Towards circularity in brick masonry: knowledge gaps and future needs

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Mot cirkularitet i tegelmurverk: kunskapsluckor och framtida behov

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Preface

This thesis is written as the final part of the master's degree in civil engineering, with a focus on structural engineering at Lund University between January and June 2025. I would like to thank my supervisor, Mohammad Kahangi, for his guidance and support throughout the project. I would also like to thank Carl Hansson from Brukspecialisten for his valuable help and clear answers.

Lana Heidar

Abstract

According to the UN Environment Programme, the construction sector is responsible for 37% of global energy and process-related CO_2 emissions. In Sweden, the latest data from Boverket – the Swedish National Board of Housing, Building and Planning – indicates that this sector accounts for 22.1% of the country's total greenhouse gas emissions. As part of national climate efforts, Fossilfritt Sverige (Fossil-Free Sweden) has set targets to reduce emissions by 50% by 2030 and 75% by 2040, with a strong emphasis on lowering energy consumption during the operational phase of buildings. Among the various construction materials, brick production stands out for its high energy demand, primarily due to the elevated temperatures required for firing. Despite its energy-intensive production, brick masonry is widely used in Sweden and is valued not only for its durability and long-term performance but also for its significant cultural and architectural role. Approximately 40–50 million new bricks are used annually in Sweden, while about 10 million bricks are demolished. However, only around 2.5 million of these are currently reused, highlighting a substantial untapped potential for reuse. This thesis presents a literature review that evaluates available methods for promoting the circular management of bricks, with a focus on demolition, separation, and cleaning techniques. The aim is to highlight current challenges in the construction sector that limit the reuse of bricks and identify strategies to support more circular construction practices. In addition to material considerations, the study evaluates the potential energy savings associated with reusing bricks rather than producing new ones. While the reuse of intact bricks for façade applications is prioritized, the study also acknowledges opportunities to repurpose non-reusable bricks, those that are crushed, damaged, powdered, or otherwise unsuitable for façade, according to the 9R framework. These approaches contribute to reduced landfilling and decreased construction waste, thereby promoting more sustainable resource management in the built environment.

Sammanfattning

Enligt FN:s miljöprogram står byggsektorn för 37 % av den globala energianvändningen och de processrelaterade koldioxidutsläppen. I Sverige visar den senaste statistiken från Boverket att denna sektor står för 22,1 % av landets totala utsläpp av växthusgaser. Som en del av Sveriges klimatmål har Fossilfritt Sverige satt upp mål att minska utsläppen med 50 % till 2030 och 75 % till 2040, med starkt fokus på att minska energianvändning under byggnaders driftsfas. Bland de olika byggmaterialen utmärker sig tegelproduktionen för sitt höga energibehov, främst på grund av de höga temperaturer som krävs vid bränning. Trots detta används tegel i stor utsträckning i Sverige och uppskattas inte bara för sin hållbarhet och långa livslängd, utan även för sin kulturella och arkitektoniska betydelse. Årligen används cirka 40–50 miljoner nya tegelstenar i Sverige, samtidigt som cirka 10 miljoner tegelstenar rivs. Endast omkring 2,5 miljoner av dessa återbrukas idag, vilket pekar på en betydande outnyttjad potential för återbruk. Detta examenarbete presenterar en litteraturöversikt som utvärderar tillgängliga metoder för att främja cirkulär hantering av tegel, med fokus på rivning, separation och rengöring. Syftet är att belysa aktuella utmaningar inom byggsektorn som begränsar återbruket av tegel och att identifiera strategier för att främja mer cirkulära byggpraxis. Utöver materialaspekter utvärderar studien den potentiella energibesparingen i samband med att återanvända tegelstenar istället för att producera nya. Även om återbruk av hela tegelstenar för fasadanvändning prioriteras, belyser studien även möjligheter att återanvända som är krossade, skadade, pulveriserade eller av andra skäl inte lämpar sig för fasad, enligt 9R-ramverket. Dessa åtgärder bidrar till att minska deponering och byggavfall, vilket främjar en mer hållbar resurshantering i den byggda miljön.

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1. Introduction & background

This chapter introduces the environmental context and identifies the key challenges associated with managing brick masonry in the construction sector, focusing on circular economy principles. It outlines the primary objectives set by national strategies aimed at reducing the environmental impacts of construction activities. The purpose of this study is clearly defined as identifying effective methods for managing brick masonry post-demolition. The chapter concludes by briefly presenting the methodologies used in this study.

1.1 Background and motivation

The construction sector plays a significant role in global greenhouse gas (GHG) emissions. According to the United Nations Environment Programme (2024), the sector accounted for 37% of global energy and process-related CO_2 emissions in 2022, equivalent to approximately 10 gigatons of CO_2. This represents a 1% increase from 2021 and is largely attributed to the production of high-impact materials such as concrete, steel, aluminum, bricks, and glass (European Environment Agency, 2024).

In Sweden, the construction sector contributes around 20% of the country's total emissions. A large portion of these emissions originates from material production and energy use during the operational phase of buildings (Fossilfritt Sverige, 2018). According to the latest data from Boverket (2025), emissions from the Swedish construction and real estate sector totaled approximately 10.8 million tonnes of CO_2 equivalents in 2022, accounting to 22.1% of national emissions. Additional emissions arise abroad due to the import of building materials, amounting to a further 6.9 million tonnes (Boverket, 2025). Fossilfritt Sverige has set ambitious targets to reduce emissions by 50% by 2030 and by 75% by 2040, using 2015 levels as the baseline (Fossilfritt Sverige, 2018).

Among the materials contributing to these emissions is brick. Brick masonry is widely used in Sweden, where it forms an integral part of the architectural landscape. It is estimated that more than 200 million square meters of masonry façades exist across the country. Brick is not only a durable, long-lasting material, but it also holds significant cultural and architectural value, making it a preferred choice for both historical preservation and contemporary design.

From a cultural perspective, brick façades are strongly associated with historical and regional identity. Their use links modern construction practices to heritage values enabling the preservation of traditional urban character. According to Länsstyrelsen Stockholm, brick buildings reflect societal and architectural development and provide opportunities for future generations to engage with built heritage.

Brick masonry has a long historical legacy, with archaeological evidence suggesting its use as early as 7000 BC (Brickarchitecture a). While concrete has become the most commonly used construction material today, bricks continue to play a vital role in both structural and cladding applications. Globally, the combined market value of bricks and mortar is estimated at approximately USD 1,837 billion and continues to grow (Zhou et al., 2020). In Europe, brick production accounts for approximately EUR 5.5 billion annually, supported by around 1,300 manufacturing facilities (Lima et al., 2024). In Sweden, the annual demand for bricks has historically ranged between 40 and 50 million units, although recent economic conditions have led to a temporary decline in construction activity and, consequently, in new brick demand (Hansson, 2025).

Technically, bricks are selected for their strength, thermal mass, and, notably, for their durability and low maintenance requirements. High firing temperatures during manufacturing cause the vitrification of the clay matrix, resulting in a dense, weather-resistant structure (Brickarchitecture b). As a result, bricks can withstand environmental stresses such as freeze-thaw cycles, wind-driven rain, and temperature fluctuations, with a typical service life exceeding 150 years (Brick Development Association, 2020). Their longevity reduces the need for repairs or replacement, thereby lowering the overall consumption of natural resources over a building's lifecycle (Brickhunter, 2024).

However, the production of bricks is associated with considerable environmental impacts, primarily due to the energy-intensive firing process. Traditional brick kilns often rely on fossil fuels such as coal, emitting substantial quantities of CO_2, sulfur dioxide (SO_2), and nitrogen oxides (NO_x), which contribute to climate change, soil and forest acidification and adverse health effects (Brickhunter, 2024; Naturvårdverket, 2025). In response, several countries are introducing measures to lower the environmental footprint of brick production. These include adopting more efficient kilns and transitioning to cleaner fuel alternative, such as natural gas, biofuels, or hydrogen, as well as promoting the recycling and reuse of bricks. These strategies are increasingly supported by technological advancements, making sustainable brick production a realistic and accessible goal (Brickhunter, 2024).

In addition to their technical and cultural benefits, bricks have demonstrated potential for reuse. According to Lima et al. (2024), under appropriate demolition and handling conditions, bricks can achieve a reuse rate of nearly 100%. However, this figure should be interpreted as an optimistic upper limit. In practice, the actual reuse rate is highly dependent on several interrelated factors, including the demolition method, the ease of separating bricks from mortar, and the effectiveness of cleaning techniques. Nevertheless, reusing bricks significantly reduces both raw material and greenhouse gas emissions.

1.2 Research purpose and objectives

The purpose of this study is to investigate and identify effective methods for managing brick masonry following demolition, with a particular focus on enhancing reuse potential. The study aims to highlight the existing challenges and limitations within the construction sector, particularly those related to energy efficiency, environmental impact, practical feasibility, and waste management practices concerning brick masonry. By synthesizing findings from the literature, interviews, and case studies, the study aims to develop a structured knowledge base that supports decision-making in the construction industry.

1.3 Methodology overview

The following section presents the methods that will be used in this study. To achieve the purpose and objectives of the study, extensive literature studies and interviews are conducted. Interviews with professionals in the field—particularly from companies engaged in brick reuse—offer industry insights and validate findings from the literature. Additionally, selected case studies and site visits are utilized to explore practical applications and evaluate the real-world feasibility of these processes, thereby enabling a more comprehensive understanding of demolition, separation, and cleaning.

1.3.1 Literature study

The literature review focused on identifying sustainable methods for managing brick masonry after demolition. Academic databases, particularly ScienceDirect, Scopus, and Google Scholar, were used to search for peer-reviewed articles relevant to the topic. Keywords such as "recycling," "reuse," "brick," "circular economy," "demolition," and "9R Framework" were also used in broader internet searches to supplement the academic literature with relevant literature and industry reports.

Given the global relevance of the topic, several international resources were consulted, including publications by the European Environment Agency. Denmark, in particular, has made notable progress in the reuse of bricks. Therefore, Danish documents—issued by both governmental authorities such as the Ministry of the Environment and companies like Gamle Mursten—were included to provide practical insights into ongoing initiatives within the region.

