	**D12: Life cycle extension alternatives for a 1989 supermarket structure, London**
Deliverable	D5.3 Policy brief and business case of building transformation
Grant Agreement No	821201
Project Acronym	CIRCuIT
Project Title	Circular Construction In Regenerative Cities
Dissemination level	Public
Work Package	5, 7
Author(s)	Peter Swallow (Grimshaw) & Colin Rose (ReLondon)

1. Mission statement, background and political decisions

This demonstrator looks at an out-of-town retail unit that is in danger of being demolished to make way for new development. The study aims to demonstrate alternatives to demolition. The applicability of transformation design strategies has been explored, assessing the feasibility of the Homebase superstore to be used for other building functions.

While this has been explored in relation to finding alternative uses for the structure in other locations, rather than on site, the findings are relevant to CIRCuIT's 'extending building life through transformation and refurbishment' focus area. The Homebase superstore is suitable for this focus area as:

- construction of the original building allows it to be fit for adaptive re-use
- the large span, column free space offers flexibility for alternative building uses
- the building has architectural merit – it is a great example of high-tech industrial architecture
- out of town retail is in decline across London (and the UK) so the findings from this study are replicable to many other sites where redevelopment is likely.

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Figure 52: Building photograph taken circa. 1987.

2. Project details

The building is a commercial shopping outlet completed in 1987 by Grimshaw Architects. The style epitomises that of high-tech architecture movement, also known as structural expressionism. The style emerged in the 1970s, with the ambition of incorporating elements of 'high-tech' industrial and technology features into the building design.

The structural scheme was created to be column free by means of a structural steel spine truss along the length of the building which was supported at an intermediate point by steel tension cables. The building is clad with sheet aluminium and sits on a concrete podium deck.

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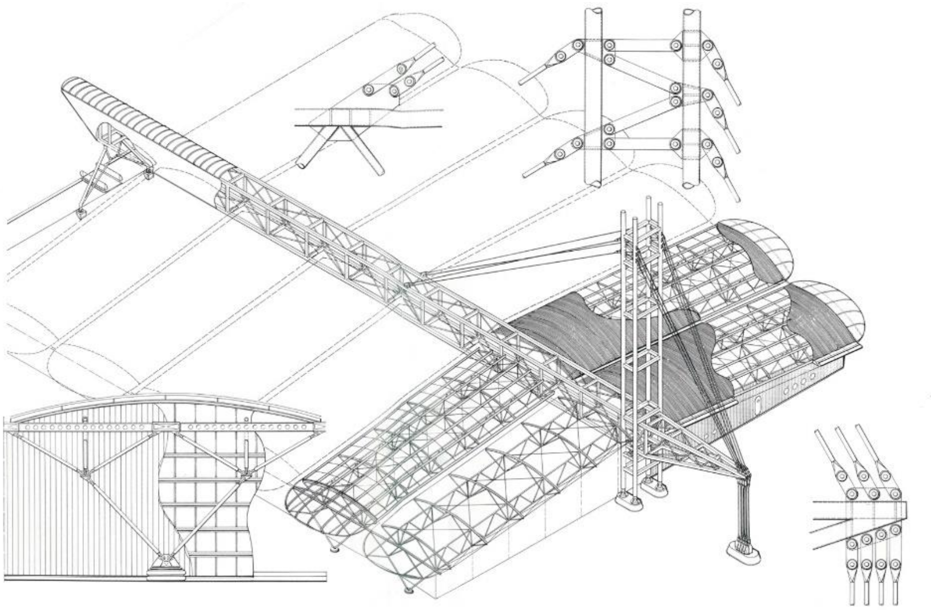

Figure 53: Original structural axonometric drawing by Grimshaw circa. 1987.

Recently, the Homebase superstore and surrounding land was acquired by St. Edward Homes (part of the Berkeley group), who intend to redevelop the site with a high-rise, mixed-use residential and retail development. The superstore is at risk of demolition as the existing building and car park does not feature in the developer's masterplan proposal.

