



Business models for the reuse of construction and demolition waste

Buchard, Martin Visby; Christensen, Thomas Budde

Published in: Waste Management & Research: The Journal for a Sustainable Circular Economy

DOI: 10.1177/0734242X231188023

Publication date: 2024

Document Version Peer reviewed version

Citation for published version (APA):

Buchard, M. V., & Christensen, T. B. (2024). Business models for the reuse of construction and demolition waste. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *42*(5), 359-371. https://doi.org/10.1177/0734242X231188023

General rights Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
 You may not further distribute the material or use it for any profit-making activity or commercial gain.
- · You may freely distribute the URL identifying the publication in the public portal.

Take down policy

If you believe that this document breaches copyright please contact rucforsk@kb.dk providing details, and we will remove access to the work immediately and investigate your claim.

Full citation for this article: Buchard, Martin Visby og Thomas Budde Christensen. "Business models for the reuse of construction and demolition waste". Waste Management & Research: The Journal for a Sustainable Circular Economy. 2023. https://doi.org/10.1177/0734242X231188023

1 Business models for the reuse of construction and demolition waste

2 Martin Visby Buchard¹ and Thomas Budde Christensen¹

³ ¹Department of People and Technology, Roskilde University: Roskilde Universitet, Universitetsvej 1, Post Box 260,

- 4 4000 Roskilde, Denmark
- 5 Abstract

6 The construction sector is the largest contributor to waste in Europe. Approximately one-third of 7 all waste originates from construction and demolition. In Europe, most construction and 8 demolition waste (CDW) is recycled as backfilling and only limited amounts of construction 9 materials are reused for their original purpose. There is a current policy push by the European 10 Commission (EC), as well as several EU member states, focused on lifting waste up the European 11 waste hierarchy from recycling to reuse to help preserve resources and reduce the environmental 12 impacts of CDW, which is considered a priority waste stream. This article explores the potential and the barriers to the increased reuse of CDW and describes several business models for reuse 13 14 based around the intersection between public authorities, waste companies and private 15 companies involved in the construction and demolition sector. The article is empirically based on a 16 study of various reuse schemes operated by waste companies, municipalities and private waste 17 operators in Denmark. Using a mixed-methods approach, in which survey methods are combined with company visits and qualitative interviews, the article analyzes the potential and the barriers 18 to the creation of direct reuse schemes for CDW. Based on the findings from these, four generic 19 20 business models for the direct reuse and recycling of CDW are synthesized specifically targeting 21 the CDW fractions that are waste managed at public recycling stations. Finally, the article

discusses how market conditions, environmental issues and quality can influence emerging reuseschemes.

24 Keywords: Business models, waste, construction, demolition, recycling

25 1 Introduction

26 The demands of modern society for materials and energy, with ever-increasing consumption and 27 production, are having significant negative impacts on the global environment. Increasing 28 industrialization, urbanization, economic growth, and population growth, etc. are leading to a 29 range of environmental issues, including climate change, acidification of the ocean, loss of 30 biodiversity, land degradation and resource scarcity. According to the UN's International Resource 31 Panel (IRP), global resource consumption increased from 26.7 billion tonnes per year to 75.6 32 billion tonnes per year in the period from 1970 to 2010 (Bringezu et al., 2017). In 2005, the 33 construction industry alone used approximately 23 billion tonnes of raw materials (Haas et al., 34 2015), and construction and demolition waste (CDW) is the largest waste stream in the EU in 35 terms of mass, with 374 million tonnes generated in 2016 (EEA, 2019). Furthermore, the building 36 industry accounted for 39% of global energy and process-related greenhouse gas (GHG) emissions 37 in 2018 (GlobalABC et al., 2019). Over the last decades, the increasing implementation of energy 38 efficiency measures (e.g. in renovations) has significantly improved the environmental footprint of 39 buildings, with energy savings of 50%–90% achieved in many existing buildings worldwide (Lucon 40 et al., 2014). Moreover, many new technologies have been introduced, improving the energy 41 intensity and reducing the total energy used in heating, lighting and appliances (GlobalABC et al., 42 2019). However, while the energy efficiency of buildings has generally improved, cities worldwide

are rapidly expanding, thus increasing the demand for virgin materials and energy. Such a scenario
is not sustainable and thus there is a need to also consider material resource efficiency.