1.3.2 Interviews

To complement the literature review with practical perspectives, a semi-structured interview was conducted with Carl Hansson, a designer at Brukspecialisten, a Swedish company specializing in the reuse of bricks. The interview began with an overview of the company's activities in brick reuse. Prepared questions were then discussed to explore specific challenges, methods, and insights related to brick recovery and reuse.

The interview provided valuable insights into industry practices and demonstrated how companies operationalize sustainability principles in the reuse of bricks. Understanding these real-world approaches contributed to a more comprehensive evaluation of the feasibility of implementing similar practices on a larger scale.

1.3.3 Case studies and site visits

To investigate how theoretical concepts are applied in practice, several case studies and one site visit were conducted. The first case study focused on a selective demolition project at a school in Ängelholm, which is further detailed in Section 4.5. Another case study examined the use of reclaimed bricks in a construction project in Eslöv, providing insight into the integration of materials in new façades. Additionally, four cleaning techniques were evaluated to understand their impact on the quality and reusability of recovered bricks.

A site visit was conducted in Drottninghög, Helsingborg, where reused bricks from three older buildings were incorporated into the construction of new residential façades. Observations during the visit revealed the use of bricks in varying colors, highlighting both the practical and aesthetic considerations in reused masonry applications.

1.4 Material properties

Below is a description of the materials, brick and mortar. The description in the chapter covers the composition and properties of the brick. This is followed by a description of various types of mortar and their distinct properties.

1.4.1 Properties of brick

Brick is one of the oldest building materials and is still widely used today. This is due to its advantageous properties in terms of availability, cost-effectiveness, and durability. Building bricks are mainly made from fired or dried clay. By shaping the clay into standard rectangular dimensions and then firing or drying it, durable bricks are created (Civil E Blog).

In addition to clay, bricks also contain lime, iron oxide, and magnesia. The lime content should not exceed 5%, as it helps reduce shrinkage, but an abundance of lime can cause the bricks to melt and lose their shape (Civil E Blog). Hydraulic lime, a key component in some construction materials, is produced by burning limestone that contains clay. It consists of a hydraulic component, which hardens when reacting with water (similar to cement), and an air lime component, which hardens by absorbing carbon dioxide from the air. When mixed with water, hydraulic lime forms calcium hydroxide—the same substance present in the lime portion of mortar (Moesgaard, 2017). Iron oxide, which accounts for 5–6%, gives bricks their characteristic red color. A higher concentration results in darker shades, ranging from dark blue to black, while a lower concentration produces a yellowish hue (Civil E Blog). Magnesia is present in small amounts and helps reduce shrinkage while giving the bricks a slightly yellowish tint. However, excessive magnesia can cause the bricks to disintegrate (Civil E Blog).

Bricks can be divided into common bricks, façade bricks, and paving bricks, which vary in size and color (Malmö Återbyggdepå). Façade bricks are fired at a lower temperature, which means that the brick becomes more porous compared to ground bricks, which are fired at a higher temperature. The high temperature that the paving brick is exposed to causes the pores in the brick to disappear, which increases the resistance to frost. Paving bricks can be used for walkways, patios, stairs, and other outdoor features (Medtech Magazine, 2021). Both paving bricks and façade bricks must meet frost resistance requirements, while common bricks have no frost resistance requirements (Wienerberger).

Bricks are manufactured as solid or with holes. Holes in bricks have varying sizes and shapes, such as round, square, or rectangular. The standard size for Swedish bricks is 250 x 120 x 62 mm, while the European standard size is 228 x 108 x 54 mm (Malmö Återbyggdepå). The brick is sorted according to the long and short sides of the brick. The long side is called the running side, and the short side is called the cup side (Wienerberger).

1.4.2 Properties of mortar

Mortar comes in various grades and is composed of a mixture of cement, lime, sand, and water. It acts as a binder between bricks, ensuring strong adhesion and a durable structure (Kima

Chemical Co., 2024). Mortar is generally divided into two main categories: lime mortar and cement mortar. Lime mortar can further be classified into air-lime mortar and hydraulic lime mortar. These mortars can be combined in various ratios to form different types of mortar adapted to meet specific structural or environmental needs.

Mortar can be categorized in two ways:

- Designed mortars are mortars that are mixed to meet certain specific properties, such as strength.
- Prescribed mortars are mortars that are mixed according to a specific recipe – with specific amounts of each ingredient – to obtain the right properties.

The designed mortar is divided into four different classes: M10, M2.5, M1, and M0.5, which were previously designated as A, B, C, and D, respectively. M10 mortar has the highest strength and is used in construction with high-strength stone or masonry blocks exposed to rough external conditions. M2.5 is suitable for most façade construction. M1 is used for façade masonry, where you want to avoid partial joints, which places requirements in terms of water drainage and is therefore not suitable for water areas such as lakes and coastal regions. M0.5 works well for the renovation of older buildings (Weber).

Mortar types are divided into cement mortar and lime mortar. Cement mortar has a higher compressive strength compared to lime mortar. While cement mortar became the standard for house construction from the 1940s onward, lime mortar was commonly used in older buildings constructed before the 1930s. Although lime and cement share the same raw materials, the kiln temperature at which the lime is burned determines whether lime mortar or cement mortar is formed (Morneon Fasad AB). Below is a comparison table between air-lime and cement mortar (Walker, 2022), as summarized in Table 1.

Table 1: Comparison between lime and cement mortar (Walker, 2022).

	Cement mortar	Lime mortar
Timeline	Developed in the 19th century and refined in the early 20th century.	Before and during the 19th century.
Composition	Modern Portland cement mortars are composed of Portland cement, sand, a plasticizer, and water. Variations of these mortars may include combinations such as Portland cement with lime, and sand mortar, or Portland cement with quicklime, and sand.	Usually made of lime and sand, it may also contain other additives such as soil and fibers.
Slaking process	Does not require slaking.	Lime is slaked by adding water.
Inclusion	Lime inclusions are rare. They do occur in mortars containing quicklime or hydrated lime, but these are few and far between.	It may have lime inclusions that appear as soft, white, powdery lumps.
Colour	A strong grey colour for most applications. White cement is often used in decorative elements to brighten the colour of the sand.	Sand determines the color, colors such as cream, beige, red or yellow shades.
Texture	Often glassy and dense. Modern cement mortars often show signs of air entrainment.	Generally has a crystalline and fluffy texture.
Strength	Strong, hard and brittle.	Depends on the type of lime, generally soft, flexible and porous.
Water Absorption	Low water absorption, less breathable and often impervious.	High water absorption due to breathable and porous
Applications	Suitable for modern cavity construction.	Suitable for solid walled historic buildings.

2 Circular economy and the 9R framework

There is an increasing demand for more sustainable and resource-efficient systems, particularly in sectors with high environmental impacts, such as construction. This demand arises from the depletion of natural resources, the sector's contribution to greenhouse gas emissions, and the generation of large volumes of construction and demolition waste. In response, several frameworks have been developed to promote sustainability and circularity in the built environment. Among these, the 9R Framework provides a structured hierarchy of strategies to keep materials in use and reduce environmental burdens throughout the product life cycle.

This chapter introduces the concepts of sustainability and circular economy in the built environment and concludes by presenting the 9R Framework, which outlines ten strategic levels for circularity. These strategies are supported by various business models, infrastructure developments, stakeholder relationships, and policies that aim to promote efficient material flows across the European Union (Lima et al., 2024).

2.1 Sustainability in the built environment

Environmental sustainability in the built environment refers to meeting current needs without compromising the ability of future generations to meet their own needs. It seeks to balance ecological, economic, and social objectives. This balance can be achieved through practices such as reducing carbon emissions, promoting the use of renewable energy sources, increasing material efficiency, and supporting equitable resource distribution (World Green Building Council).

In the context of brick masonry, sustainability can be promoted by extending the service life of existing brick façades, reducing the demand for newly produced bricks, and encouraging the reuse of demolition waste. These strategies contribute to lower embodied carbon, reduced material extraction, and minimized construction waste. Additionally, well-maintained brick structures often require less energy for heating and cooling, further supporting environmental goals. By integrating such practices, brick masonry can play a key role in advancing sustainability within the construction sector.

2.2 From linear to circular economy

The linear economy is a traditional production and consumption model where raw materials are extracted, used to manufacture products, and then discarded as waste after use. This model results in high resource consumption and significantly contributes to environmental degradation, including air, water, and land pollution (Chirumalla et al., 2024). According to the European Environment Agency (2024), the linear model is linked to unsustainable resource exploitation, biodiversity loss, and climate change.

In contrast, the circular economy (CE) aims to decouple economic growth from resource consumption by keeping materials and products in circulation for as long as possible. It emphasizes waste prevention, product longevity, resource recovery, and systemic efficiency.

The European Commission estimates that adopting CE practices could generate economic benefits of up to €600 billion (Korhonen et al., 2018).

The application of CE varies across countries depending on political, social, and economic contexts. Germany introduced CE in the 1990s to promote resource conservation. China focused on developing industrial systems, while countries such as the UK, Denmark, and Switzerland implemented circular economy (CE) principles in their waste management systems. In Europe and North America, CE approaches often include life cycle assessments, product reuse, and recycling (Winans et al., 2017).

The CE- concept focuses on maximizing resource efficiency by reusing materials instead of discarding them. This is achieved through recycling, renewable energy use, and smart energy conservation. A well-functioning circular economy supports sustainable development across environmental, economic, and social dimensions. The goal of CE is to minimize resource consumption to a level that nature can sustain while aligning economic activities with natural cycles (Korhonen et al., 2018).

To meet the increasing demand for resources, transitioning to a circular economy is considered an effective solution (Chirumalla et al., 2024). The transition is expected to have several positive effects in Europe and globally, including reduced pollution and climate change, as well as contributing to the preservation of biodiversity (European Environment Agency, 2024).

Despite its benefits, shifting from a linear to a circular model presents significant challenges, including technical requirements and economic sustainability. Companies and policymakers often struggle to adapt business models and invest in long-term strategies, which requires additional efforts to facilitate the transition (Chirumalla et al., 2024).