Location: Syon Lane, Brentford, London TW7 5QE
Stakeholders: Berkeley Homes Group (asset owner/developer), Grimshaw (architect), OPS (structural engineer) Rider Levett Bucknall (cost manager/MEP engineer), Imperial College (building surveyor), BRE (pre-demolition audit).
Building typology: Out-of-town retail superstore
Year of completion: 1987
Style: High-tech
Size: 4,248 sqm

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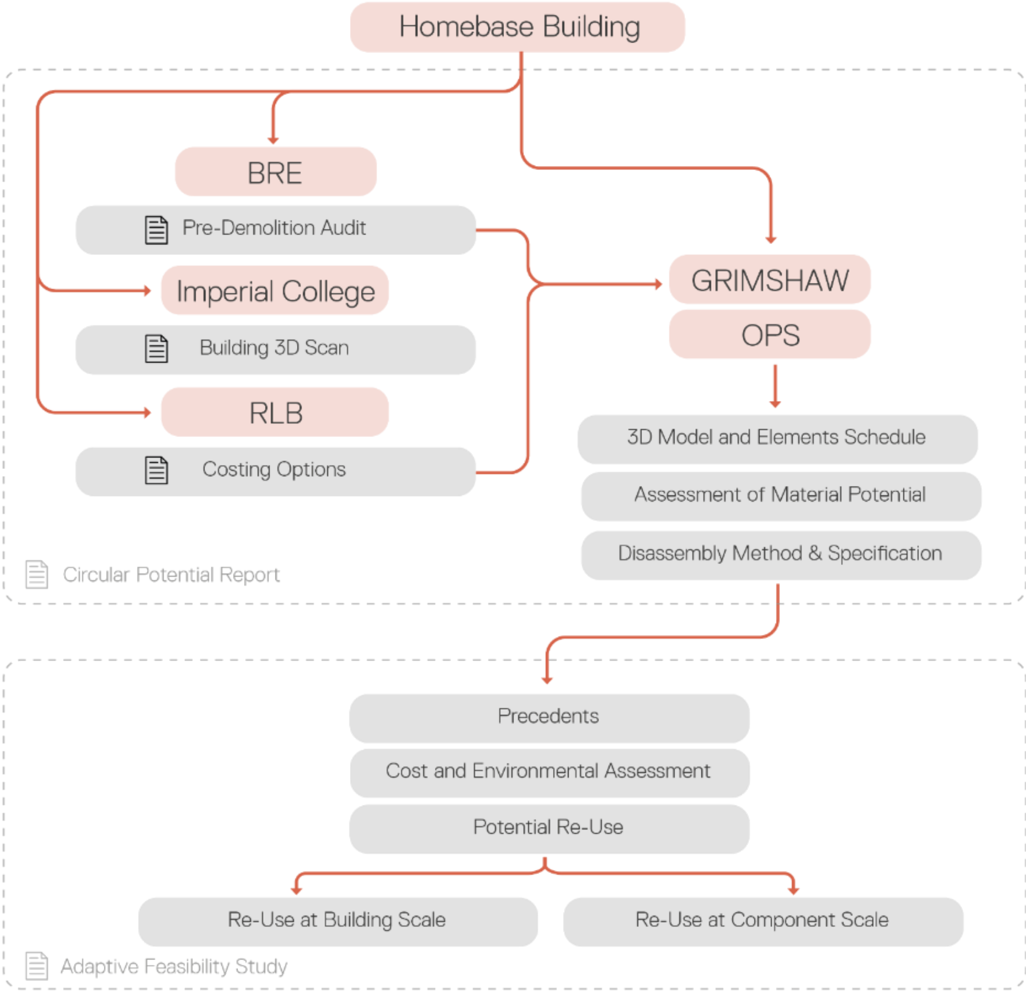

Figure 54: Demonstration team responsibility organogram

3. Objective

The primary aim of this demonstration was to provide evidence of the economic and technical viability of the highest value transformation strategies applicable to the building. The secondary aim was to explore replicable transformation options that could be applied to other out-of-town retail units and similar building typologies such as light industrial warehouses.

4. Technical analysis

4.1 Challenges

Whilst the technical challenges of transforming the building were relatively simple to address, the main challenge was making the case for retaining the building in its current location as part of the wider masterplan. To make the case to the developer, the transformation business case had to demonstrate that the return on investment offered by the most viable transformation scenario would better that of the current masterplan.

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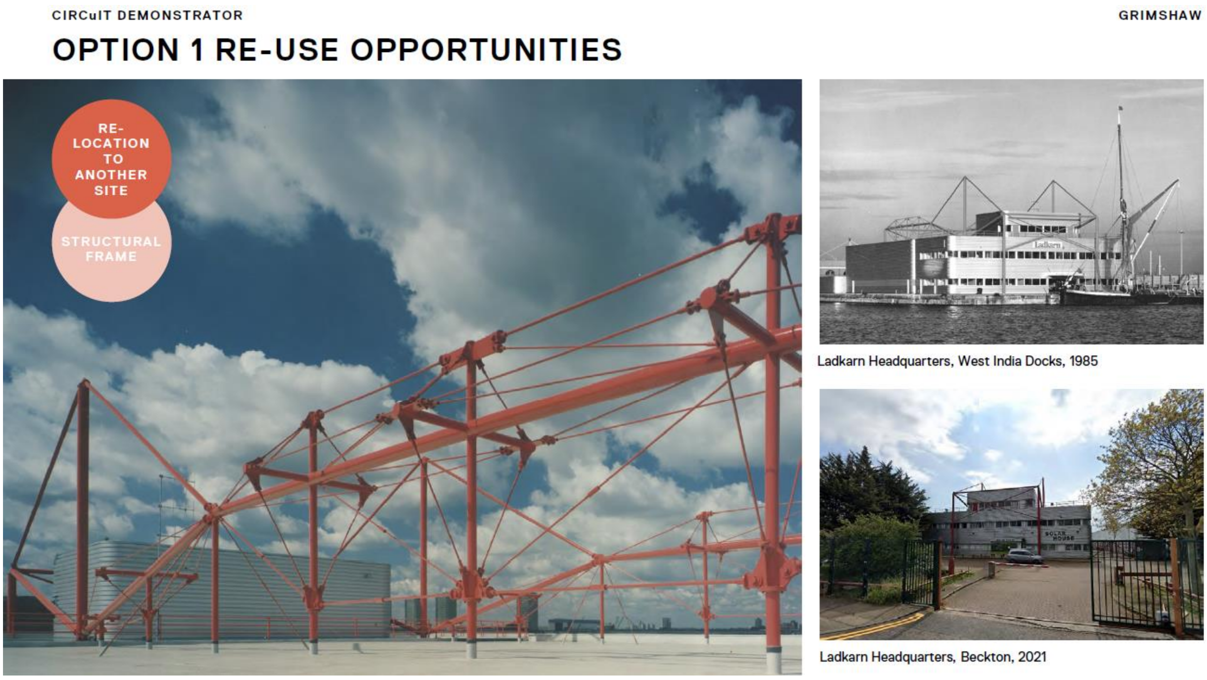
The building was assessed for its suitability to be transformed into a range of other functions. However, the developer concluded that none of the transformation typologies are suitable for the site, so the building remained scheduled for demolition.

Therefore, the challenge became to understand the potential embodied carbon and capital costs of dismantling the structure and re-erecting the entire frame in its current form on another site.

4.2 Solutions

A desktop study was undertaken to demonstrate the reuse potential of the primary structure and cladding. The study illustrated how disassembly can be achieved at two different scales: Dismantle the structure and re-erect entire frame in its current form; Dismantle the structure and sell off in sub-sections or single elements. The latter option is addressed in the WP4 Homebase superstore business case.

The potential for whole building re-use has been appraised. This has involved a series of volumetric assessments that demonstrates the re-use potential of these elements in the form of test fits. A test fit is a floor plan used to confirm that the re-use stated can be accommodated within the proposed space. Through these series of test fits, the report covers the re-use potential of the Homebase superstore within retail and alternative sectors such as healthcare, transport, education, industrial, agricultural and multifunctional spaces.