Key actions for a circular economy (European Environment Agency, 2024):

- Reduce resource use and create a less material-intensive economy.
- Extend the lifespan of products through increased use and better design.
- Streamline waste management with high-quality recycling and reusing secondary materials.

2.3 The 9R framework for circular resource management

The 9R framework is a hierarchy of strategies used to guide circular economy implementation. It categorizes circular actions based on their potential to reduce material consumption, with the most preferred actions (e.g., refuse, rethink) placed at the top. The lower levels involve actions such as recycling or recovery, which, while still useful, typically retain less value from the original product. The following definitions are adapted from CE Grow Circular and contextualized for brick masonry:

Refuse: Refuse is defined as avoiding waste by refusing to use raw materials or produce new products. Refuse is also about making a certain product completely useless by the product losing its function or by offering the function with another product. In the case of bricks, this could involve preventing unnecessary demolition by prioritizing the preservation and continued use of existing brick structures through proper design, planning, and maintenance.

Rethink: Rethink refers to making products more efficient and usable. This is done by dividing original products into several other products or by making products multifunctional from the start. Making products multifunctional requires thinking through the uses of the product before production. This results in lower environmental impact and reduces the proportion of resources and raw materials required to produce products.

Reduce: Reduce means increasing the efficiency in the design or manufacture of products. This entails using fewer materials and natural resources. The idea behind this strategy is to reduce the environmental impact of the products. In brick masonry, this can include optimizing wall designs to use fewer bricks, improving kiln efficiency, or incorporating alternative low-impact materials in the production process.

Reuse: Reuse refers to the product being able to be used by another consumer. The strategy is crucial to keeping materials in use for a longer period, which promotes circularity and sustainability of material flows. Reuse advocates manufacturing products with extended product life. For bricks, the reuse strategy can be implemented through direct reuse of intact bricks.

Repair: Repair is defined as the maintenance and restoration of a damaged product to restore its original function. For bricks, it involves regular maintenance of brick façades to extend their lifespan. This can be done by regularly cleaning, polishing, repairing, or replacing damaged stones.

Refurbish: Refurbish is a strategy that specifies an update or new variant of a product, resulting in an extension of the product's lifespan. For example, upgrading existing masonry from old buildings to more modern use.

Remanufacture: Remanufacture involves using working parts from defective products to create new products with the same intended use. By cleaning and restoring the used bricks for reinstallation, the remanufacture strategy can be utilized.

Repurpose: Repurpose involves using functioning parts of defective products in new products with different uses. Using recycled bricks for new applications such as landscaping

Recycle: Recycling is about managing waste so that it can be converted and recycled into new raw materials. This means that old goods can be treated and become part of new goods.

Recover: Extract energy from materials through incineration, typically used as a last resort when reuse or recycling is not feasible.

3 Circular strategies in brick masonry

This chapter outlines strategies for implementing circular management in brick masonry, both during the use phase and after demolition. In accordance with the circular economy and the 9R framework, preserving and extending the lifespan of existing masonry should be prioritized over demolition and material replacement. However, in cases of urban redevelopment, functional change, or structural deterioration, demolition may become unavoidable. When this occurs, post-demolition strategies should focus on retaining as much material value as possible.

3.1 Preserving existing brick masonry

While the main focus of this thesis is on reuse strategies following demolition, it is essential to emphasize that maintaining existing brick masonry aligns more closely with the upper tiers of the 9R framework. Brick is inherently durable, often lasting over a century with minimal maintenance, and plays a significant role both functionally and culturally in the built environment. Preservation not only reduces environmental impact but also conserves the aesthetic and historical integrity of buildings. Several key methods can prolong the service life of brick façades:

- Cleaning contributes to both aesthetic appeal and technical performance. Dirt, algae, and mold not only degrade appearance but also increase moisture retention, which can accelerate damage to the masonry. Cleaning can delay the need for more extensive maintenance and is especially useful in revealing hidden defects during inspection. Methods include abrasive, chemical, and water-based cleaning. Care must be taken to avoid surface damage, particularly for historic façades (Kahangi, 2024). Due to quality requirements and the risk of damage, especially to cultural heritage façades, cleaning should be carried out using the right technology and by specialists. The frequency of cleaning depends on several factors, including weather conditions, the quality of the building materials, and the proximity to natural sources of pollution (Hjälmared Ställning & Fasad AB).

- Repointing is a widely adopted strategy to maintain the integrity of clay brick façades. It involves removing eroded mortar to a depth of approximately 25 mm and applying fresh, compatible mortar. This is generally performed every 40–50 years or when signs of moisture penetration, cracking, or erosion are observed. Repointing can substantially reduce rainwater penetration and delay the onset of dampness—benefits linked to filling voids in joints and improving compaction. However, care must be taken in material compatibility and execution; inappropriate practices can accelerate deterioration or result in aesthetic mismatches (Kahangi, 2024).

- Water-repellent coatings and surface treatments (e.g., silane/siloxane creams) have shown potential in reducing water absorption. Cementitious plasters can also be effective but are generally unsuitable for historical façades due to their visual impact. The long-term performance of water-repellent treatments varies, and repeated application may be necessary. Improper application can even lead to delayed drying or water entrapment, causing more harm than good (Kahangi, 2024). Therefore, it is important to carefully consider both the condition of the building and the suitability of the treatment method before implementing it.

- By applying appropriate sealants and waterproofing, brick structures can be protected from the effects of various weather conditions, including precipitation, frost, wind, and temperature changes (Turnbull Masonry). These protective measures help prevent water from penetrating porous materials in bricks, thereby reducing the risk of moisture damage and frost cracking. Proper sealing extends the life of the structure and preserves its functional and aesthetic properties over time.

- Where bricks show signs of frost damage or spalling, replacement is typically the only viable option. In older façades built before the 1970s, corrosion of embedded reinforcement (e.g., in bed joints) is a concern. Cracked reinforcement should be removed and replaced with corrosion-resistant alternatives, such as stainless steel.

In conclusion, well-functioning maintenance methods of existing brick masonry are crucial to extending the lifespan of the structure and preserving its functional and aesthetic properties over time.

3.2 Strategies after demolition

When preservation is no longer feasible, circular strategies for post-demolition brick management become essential. In line with the 9R framework, preference should be given to high-value retention strategies like reuse and repurpose, followed by recycling. Landfilling should be considered a last resort. To contextualize the strategies, key terms are defined below:

- Demolition: The process of dismantling a structure, either fully or partially (Occupational Safety and Health Administration), through manual or mechanical means. According to Boverket (2014), even relocating a building constitutes demolition. While some demolitions are planned and controlled, others may pose significant safety and environmental challenges (Occupational Safety and Health Administration).
- Separation: Following demolition, materials need to be separated into distinct components. In brick masonry, this refers to separating intact bricks from mortar and other building elements, which is a critical step in facilitating reuse or recycling.
- Cleaning: Cleaning follows separation and involves removing surface contaminants, including dirt, cement, and mortar residues. Proper cleaning is crucial to restore the brick’s appearance and ensure functional reuse (Environ Property Services).

3.2.1 Reuse

Reuse refers to the use of a product or component again for the same function with minimal processing. In the context of brick masonry, this means salvaging intact bricks during demolition and reusing them as bricks in construction—ideally as façade bricks or load-bearing units, depending on their quality. Bricks that meet technical and aesthetic standards can be reused directly in new façades or walls. This preserves the product's original function and retains the most embedded environmental value. In some cases, minor preparation is needed, such as cleaning off mortar residues or regarding by color or size. Reuse avoids the energy-intensive processes involved in recycling or producing new bricks and thus represents one of the most preferred strategies in the circular hierarchy.

3.2.2 Repurpose

Repurpose means using a product or component for a different function than originally intended, often involving adaptation or creative redesign. In brick masonry, this includes applications where the bricks no longer function as structural or façade units but are instead used in other contexts.

Repurposed bricks might be used for landscaping (e.g., in garden paths, retaining walls, or seating), as filler material in noise barriers, or in non-loadbearing decorative elements. These applications require minimal to moderate processing and allow bricks with irregular dimensions, discoloration, or surface damage to continue contributing value in new forms.

3.2.3 Recycle

Recycling refers to the process of transforming waste materials into new raw materials for use in manufacturing. When bricks are too damaged for reuse or repurposing, they can be recycled into secondary materials. Crushed brick waste can serve multiple functions: as aggregate in concrete production, as a binder component in blended cement, or as a soil amendment to improve aeration and drainage. Moreover, recycled bricks can contribute to the manufacturing of new bricks. According to Lima et al. (2024), approximately 6% of newly produced bricks in some industrial contexts incorporate recycled material from construction and demolition waste or other sectors. Although this proportion is relatively small, it demonstrates the potential for integrating recycling practices into production lines and reducing dependency on virgin resources.

3.2.4 Landfilling and waste management

Landfilling is the least preferred option in circular material management and should be treated as a last resort. Bricks that cannot be reused, repurposed, or recycled—often due to contamination, excessive damage, or logistical constraints—are typically categorized as construction and demolition (C&D) waste and sent to landfills. While landfilling cannot be eliminated entirely, it can be minimized through:

- Improved selective demolition techniques that preserve material integrity,
- Better on-site sorting and separation practices,
- Incentives for developing regional reuse and recycling networks.

In line with circular economy goals, efforts should focus on keeping materials in circulation for as long as possible before disposal. Therefore, landfilling should be approached not as a waste endpoint but as a signal to enhance upstream strategies for resource efficiency.

4 Reuse of bricks

Compared to other materials, such as wood, brick is easier to renovate, reuse, and recycle. In the past, the brick industry has been cautious about reusing brick due to a lack of knowledge about its long-term durability and performance. However, with the growing climate and environmental challenges, the industry has taken steps forward to develop its understanding of how bricks can be used and managed at the end of their life cycle (Brick Development Association, 2020).

Reusing existing bricks reduces the demand for new production, thereby lowering energy use and associated carbon emissions. Despite the availability of newly manufactured bricks with traditional aesthetics—produced either by hand or through automated methods—reclaimed bricks are often preferred for their authentic appearance and patina. These characteristics are particularly valued in restoration projects and in designs aiming to evoke historical continuity (Brick Development Association, 2020). Thus, integrating reclaimed materials offers both environmental and architectural benefits.

In Sweden, approximately 10 million bricks are demolished each year, yet only around 2.5 million are reused, according to the interview. This indicates a significant untapped potential. Given the durability of bricks and the high energy intensity of their production—particularly due to the high-temperature firing process—there is a strong case for increasing brick reuse. To realize this potential, it is essential to identify current opportunities and address the barriers that limit reuse and recycling of bricks.

4.1 Demolition

The demolition process plays a key role in determining the feasibility and quality of brick reuse. This section presents selected demolition techniques, focusing on their working principles, advantages, and limitations when applied to brick masonry.

4.1.1 Controlled demolition using mechanical equipment

Selective demolition is a process that involves dismantling all or parts of a structure. The process is carried out with care and control in order to retain or recycle parts of the building. Demolition is divided into traditional and modern demolition. With traditional demolition, the entire building is demolished, and all materials end up as waste. However, modern demolition aims to reduce waste from building materials and increase the recycling rate by reusing materials in different types of projects (Demoleringsgruppen).

According to the Danish organization BYG-ERFA, selective demolition is divided into four stages: initial planning, detailed planning and layout of demolition, demolition work, and delivery of demolition materials. Selective demolition requires a special organization to conduct the work, which must be approved by the demolition companies. The designated party must have sufficient knowledge to ensure selective demolition and correct waste management. Continuous monitoring of work is done by the responsible party. During demolition, materials can be sorted mechanically. It is essential that environmentally hazardous substances are not mixed, as this can cause deterioration of other materials. It is essential that transportation and packaging meet high-quality standards, including cleanliness and the separation of waste from materials (BYG-ERFA, 2025).

If a building is demolished without justifiable reason, materials will be mixed, which makes recycling and reuse difficult. A common mixture of concrete, bricks, and roof tiles. In such a case, the bricks cannot be reused as façade walls but instead used as crushed or, in the worst case, reused in a façade with moisture problems. Insufficient planning for selective demolition causes a risk of loss of resources (BYG-ERFA, 2025).

Figure 1 – Figure 3 show a selective demolition of a building located in a school in Ängelholm where a large excavator is used. With the help of the excavator, walls of red brick were taken down. As can be seen, the machine is designed to remove parts of the brick wall that hold it together without completely destroying it. The demolition process was done with a certain amount of care to enable the reuse of bricks. Then, all the stones are collected for further processing, as shown in Figure 3.

Figure 1: Demolition of a school building located in Ängelholm (taken by Mohammad Kahangi)

Figure 2: Demolition of a school building located in Ängelholm (taken by Mohammad Kahangi)

Figure 3: Collection of brick parts with an excavator during demolition work in a school in Ängelholm (taken by Mohammad Kahangi)

4.1.2 Soundless chemical demolition agents (SCDAs)

Soundless chemical demolition is a demolition method that relies on a chemical reaction where SCDA slowly diffuses into the small holes in the material. The method is primarily used for concrete and stone demolition and has finally been investigated on masonry. SCDA causes cracking in the mortar without damaging or affecting the stones or bricks (Natanzi et al., 2020).

The chemical demolition method (SCDA) is a silent chemical demolition agent that slowly disperses the material using a chemical reaction. It has been proven to be safe compared to other methods, such as hammers and explosives. The method has been demonstrated to be suitable for demolishing stone and existing concrete structures near historic sites or in environmentally sensitive and populated areas, with no adverse effects (Natanzi et al., 2020).

Most SCDA are grayish, powdery, dry materials similar to Portland cement but with a higher proportion of calcium oxide (CaO). Other substances are added to the SCDA to balance the hydration process. Examples of these substances are iron oxide (Fe_2O_3), magnesium oxide (MgO), aluminum oxide (Al_2O_3), silicon (SiO_2), Portland cement, clinker materials, and calcium fluoride (CaF_2) (Natanzi et al., 2020).

A study of mortar revealed that two types of cracking occur: one associated with high stress and the other with low strength. It has been shown that cracking can start at a point where the stresses are not at their highest value but rather where the local strength is lower due to the influence of pores and microcracks. It has also been observed that drill holes with a larger diameter form cracks faster compared to the same type of stones that have drill holes with a smaller diameter and are exposed to the same temperature. The spacing between drill holes also affects the success of the demolition. Namely, if the space between drill holes is large, the demolition would be successful (Natanzi et al., 2020). Other influencing factors include wall confinement, load conditions, geometry, and the bond strength between the brick and mortar. These parameters affect the time to crack initiation, the rate of crack growth, and the final cracking pattern, all of which are important in ensuring that the bricks remain intact and reusable after demolition.

4.2 Separability of brick and mortar

One of the key challenges in reusing bricks lies in detaching the mortar without damaging the masonry unit. This is particularly challenging for buildings constructed after the 1950s, when cement-based mortars—stronger and more adhesive than lime-based ones—became more prevalent. This section presents two promising methods for separating bricks from mortar: thermal treatment (heating) and pressure wave-based separation.

4.2.1 Heating

The Ministry of the Environment in Denmark published the report *Direct reuse of bricks from masonry with strong mortars (Miljøstyrelsen, 2020)*. The report describes a method where the mortar binder is broken down by heating, which allows the bricks and mortar to be separated. During this process, different components decompose at varying temperatures. This technology works at a lower temperature compared to the production of new bricks. This means reduced energy consumption and, therefore, lower climate impact (Miljøstyrelsen, 2020). The different steps in the separation process are described in more detail below.

After demolition, the material is sorted, ensuring that highly contaminated materials, such as PCB-containing masonry, are removed (Miljøstyrelsen, 2020) and are an organic compound found in some building materials, including brick and concrete. It was widely used in construction between 1956 and 1973. Over time, PCBs can leach into the surrounding environment, causing contamination of soil and air, which poses risks to living organisms. Exposure to PCBs has been linked to negative health effects, including problems with nervous system development, immune suppression, and an increased risk of cancer (Rex et al., 2002).

The next step in the process is heating, where the bricks are first placed in a kiln. Cement-based mortar breaks down at temperatures between 400–500°C, while lime-based mortar requires higher temperatures, up to 800°C. When heated, the materials expand at different rates, creating tensions that facilitate the separation of brick and mortar. At approximately 572°C, a sudden change in the mortar occurs. At the same time, the bricks undergo a slower expansion. A conclusion can be drawn that the higher the heating temperature above 572°C, the greater the expansion of the brick and mortar. Stresses can cause cracking in the bricks, which can also affect the quality of the outer parts of recycled bricks. If the cohesive force of the mortar is poor enough due to the breakdown of cement components, the materials can move freely without being affected. This causes positive effects on the bricks, where they can be separated without creating any cracks. When heating the bricks, iron compounds in the bricks react, causing a change in the brick's color from yellow and red to gray or black (Miljøstyrelsen, 2020).

As the mortar loses its cohesion, the bricks can be easily detached. In some cases, additional cleaning may be necessary to remove any remaining mortar (Miljøstyrelsen, 2020). The removed mortar can be finely ground and reused as a raw material in new brick production. Studies show that up to 5% of finely crushed brick from demolition can replace sand in the production of new bricks without compromising their quality. Based on tests according to the Miljøministeriet report, during the hydration phase of the cement's decomposition, it reacts with the air and absorbs moisture from the mortar after heating. This causes further expansion in the material, which facilitates separation (Miljøstyrelsen, 2020).

Heating the mortar enables the recycling of bricks from buildings constructed after 1955, where strong cement-based mortar was commonly used. This process results in a lower environmental impact compared to producing new bricks. Additionally, it helps reduce construction waste by making both bricks and mortar reusable (Miljøstyrelsen, 2020).

Despite its benefits, this method also has its disadvantages: bricks may crack at high temperatures, with damage starting at 550°C and all bricks exhibiting damage by 700°C. Although the energy demand for this process is lower than that of new brick production, it remains significant. Further technical development is required to improve the efficiency and practicality of this method (Miljøstyrelsen, 2020).

4.2.2 Pressure waves

Pressure waves are a process that occurs in water. During the process, waves are formed that are exposed to a pressure that is higher than the cohesive strength of the water. The strength of the pressure for the liquid depends on several factors, such as tensile strength and the amount of liquid. When the tensile strength is exceeded, rupture occurs, which weakens and reduces the pressure. At low pressure, the molecules in the water are exposed to tensile stresses, which means larger gaps between the molecules. The molecules can separate at low pressures, and this depends on the properties of the liquid and its impurities. On the other hand, at high pressure, compression occurs within the water molecules, forming a denser space between them. The compression process is called cavitation (Gregory, 2005). Below is a description of how cavitation works and how this process enables separation between brick and mortar.

The cavitation process occurs through various sub-processes. First, a cavity is formed on the surface of a certain object around the dirt by the action of cavitation. In the next step, water flows at high speed to fill the forming cavity. Furthermore, when the cavity is closed, the force of the water acting on the object and the dirt breaks the adhesion between them. It has been shown that with the help of the cavitation process, solid metal can be broken down, which means that the process has enough energy to separate the mortar from the bricks. The mortar and bricks are filled with pores and air cavities, and at the contact surface between the mortar and the bricks, there are larger amounts of air cavities. If the air cavities were filled with water, it could cause cavitation along the joint between the brick and the mortar. This leads to the bond between the bricks and the mortar to weaken. This means that for cavitation to be considered part of the separation, it would have to occur at the contact surface between the bricks and the mortar. The cavitation process is prevented at the interface; this is because the bricks are not sufficiently saturated. The separation can take place in the ultrasonic bath instead (Gregory, 2005).

In the ultrasonic bath, the bricks and mortar will vibrate at their own natural frequencies. Since bricks and mortar have different properties, they will exhibit different results at the natural frequencies. This causes stresses and pressures at the interface between the bricks and mortar, which leads to separation (Gregory, 2005).

Moreover, the bricks were identified as rough or smooth, where the same brick could have different sides. The rough sides could be set against the mortar. A time of 15 minutes is set for the separation process to occur. The failure of some of the couplets to separate in fifteen minutes is a potential problem, although this only occurs when a strong mortar is used in combination with rough bricks and/or mortar joints with a lip profile (Gregory, 2005).