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OPTION 1 RE-USE OPTIONS

RETAIL

HEALTHCARE

MULTIFUNCTIONAL SPACE

Nightingale Hospital Excel London, source: bdp.com

OPTION 1 RE-USE OPTIONS

UCL at Here East, London. Source: hereeast.com

INDUSTRIAL / MANUFACTURING

AGRICULTURAL

RESEARCH / EDUCATIONAL

TRANSPORT

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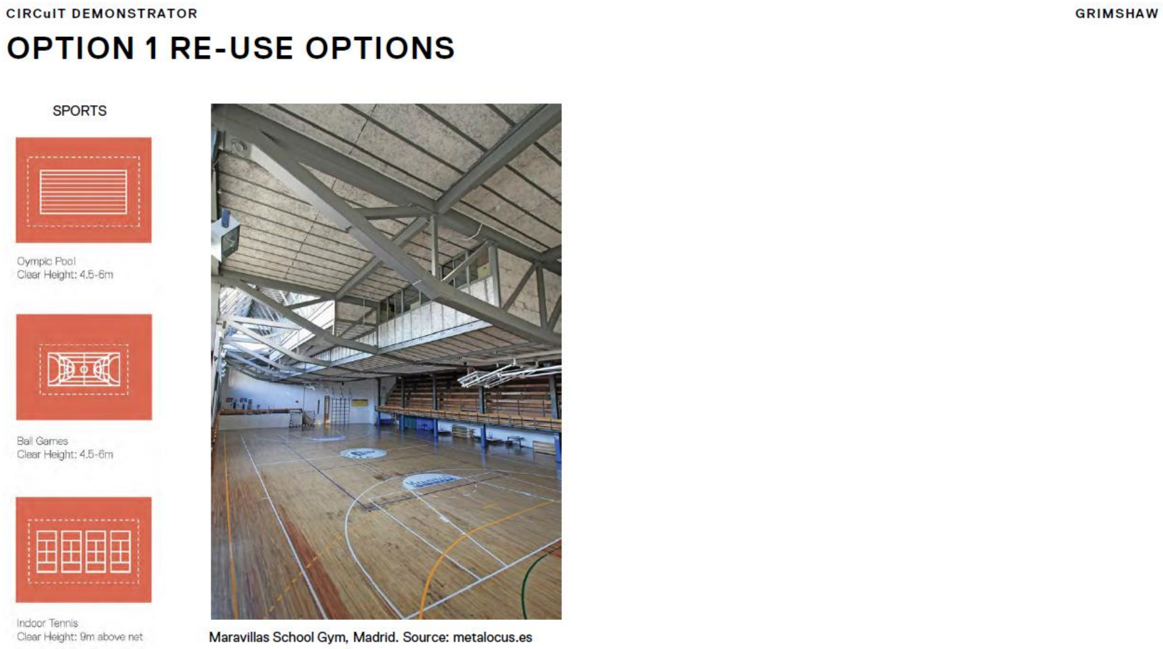

Figure 55: Precedent for relocation of whole high-tech building and test fit studies to confirm that various potential new uses can be accommodated within the existing structure

4.3 Lessons learnt

The UK's changing economy of declining retail and housing shortage means that it is difficult to resist the whole site redevelopment and intensification of out-of-town retail parks. However, the test fit approach could be implemented in other instances of superstores facing demolition. Growing markets such logistics warehouses may increasingly require this type of large-span structure. Making connections between such demand projects and teams looking at redevelopment of retail parks will be key to extending these buildings' lifespans.

5. Performance measures

5.1 Baseline

Performance of the project has been assessed over a period of 60 years for life cycle costing purposes. For context, the performance has been compared to a base case without circular construction objectives. For this project the business-as-usual base case assumes the construction of a single-storey new building to the same design and floor area as the existing store (3,612 m2 warehouse to shell only specifications, with 636 m2 of offices at ground floor level), to Homebase standards and does not assume any re-use of the existing building frame or building envelope.

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5.2 Environmental performance indicators

Environmental performance has been assessed against a range of indicators that represent different aspects of circular construction. The indicators selected for this project are highlighted in Table 1.

Table 31. Environmental performance indicators

Indicator name	Unit
Reused content	% reused content
Tonnes of materials used	Tonnes of materials used in the building
Total waste arisings (whole life)	Tonnes of waste arising
% of waste arisings reused, remanufactured, recycled	% reused, remanufactured, recycled
Whole life carbon emissions	kgCO2e

5.3 Environmental performance results

Overall, the circular intervention improved the performance of the project on 4 out of the 4 indicators considered.

The biggest improvement was in whole life carbon emissions, which was improved by 47%. This was because the steel frame is highly carbon-intensive in business-as-usual production in the base case, so its reuse has a proportionally large benefit compared to indicators based on material quantities.

Table 32. Environmental performance results

Indicator name	Base case	Intervention	Savings
% reused content	0%	14%	+14%
Tonnes of materials used	2,195 tonnes	2,195 tonnes	0 tonnes
Total waste arising	2,195 tonnes	1,895 tonnes	300 tonnes
% of waste arisings reused, remanufactured, recycled	0%, 0%, 100%	14%, 0%, 86%	+14%, no change, -14%
Whole life carbon emissions (kgCO2e) (structural frame)	2,536,342 kg CO2e	1,335,902 kg CO2e	1,200,449 kg CO2e / 47%

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Figure 56. Environmental performance comparison

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6. Economic analysis

6.1 Baseline

As with the environmental performance, the economic analysis has been undertaken in comparison to a base case. This 'baseline' is described in section 5.1.