A conclusion that can be drawn from investigations from the report *Separation of bricks and mortar using pressure waves*, separation of the mortar with pressure waves method is associated with the strength of the mortar. The strength, however, is proportional to the time required for the sparging process to be carried out. But even if couplets had mortar with lip edges, it would take longer to separate and clean in an ultrasonic bath (Gregory, 2005).

4.3 Cleaning techniques

Brick cleaning can be carried out both on-site and in larger facilities, depending on project conditions and available resources. The different cleaning methods are presented: friction and raking on a net steel mesh, chisel + hammer, angle grinder, and saw cutting.

In companies such as Brukspecialisten or Gamle Mursten, brick cleaning involves both manual and mechanical work. For instance, workers sort bricks and sometimes use tools like hammers and chisels to remove mortar.

The first step in cleaning is to sort the bricks according to their condition and remove the damaged or defective ones. Tools such as a trowel, hammer, chisel, and wire brush are then used to remove the mortar from the bricks. A hammer is used to loosen larger pieces of mortar, while a trowel and chisel help to remove smaller fragments. In some cases, an angle grinder with a specially adapted disc is used to facilitate the process (Trafik- og Byggestyrelsen, 2015).

After most of the mortar has been removed, any residue is polished off, and the cleaned bricks are stacked on pallets for transport or storage. It is estimated that two workers can clean approximately 250 bricks per hour. This method allows up to 70% of the bricks to be recycled, with approximately 30% being lost during the cleaning process. Manual handling, when done with the right technique and safety measures, helps preserve the original character and historical value of the bricks (Trafik- og Byggestyrelsen, 2015).

Cleaning in large facilities such as Brukspecialisten or Gamle Mursten enables more efficient processing due to the availability of purpose-built equipment and optimized workflows. According to (Trafik- og Byggestyrelsen, 2015), the process consists of several steps:

1. Initial Preparation: Before cleaning begins, any loose or non-adherent material is removed.
2. Friction-Based Cleaning: The bricks are placed on a roller conveyor and fed into a rotating system that removes mortar through friction.
3. Quality Control: After cleaning, a sensor-based inspection system identifies and sorts out damaged bricks.
4. Storage and Packaging: Undamaged bricks proceed to palletizing and storage for future use.

Facilities can process approximately 18,000 bricks per day, achieving a 63% recycling rate (Trafik- og Byggestyrelsen, 2015). However, facility-based operations also require transportation of the reclaimed bricks, which must be considered in terms of extra costs.

Cleaning methods such as saw cutting, chisel hammering, and angle grinding can be performed both on-site and at the facilities. On-site operations eliminate the need for transportation but require necessary equipment to be available at the location or the use of manual techniques. In contrast, facilities offer greater efficiency and better control over the cleaning environment, though at the cost of transportation and setup.

Each cleaning method has advantages and disadvantages depending on the chosen setting and tools. Manual techniques offer a high level of control and minimal environmental impact in terms of emissions but are labor-intensive and time-consuming. Mechanized systems increase efficiency but require higher investment and may have environmental implications, such as dust, noise, and emissions from heavy machinery, which can negatively affect both the surrounding environment and human health. However, these systems can enhance workplace safety by enabling workers to maintain a safe distance from falling materials and other hazards (Perfect Contracting, 2023).

The suitability of each brick-cleaning method depends on several factors, such as the condition of the mortar, the scale of the project, site accessibility, and structural considerations. For example, cement mortar is typically harder to remove manually due to its strength. In such cases, manual cleaning on-site may not be feasible. However, when the cleaning is done at specialized facilities, such as Brukspecialisten, reclaimed bricks can be transported there and processed more efficiently. These facilities are equipped with machinery that facilitates brick cleaning and reduces the amount of manual labor required.

4.3.1 Friction and raking on a net steel mesh

By friction and raking on steel mesh, the bricks can be cleaned manually. The brick is placed on a steel mesh, which serves as a friction base, as shown in Figure 4. The brick is rubbed against the mesh to remove mortar or dirt present on the brick, as shown in Figure 5. The method is cheap, simple, safe, and environmentally friendly. The disadvantage of the method is that it is labor-intensive and time-consuming.

Figure 4: Cleaning of the brick friction and raking on steel mesh (taken by Rasmus Stenholt-Jacobsen)

Figure 5: Cleaning of the brick by friction and raking on steel mesh (taken by Rasmus Stenholt-Jacobsen)

4.3.2 Chisel + hammer

Using a chisel and hammer, the mortar can be cleaned from the bricks. As shown in the Figure 6 – Figure 9, cleaning is done manually with a chisel. This cleaning method works for different types of bricks and is done with care to avoid damaging the bricks during cleaning.

Figure 6: Cleaning of the bricks by chisel technique (taken by Rasmus Stenholt-Jacobsen)

Figure 7: The bricks after cleaning with a chisel (taken by Rasmus Stenholt-Jacobsen)

Using a chisel, the bricks that are bonded together can also be separated. First, the bricks are separated from each other and then the mortar is separated from the bricks, see Figure 8 – Figure 9 below.

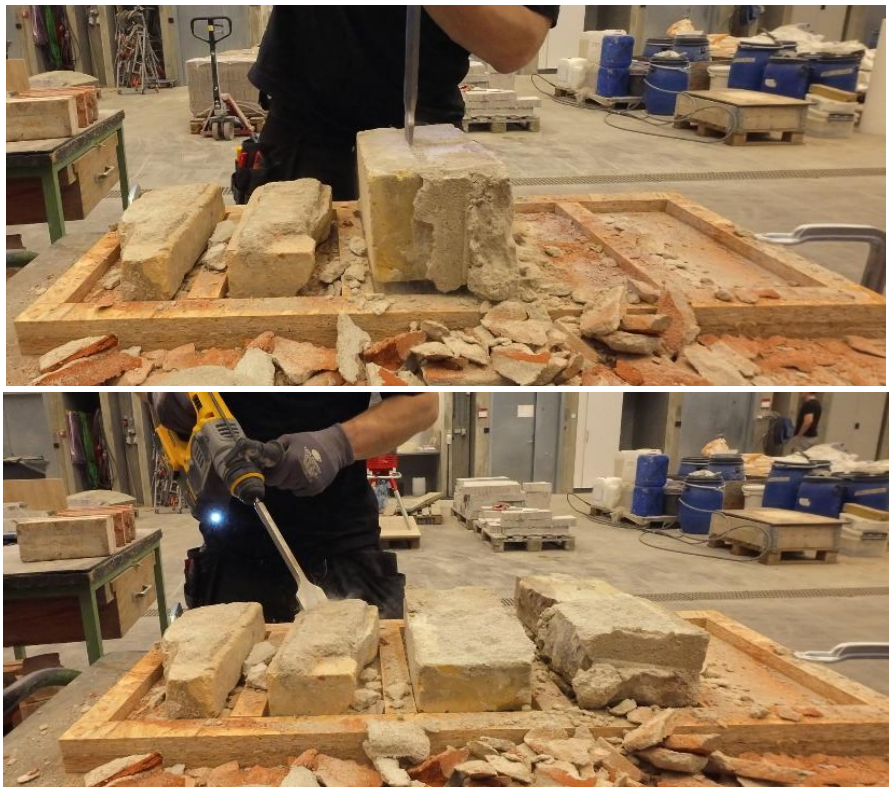

Figure 8: Separating and cleaning bricks with a chisel (taken by Rasmus Stenholt-Jacobsen)

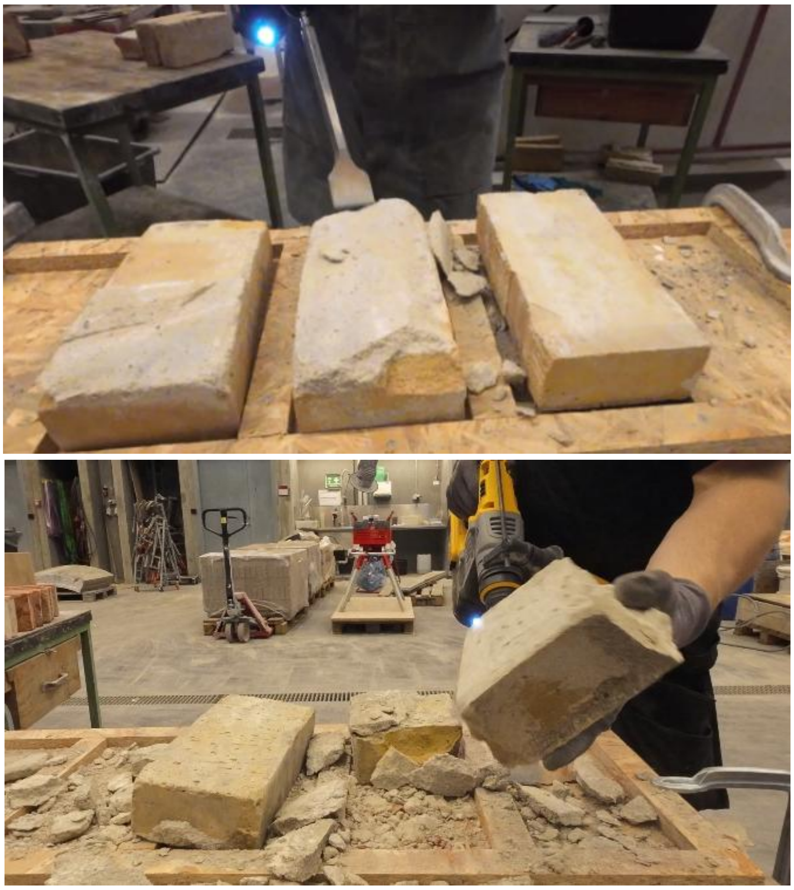

Figure 9: Cleaning of the bricks by chisel technique (taken by Rasmus Stenholt-Jacobsen)

A hammer and chisel are used to clean the bricks from the mortar manually. This cleaning technique is slow and requires great care to keep the bricks intact, see Figure 10.

Figure 10: Cleaning of the brick by chisel hammers (taken by Rasmus Stenholt-Jacobsen)

4.3.3 Angle grinder

The angle grinder is a tool that can be used to remove mortar from bricks. It is a simple tool and is easy to move to different places. The angle grinder is also a manual tool, which means it takes time and requires work. You can see in Figure 11 below that much dust is formed. It also creates noise, and there is a risk of grinding too much of the brick, which means reducing its size. This technique can be used for different types of bricks, as shown in Figure 11.

Figure 11: Cleaning of the bricks by angle grinder technique (taken by Rasmus Stenholt-Jacobsen)

4.3.4 Saw cutting

Saw cutting is an effective method for separating solid materials in construction and demolition. There are two common types of saw cutting, which are diamond saw and bench saw. The bench saw features a bench that holds the object to be cut, making it suitable for small and medium-sized objects. The motor speed is 3000 rpm. A diamond saw is more suitable for large objects; however, test results have shown that it is not effective for brick, as it is difficult to hold the brick securely when using water to suppress dust (Zhou et al., 2020). Figure 12 below shows how the Bench Saw works for cleaning bricks with water to suppress dust.

Figure 12: Cleaning of the brick by saw cutting with water (taken by Rasmus Stenholt-Jacobsen)

4.4 Characterization of reclaimed bricks

Before recycled bricks can be used in new construction projects, it is important to check their properties. This is done to assess its durability and ensure that it meets today's requirements. The following section describes the most important properties that assess whether a brick is suitable for reuse or not. In Sweden, commonly tested parameters include compressive strength, density, net density, water absorption, and frost resistance.

Compressive strength refers to the ability of bricks to resist compression forces, which is a factor that assesses the load-bearing capacity of a brick wall. The compressive strength of bricks is measured with a compressive strength test (UltraTech Cement).

Density and net density show how hard the brick is fired. This means the higher the temperature the brick is exposed to, the higher its density.

Water absorption indicates how much water can be absorbed by bricks per minute. Bricks with a low absorption rate are suitable for structural construction, as they are less likely to crack or break if exposed to water (UltraTech Cement).

Frost resistance indicates the brick's ability to resist damage from freezing; this is estimated by measuring the amount of water that penetrates the pores that can freeze and expand.

According to European guidelines, several test methods are recommended to assess the mechanical, physical, and durability-related properties of recycled bricks. Test methods serve as a basis for declaring the properties of the product and checking whether they meet the CE marking. According to European assessment document (2017), a compilation of test methods and their standards is followed:

- Reaction to fire
  Tested according to EN 13501-1 and classified according to EC Delegated Regulation 2016/364/EU.
- Dimensions
  Measured according to EN 772-16, where the external dimensions (length, width, height) are measured to the nearest 0.1 mm, 0.2 mm, or 0.5 mm, depending on the tolerance.
- Compressive strength
  Measured according to EN 772-1 after a specific procedure with dried and conditioned samples. Statistical assessment of 50% fraction at 95% confidence level according to CEN/TR 16886.
- Determination of volume and percentage of voids and net volume
  Determined using methods in EN 772-9 to measure volume, pore volume, and void fraction.
- Durability, including Freeze/thaw
  Freeze/thaw resistance is assessed via the boiling volume method, where the pore volume is measured.
- Initial rate and water absorption
  Measurements follow EN 772-11.
- Bond strength
  Tested according to EN 1052-5 by the "bond wrench method".

4.5 Case studies in brick reuse

This section presents examples of how reclaimed bricks have been given a second life in building projects, with a focus on façade applications. Real project cases from Sweden are introduced to highlight both the technical feasibility and aesthetic value of brick reuse in contemporary architecture.

One notable case is the project by Helsingborgshem, which actively promoted the reuse of various construction materials, including railings, bricks, concrete elements, and stainless-steel sinks. The reclaimed components were salvaged from three residential buildings constructed in the Drottninghög district between 1965 and 1975. The new development—comprising 198 homes in two blocks—reused these materials, particularly the bricks, which were sawn into panels of approximately 0.25 m² (Byggnyheter, 2021).

These panels were installed as façade cladding in the Stadskvarteret project. The integration of reclaimed bricks aimed to reduce climate impact and support circular construction practices (Byggnyheter, 2021). As shown in Figure 13, it exhibits a rich variation in color due to the combination of old and new bricks. This contrast provides a unique and visually engaging appearance.

Figure 13: The recycled bricks are used as façade bricks in the new façades in Drottninghög, Helsingborg

Another compelling example of brick reuse is the transformation of the historic distillery in Eslöv, originally constructed in 1904 as a milk powder factory under the name AB Siccator. By 1910, the facility shifted operations and became Skånsk Spritförädling AB, a distillery. In 1917, it was acquired by the state-owned AB Vin & Spritcentralen, continuing production until its closure in 1957. Between 1957 and 2005, the premises served various functions, including use as a warehouse, nightclub, and film location (Eslövs kommun).

In 2013, the property was acquired by Eslövs Bostads AB, which initiated an extensive renovation project to repurpose the industrial complex into rental housing. The redevelopment includes 55 apartments, 45 garage spaces, and approximately 1300 m² of commercial space. A central objective of the project was to preserve the original architectural character of the building by maintaining its industrial identity while incorporating modern materials and sustainable solutions (Eslövs kommun, 2024).

As seen in Figure 14, the façade has been reconstructed using a combination of reused and newly manufactured bricks. This blending of old and new materials supports environmental goals while also retaining historical aesthetics.

Figure 14: Façades built with a mix of new and recycled bricks in Spritfabriken in Eslöv (taken by Mohammad Kahangi)

4.6 Environmental and energy savings through brick reuse

Brick production is a resource- and energy-intensive process that significantly contributes to environmental impact, primarily due to the high energy consumption during firing and associated greenhouse gas emissions. This section presents data from environmental product declarations and other sources to evaluate the energy use and environmental footprint of brick production. It also assesses the potential savings—both in energy and emissions—that can be achieved through increased reuse of reclaimed bricks.

The analysis focuses on Sweden, where the annual demand for bricks is estimated to be between 40 and 50 million units. For the calculations presented here, the annual demand is assumed to be 40 million bricks. Based on expert input, approximately 10 million bricks are currently demolished each year in Sweden.

For consistency, the assumed standard brick dimensions are 250 x 120 x 62 mm, corresponding to a weight of approximately 2.69 kg per unit (Hornbach). According to a study by the University of Borås (2023), selective demolition can preserve 70% or more of the bricks. Further, Zhou et al. (2020) report that around 85% of bricks bonded with lime-based mortar can be retained following mortar separation. As discussed in Section 4.3, subsequent cleaning processes retain approximately 70% of the bricks through manual methods and 63% through mechanical cleaning.

Figure 15 and Figure 16 illustrate the stepwise decrease in recoverable bricks throughout the reuse chain. Manual cleaning yields a higher recovery rate than mechanical methods, likely due to the greater care involved, which minimizes brick damage and improves the final yield of reusable units.

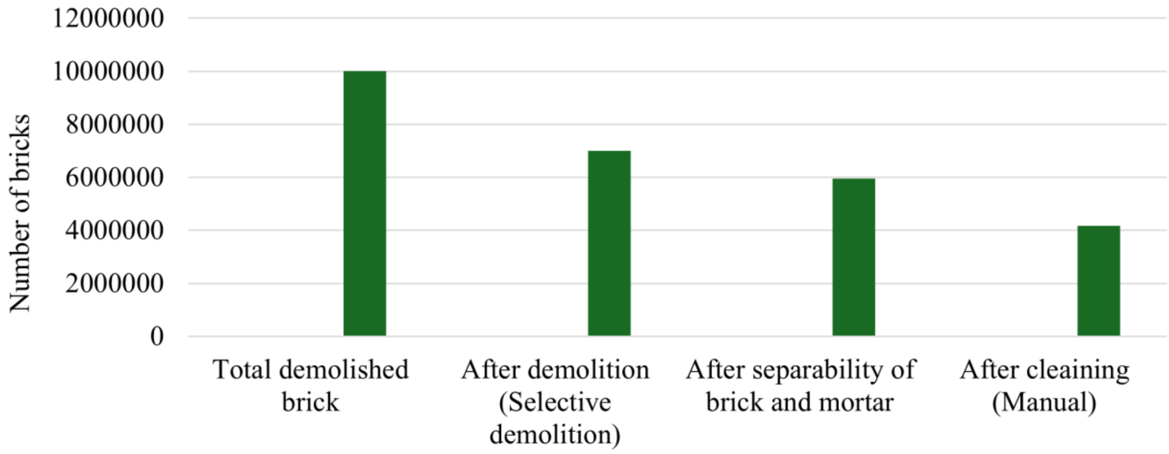

Figure 15: The diagram shows brick flow in the reuse process with selective demolition, separation, and manual cleaning.

Figure 16: The diagram shows brick flow in the reuse process with selective demolition, separation, and mechanical cleaning

Bricks require a lot of energy, especially during the production phase, based on modules (A1-A3) in the life cycle assessment, which includes raw material extraction, transport to the factory, and the production of new bricks. It is estimated that 90% of the energy is used during the firing of bricks. The energy below is calculated based on the results of the report "A Comparative

Lifecycle Impact Analysis: Assessing Global Warming Potential of Newly Manufactured and Reused Bricks for Building Construction in Sweden", which indicates that the energy required in the production phase of brick manufacturing can be sourced from either fossil fuels or electricity. According to the Swedish National Board of Housing, Building and Planning's database, the energy use for newly manufactured bricks varies in values between 3562 and 4189 MJ per ton (Set Nyi Aung & Panda, 2023).

For these calculations, the lowest value for energy was used. Since 90% of the energy is used during the firing of bricks, this means that reused bricks only need 10% of the energy that is needed to produce new bricks. In Figure 17 below, the total energy was calculated to cover the need for 40 million bricks and the energy needed for reused bricks. The value here is taken for reused bricks but with manual cleaning; see Figure 15. The third bar in the diagram represents the amount of energy required to meet the annual demand for bricks in Sweden, where reused bricks were used and the remainder were newly manufactured.