Demolition and disassembly of the existing building for re-use is considered as a separate demonstrator project in WP4, and as such no demolition costs are included in this appraisal.

The baseline option assumes a single stage Design & Build fixed price procurement route is used.

As the building is not proposed to be located within an area of particular Planning interest, no allowance has been included for any enhancement beyond current typical industry standards. The capital cost estimates for both options assume reasonable ground conditions sufficient for standard pad foundations, and the provision of a 'shell' only warehouse, with tenant Cat B office fit-out standards. As such BREEAM is excluded but allowances have been made for photo-voltaic renewable energy and EV charging points.

For the circular intervention option, it assumes the relocation of the entire steel frame to re-create the same facility on an alternate site.

For both options, the costs include for on-plot external works, but exclude any works off-site beyond the site boundary. Capital costs assume drainage connections and mains utility services will be available at the site boundary, but excluded any off-site network reinforcements.

The LCC analysis excludes End of Life costs at the end of the 60-year period for demolition termination or replacement of the buildings.

This analysis uses a net present value (NPV) methodology and uses the application of a 3.0% discount rate.

6.2 Economic analysis indicators

The economic analysis has been considered in relation to the components of life cycle costs, as described in ISO 15686-5 2017 Buildings and constructed assets — Service life planning — Part 5: Life Cycle Costing and includes the following:

- initial construction costs
- renewal costs
- maintenance costs
- operating costs – utilities (energy & water), cleaning, administration

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As well as these indicators being considered in isolation, they have also been combined to reflect the overall financial performance of the demonstrator in terms of net present value (NPV). For this a discount rate of 3.0% has been assumed. Depreciation nor appreciation of the asset itself over time has not been included in the modelling.

The following life cycle components were considered irrelevant for the purposes of this demonstrator and are therefore excluded from the analysis:

- end-of-life costs including residual values and terminal values
- externalities
- non-construction costs
- income
- occupancy costs
- return on investment

For the life cycle costs, a 60-year period has been assessed. See appended to this report a full Life Cycle Costing Analysis of each scenario (refer Appendix B).

6.3 Economic analysis results

This LCC analysis has established that by comparison to the base case, the circular construction intervention has resulted in a 15% saving in the capital construction cost, and reduced the Whole Life costs by 2%, all as set out in Table 3 below.

For the transformation and re-use option, the construction cost estimate does not make any additional preliminaries cost allowance due to any extension to the construction period.

It should be noted that the cost estimates for this WP5 demonstrator includes deconstruction and relocation of the structural steel elements but do not take into account, make any allowance, or make any adjustment for the potential to carefully salvage greater demolition material for re-use, such as reclaiming cladding or the like. Under the Homebase WP4 business case there is a separate review for salvaging and repurposing of the structural steel elements so that they can be redistributed for reuse on other projects.

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Table 33. Economic analysis

	Baseline	Intervention	Difference	Saving/Extra %
Construction costs	£3,726,312	£3,173,204	-£553,108	-15%
Renewal costs*	£3,681,788	£3,681,788	£0	0%
Operation costs*	£30,161,460	£30,161,460	£0	0%
Net present value (NPV)	£28,528,541	£27,975,433	-£553,108	-2%

* These costs are discounted Net Present Values and take a 3.0% discount time-based factor into account.