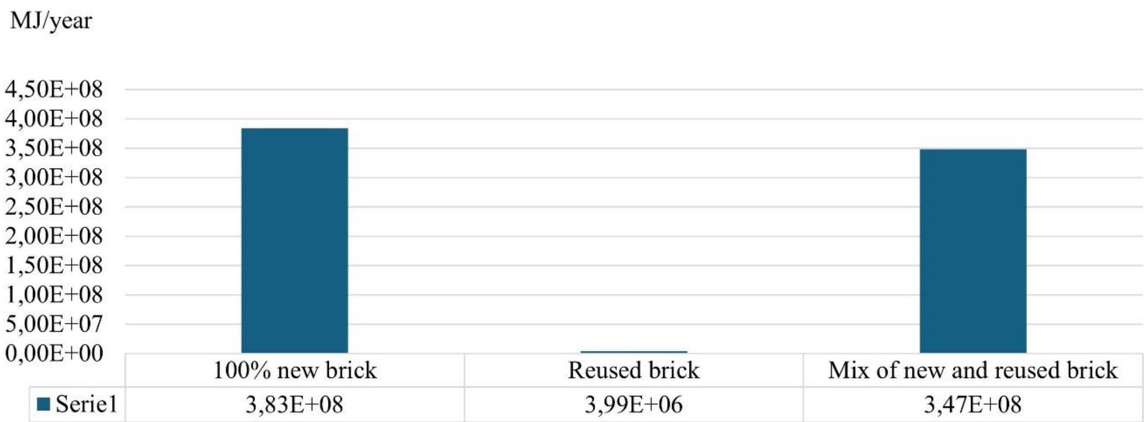

Figure 17: The diagram shows the total energy consumption for new bricks, reused bricks, and a mix of reused and newly manufactured bricks for the annual demand

Fossil fuels in the form of coal or natural gas or fuel in the form of electricity cause climate impact in the form of global warming potential (GWP) expressed in the unit kg carbon dioxide equivalents CO_2 eq per ton of brick. When using fossil fuels such as coal and natural gas (A1-A3), the GWP amounted to 220 kg CO_2 eq per ton of brick, whereas production with electricity alone yielded a lower value, approximately 110 kg CO_2 eq per ton of brick (Set Nyi Aung & Panda, 2023). By reusing bricks, up to 96% of the climate impact is saved compared to newly manufactured bricks (Brukspecialisten). This means that reclaimed bricks contribute to only 4% of the climate impact that newly manufactured bricks induce. Figure 18 shows the GWP for newly manufactured, recycled, and new mixed with recycled bricks.

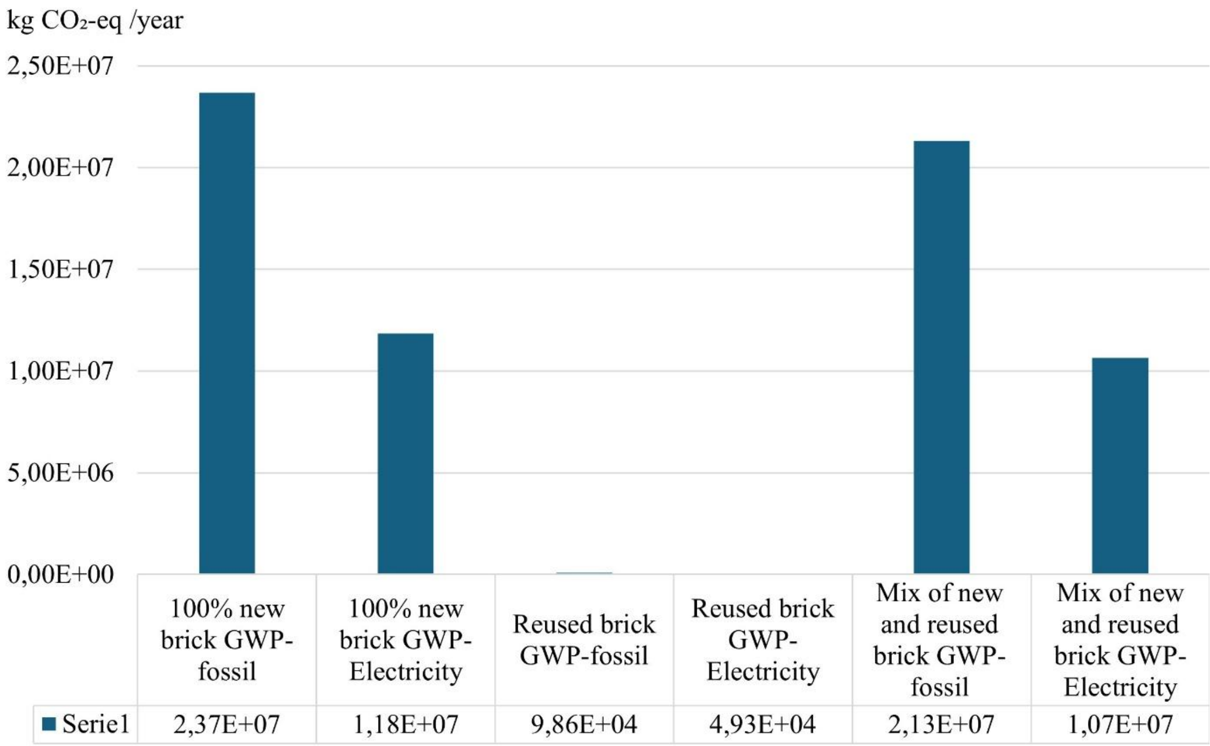

Figure 18*: GWP for the annual brick demand, comparing the use of fossil fuels and electricity in stages (A1–A3) for new bricks, reused bricks, and a combination of both*

When reused bricks have been damaged or crushed and cannot be used as façade bricks, brick scraps can instead be crushed into smaller pieces of varying sizes, which can be applied in various applications. Crushed bricks can be repurposed in concrete as aggregate in the form of coarse or fine aggregates. Brick scraps that have been turned into powder can be repurposed as a replacement material for cement in concrete.

A study investigated the potential use of crushed bricks as aggregates in concrete in the form of coarse or fine aggregates. The study has investigated the possibility of replacing up to 25% of the coarse and 50% of the fine aggregates with crushed bricks without impairing the properties of the concrete. With this distribution of crushed brick residues, the compressive strength of the concrete can be preserved as its natural value. However, at a higher degree of replacement, the strength can be reduced enormously; this is because the brick aggregates are more porous and less strong than natural aggregates. Concrete with brick aggregates shows increased capillary absorption and water permeability, which can reduce its durability. By incorporating these additives into the concrete mixture, water absorption is reduced, thereby improving the concrete's properties (Debieb & Kenai, 2008).

In the study "*Effectiveness of replacing cement partially with waste brick powder in mortar*," they investigated different mixtures with 10% to 50% of the cement replaced with brick powder. The results showed that replacing cement with brick powder by 15–20% can improve cement properties without negative effects. Replacing 20% of cement with brick powder causes several benefits for the properties of the mortar. The strength of the mortar is improved due to the smaller particle size of the brick powder, which creates a denser microstructure in the mixture, resulting in increased compressive and flexural strength. The ability of the mortar to absorb water was reduced, which improves strength and durability, especially in environments with high humidity. Replacing 20% of cement with recycled brick powder reduces the need for cement, which is beneficial from both a cost and environmental point of view, as it reduces CO_2 emissions and waste that would otherwise end up in landfills (Mansoor et al., 2024).

In Figure 19, the Global Warming Potential (GWP) was examined when using one ton of cement in concrete, and when replacing it with 20% recycled brick. The value was then calculated for a cement mixture with 80% regular cement and 20% brick powder. According to previous information from the FMIN30 course, the climate impact is approximately 100 kg CO_2-eq per ton of cement. It is assumed, as in previous calculations for GWP, that fossil fuels are used at a rate of 220 kg CO_2 e per ton of brick and that the energy savings correspond to 96% of the climate impact compared to newly manufactured brick.

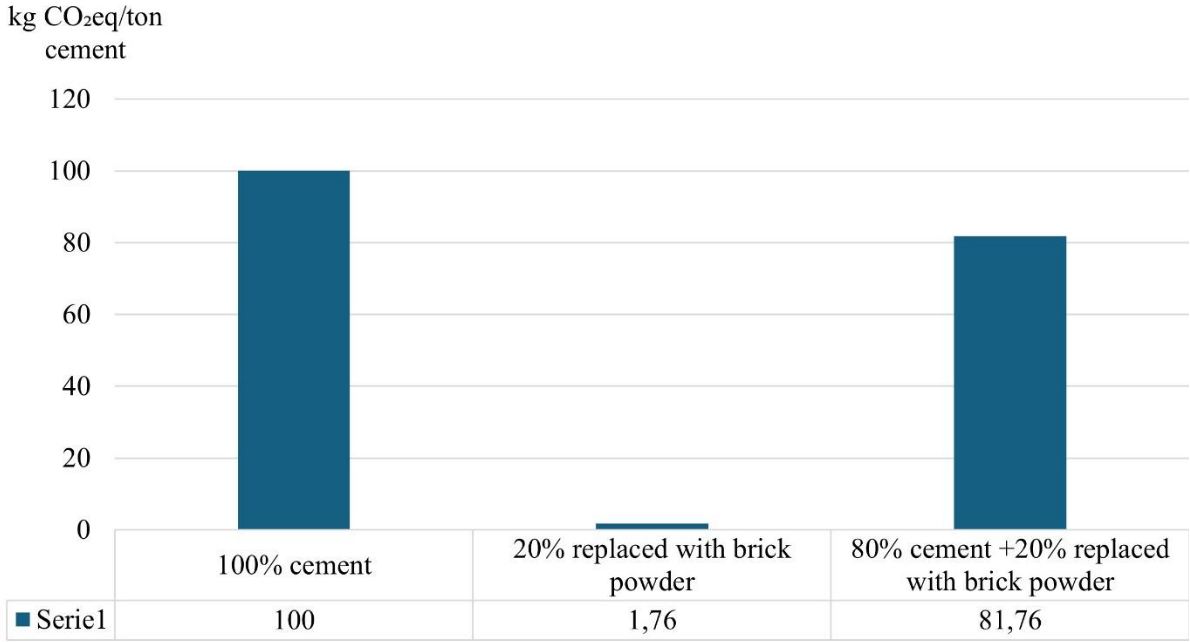

Figure 19: GWP for one ton of cement, compared to replacing 20% of the cement with replaced brick powder and a mix of both

5 Future research and development needs

Despite growing interest in the reuse of building materials, several challenges remain in maintaining bricks as a sustainable resource and advancing circular construction. Achieving widespread and reliable reuse requires further research and development in areas such as material characterization, demolition techniques, and design strategies. This chapter outlines key areas where progress is needed to enhance the reuse of bricks and promote a safe, efficient, and sustainable construction sector.