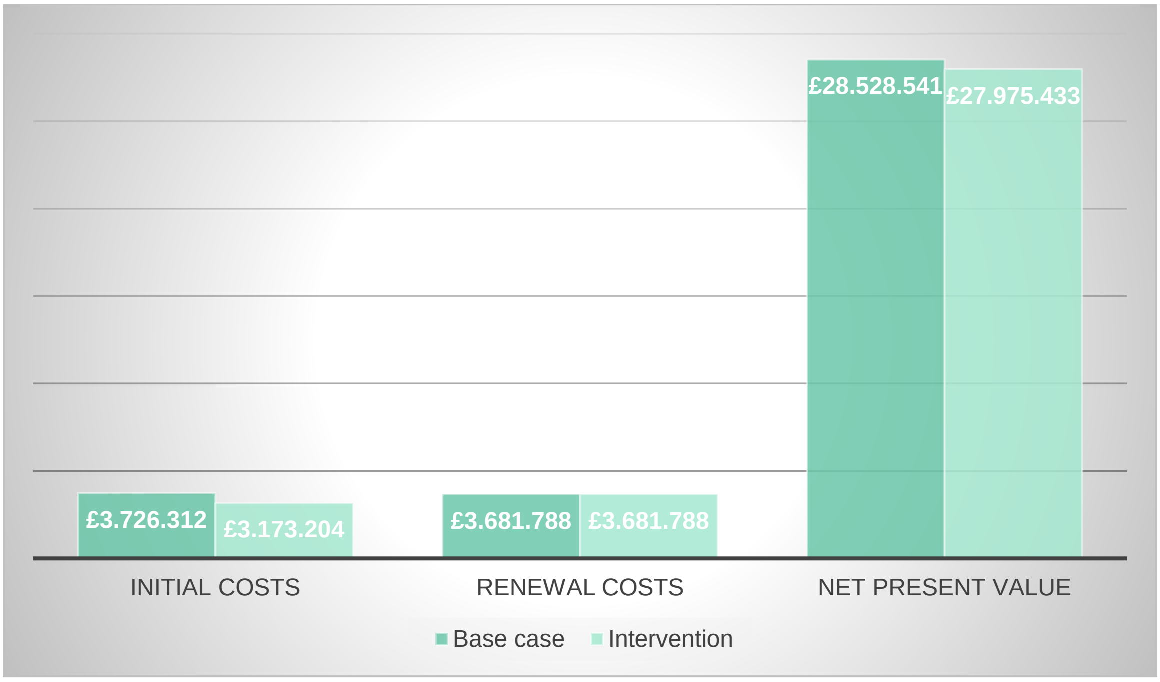

Figure 57. Economic analysis comparison

7. Scaling the impact and assessment of needs

7.1 City level potential

This business case could potentially be replicated across 372 other out-of-town retail units of this era,[11] if it is assumed that all land of this use category is at risk of redevelopment in the short- to medium-term. The Homebase superstore investigated in this demonstrator is around 10% larger than the average footprint of these retail units. Assuming that the carbon savings from this demonstrator can be repeated proportionally for other retail units, re-erecting structural frames in lieu of new steel frames could potentially result in a reduction in

[11] Based on Verisk UKLand and UKBuildings databases: retail units on retail parks in Greater London built from 1980-current with steel structure = 373 results, total 1,442,779.3 sqm.

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whole life carbon emissions of 400,000,000 kgCO2e across Greater London. This is equivalent to the annual emissions from 50,000 homes.

The calculation rests on the assumption that there is demand for 373 large-span steel frame structures in Greater London, and that enough of that latent demand would be willing and able to accommodate existing structures in terms of dimensions, load capacity, aesthetics, timeframes etc.. The Homebase superstore investigated in this demonstrator has a distinctive design with far greater architectural merit than most out-of-town retail units, which may be expected to make it easier to resell. Conversely, other less distinctive, simple shed structures could prove more versatile and relocatable.

7.2 Realising the potential

- Matching up the 'supply' of whole retail units from land that is to be redeveloped with demand for their structural frames in new developments will rely on better information about the existing structures.
- Demand will need to be tested by marketing these opportunities to the industry at large, and in a targeted way to developers at pre-application or outline planning stage preparing schemes that could make use of relocated structures.
- A developer may see planning risk where a whole building structure is relocated, rather than having a new structure designed to suit its specific context. Introducing planning policies that allow more dimensional freedom when an existing building is relocated, or a softer approach to planning decision determination in such cases, may be perceived to reduce this risk.
- Places to store, test and recertify structures in scenarios where they cannot be moved directly from one site to another will be key.
- A more developed organisational infrastructure of companies with expertise in assessing relocation potential, carrying out careful deconstruction and re-erection (and potentially intermediate storage) is required.
- The carbon emissions case is very clear in this demonstrator, so introducing stronger regulation of embodied carbon will incentivise relocation of retail unit structures.
- Zero rating or reduced rating VAT on building relocation will level the playing field with conventional new build.
- The steel industry is making incremental steps towards component recertification rather than whole building relocation. It will be important for these two strategies to progress in a complementary way; both are likely to have scenarios where they are the preferable strategy (e.g., whole building relocation preferable for distinctive, high-quality design such as Homebase Brentford). The potential quantity of end-of-service-life retail units suggests both forms of structural steel reuse can grow considerably.

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