5.1 Pre-demolition characterization and grading of bricks

Effective reuse of bricks begins with reliable pre-demolition assessment. This involves evaluating the condition and performance potential of bricks while they are still in situ, ensuring that only materials with sufficient durability and quality are selected for reuse.

In practice, initial inspections are often visual and rely on indicators such as surface conditions, exposure history, and microclimate effects. However, visual inspections alone may not provide sufficient accuracy, especially for bricks subjected to long-term environmental stresses. Some bricks may fail during post-demolition testing, even if they could have remained serviceable in their original location. To address this, quality assurance procedures often adopt conservative safety margins, which may result in the unnecessary rejection of otherwise viable bricks.

Currently, key properties such as compressive strength, porosity, and water absorption are tested by third-party laboratories, such as Brukspecialisten, to determine the reusability of bricks. However, these tests are destructive, time-consuming, and costly, making them less suitable for large-scale applications or early-stage assessments.

To overcome these limitations, current initiatives aim to develop harmonized criteria for assessing reused bricks and to explore the potential of non-destructive testing (NDT) methods for in situ evaluation. Integrating NDT into pre-demolition assessments would enable faster, less invasive, and more cost-effective brick characterization, thereby increasing confidence in the reuse of these materials. Establishing standardized, reliable grading methods based on such techniques would not only improve material recovery but also contribute to climate mitigation and resource efficiency by reducing the demand for newly produced bricks.

5.2 Controlled demolition for enhanced brick recovery

Careful and controlled demolition plays a critical role in maximizing the recovery of whole, reusable bricks. According to Lima et al. (2024), recovery rates can increase from 25–30% in conventional demolition practices to 80–85% through improved handling and technique.

Selective demolition can be improved by detailed planning of the work process. A slower demolition pace increases the recovery rate of bricks. Additionally, equipping excavators with a softer material—such as rubber—on the tips of the grapple arms can help protect the bricks. This soft covering, which fits snugly over the grapple, reduces the risk of damaging or disintegrating the bricks during handling.

Despite its potential, limited data is available on the performance of soundless chemical demolition agents (SCDA) in masonry applications. This lack of comprehensive studies makes it difficult to assess the efficiency and recovery rate of SCDA-based methods. Without such data, it is challenging to evaluate the method's environmental benefits or compare it with conventional techniques. Future research should, therefore, focus on quantifying SCDA effectiveness and conducting life cycle assessments (LCA), along with the development of environmental product declarations (EPD), to better understand its role in sustainable demolition practices.

5.3 Mortar choice and design for reusability

Bricks laid with lime-based mortar are generally easier to reclaim and handle compared to those laid with cement-based mortar. This is due to the inherent properties of lime mortar, which is softer and more porous, whereas cement mortar is harder and forms a stronger bond with the brick. These characteristics make lime mortar more conducive to separation and reuse. (See Table 1 for a detailed comparison). In future construction projects, the selection of mortar type and construction technique can be strategically adapted to facilitate reuse. For instance, where technically feasible, using lime-based mortar instead of cement-based mortar may be preferred, as it simplifies the demolition process and increases the likelihood of successful brick reuse.

5.4 Knowledge gaps and innovation opportunities

One of the major barriers to increased brick reuse lies in the persistence of outdated practices within the construction industry. Despite growing evidence of the environmental benefits, a widespread perception persists that reuse is unnecessary or offers no economic advantage. In many cases, disposal is viewed as easier and more cost-effective than recycling, which leads to missed opportunities for resource conservation and emissions reduction.

Another misconception is that reused bricks are of inferior quality or more difficult to use than newly manufactured ones. However, experience from real-world construction projects has demonstrated that reused bricks can perform just as well, and their use does not compromise structural integrity or aesthetic value. As more projects incorporate reused bricks, these misunderstandings are gradually being corrected, helping to normalize reuse as a viable and reliable option.

Cost remains a significant challenge. Manual cleaning, sorting, quality control, and transportation are labor- and time-intensive tasks. Some processes cannot be conducted on-site, requiring the material to be shipped to specialized facilities, which increases logistical complexity and expenses. As a result, reused bricks often become more expensive than new ones despite their environmental advantages.

To overcome these barriers, innovation in materials science, demolition techniques, and cleaning technologies is essential. Automated cleaning systems that can identify and remove mortar without damaging the brick could drastically reduce labor demands and make the process safer and more cost-effective. Continued development in this area could significantly improve the scalability and feasibility of brick recycling in future construction projects.

6 Discussion

Brick is a durable building material with a typical lifespan exceeding over a century. Nevertheless, situations arise where entire buildings or parts of structures must be demolished. In such cases, efficient post-demolition handling of bricks becomes important, with a particular focus on demolition, separation, and cleaning methods. The proportion of bricks that can be reused or recycled depends largely on the design of the masonry and the condition of the materials, both of which significantly influence resource efficiency and the environmental footprint of the construction sector.

Results from this study indicate that up to 4.16 million bricks could be reused annually through a combination of selective demolition, mortar separation, and manual cleaning, provided that the masonry is laid with low-strength mortar (see Figure 15). In comparison, mechanical cleaning would allow for the reuse of approximately 3.75 million bricks per year (see Figure 16). The higher recovery rate associated with manual cleaning is attributed to its greater precision, which reduces the risk of damaging the bricks, albeit at a higher cost due to labor requirements. These estimates are based on extrapolated data from prior studies and reflect idealized conditions. The discrepancy between the theoretical recovery potential and the current potential of the reuse rate is attributable to several limitations. First, the percentage values used in this study are derived from a small number of case studies, which may not adequately capture the variability of construction practices across Sweden. Second, the actual recovery rates are highly dependent on multiple interacting factors, including the demolition method, the compressive strength of the mortar and brick, the bond strength between brick and mortar, the geometric configuration of the masonry (e.g., bond pattern, joint dimensions), and the specific cleaning technique employed.

Energy calculations reveal that the use of reused bricks can reduce the annual energy requirement by approximately 9.37%. This figure assumes that 4.16 million reused bricks are combined with newly produced bricks to meet Sweden's estimated annual demand of 40 million bricks. The assumed brick weight is 2.69 kg, and the energy demand for new brick production (Modules A1–A3) is estimated at 3.83×10^8 MJ/year. When reused bricks are incorporated, this drops to 3.47×10^8 MJ/year. In terms of climate impact, measured as global warming potential (GWP), the reduction is also substantial. Assuming GWP values of 2.37×10^7 kg CO_2-eq/year from fossil fuels and 1.18×10^7 kg CO_2-eq/year from electricity for new brick production, the combined scenario reduces these to 2.13×10^7 and 1.07×10^7 kg CO_2-eq/year, respectively. Notably, GWP from electricity is approximately half that of fossil fuels, suggesting that switching energy sources could further reduce emissions. Although electricity generates a significantly lower emission value than fossil fuels, it is still high. This is because the electricity used is of low quality from an environmental point of view. If electricity with better climate performance had been used, the figures would be significantly lower.

Bricks unsuitable for reuse in façades—due to damage, crushing, or pulverization—can be repurposed. Crushed bricks may be used as aggregates in concrete or even as cement replacements. In cases where brick powder replaces cement, energy savings of approximately 18.24% per ton of cement can be achieved compared to concrete produced with 100% cement.

The results for energy savings and GWP would have been different if the reuse rate had been higher. For example, if 50% of demolished bricks were reused, the energy savings and GWP would increase by approximately 12%. This means that the more reused bricks can be used, the fewer new bricks are produced, resulting in reduced energy use and a lower climate impact. Although the process itself requires energy for demolition, separation, cleaning, and transportation, these energy demands are considerably lower than those associated with the production of new bricks. This is primarily because the firing process—a high-temperature, energy-intensive step—is avoided entirely in reuse scenarios.

In addition to environmental benefits, brick reuse helps reduce construction and demolition waste, easing the burden on landfills and contributing to more sustainable resource use. These outcomes align with national and international policy goals that emphasize circularity and reduced environmental impact in the built environment. The 9R framework provides a useful lens through which to evaluate reuse from a circular economy perspective. In this hierarchy, strategies such as “Refuse” and “Reduce” rank highest in resource efficiency, with “Reuse” being a critical component that supports extended material life and minimizes resource extraction.

7 Conclusion

Reducing the carbon footprint of the construction and real estate sector—both globally and in Sweden—requires promoting circular construction, particularly by identifying strategies that facilitate the reuse of materials, such as bricks. This study demonstrates that the reuse of bricks significantly reduces both energy consumption and climate impact compared to the production of new bricks. The results show notable energy savings and a reduction in global warming potential (GWP) when reused bricks are employed, particularly in cases where brick powder replaces a portion of the cement in concrete mixtures.

Several factors influence the feasibility of reuse, including the material properties of the bricks and the techniques applied for demolition, separation, and cleaning. While the environmental benefits are evident, practical obstacles remain—particularly high costs, reliance on conventional methods, and limited awareness or misconceptions about the quality and reliability of reused bricks. To increase brick reuse, these barriers must be addressed through targeted research, education, and industry engagement. More information and case-based evidence are needed to support decision-making in the construction sector and to improve the efficiency of brick recycling.

Creating the right conditions also requires a holistic lifecycle perspective—starting from the production of new bricks. Considering reuse potential during the design and manufacturing phase can help ensure that bricks are easier to preserve and recover for future applications. Proactive planning and the adoption of reuse-friendly solutions will ultimately contribute to more resource-efficient and climate-resilient construction practices.

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