45 As a major user of resources and a major waste producer, the construction sector has a key role to play in improving material resource efficiency and there is clearly a need to rethink the current 46 47 construction and demolition practices to reduce the generation of waste and the consumption of 48 virgin resources. In this regard, extending the lifespan of buildings and introducing secondary 49 materials in new buildings and renovations are key strategies. However, the application of 50 secondary materials is not straightforward and faces a number of challenges. Nußholz et al. (2019) 51 found that access to quality secondary materials in the current industry set-up is insufficient and 52 the market is dominated by a few market actors with low incentives for cooperation. Furthermore, 53 the current waste management infrastructure and separate collection is inefficient (Kabirifar et al., 54 2020). These conditions make it difficult to increase sales and market share to promote circular 55 business cases (Nußholz et al., 2019). To fully enable business model innovation, buildings should 56 be designed for deconstruction with an aim to lower the end-of-life demolition operation costs 57 and increase the quality of the possible resource output that can be recovered (Salama, 2017). 58 This can be promoted by introducing Design for Disassembly (DfD) principles, thus rethinking the 59 practices applied for the documentation, design and construction methods used for constructing 60 buildings to facilitate their end-of-life demolition and the recovery of materials and systems, while 61 supporting better labour practices, productivity and safety (Rios et al., 2015). It is also essential 62 that the number of companies engaged in the promotion of secondary material use should be 63 increased, e.g. by improving certification schemes, or by making management plans for CDW 64 obligatory to improve the sorting, collection and treatment of such waste (Nußholz et al., 2019).

65 Selective demolition has been presented as an alternative to conventional demolition, focusing on optimizing the reuse and recycling of building materials in the demolition process (Christensen et 66 al., 2022). By the systematic deconstruction of a building, it would be possible to sort out the 67 68 resources and thereby maximize their reuse and recycling (Gálvez-Martos et al., 2018). However, 69 while this process would increase the environmental performance of the building, the economic 70 feasibility will vary depending on several factors, such as labour costs, market prices and tipping 71 fees (Ghisellini et al., 2018; Silva et al., 2017). In a comparative study of demolition methods, 72 Hoang et al. (2022) demonstrated that the higher costs for labour, machinery and hazardous 73 abatement must be accommodated by the resale value of the recovered, reused and recycled 74 materials. When a building is dismantled, waste management should focus on sorting materials 75 based on their nature and characteristics (Christensen et al., 2022). Materials should moreover be 76 categorized in different classes to match the quality requirements of aggregates and the grade of 77 application (Silva et al., 2017). The certification of recycled aggregates could be supported by 78 setting up common rules and standards for producers, thereby systematizing and improving the 79 methods for sorting and providing a measure of quality control in the production of aggregates. 80 Assuring the quality of aggregates would increase the confidence of users, and hence support a 81 maturing market for secondary materials (Gálvez-Martos et al., 2018; Silva et al., 2017). Overall, 82 there is a critical need to establish effective practices for demolition, processing, design and 83 logistics that could secure the quality, purity and traceability of materials to prepare for their 84 reintegration into the value chain through reuse or recycling (Nussholz & Milios, 2017; Wahlström 85 et al., 2020).

Therefore, the promotion of circular economic practices in construction and demolition calls for systemic innovation throughout the value chain (Ness & Xing, 2017) and collaboration among the various value chain actors. To achieve environmental and social value creation while ensuring economic benefits, such innovation needs to be embedded in proven business models. Thus, to create value for a network of stakeholders not relying on an increased flow of resources, the current business models need to be redesigned (Leising et al., 2018).

92 1.1 Sustainable business model innovation

93 A business model is a conceptual tool that illustrates how a firm does business by describing how 94 all elements of the business as a system work together, linking the firm's strategy to its activities. 95 A business model can thereby also provide feedback from every activity for managers to make 96 conscious decisions in how they operate their business (Magretta, 2002; Osterwalder et al., 2005). 97 To describe a model of a firm and its functioning, Richardson (2008) condensed the business into a 98 system with three main components: i) value proposition, which describes what the firm will 99 deliver to its targeted customers and why the customers will value the offering. In sustainable 100 business models, value proposition focuses on balancing economic, social and ecological values 101 (Boons et al., 2013); ii) value creation and delivery, which are the processes for putting the proposed offering into action. These describe and link all the activities involved in creating, 102 103 producing, selling and delivering the firm's offering. It illustrates the structure of the organization, 104 including the capabilities and resources within the firm, and moreover the key partners and 105 channels for creating and delivering value. In sustainable business models, value creation is 106 broadened out to not only focus on aspects within the firm but also on the firm as part of a larger

107 system (Boons et al., 2013) and how it can also create value in its supply chain relations and for 108 customers and the public (Lüdeke-Freund, 2010); iii) value capture, which concerns how the firm 109 can produce revenue from the value that it has created and delivered, while also considering the 110 cost structure in terms of how it can achieve a profit margin while recovering its costs. Sustainable 111 business models also require a balance in costs and revenue for all actors involved (Boons et al., 112 2013) but may challenge traditional value chain relations, e.g. by introducing concepts like 113 product-service-system (PSS) models, in which value capture is focused on delivering a service 114 rather than ownership of a product (Bocken et al., 2014).

115 According to Schaltegger et al. (2012), some firms may react to sustainability concerns by adopting 116 a defensive strategy, focusing on regulatory compliance, to protect the firm against costs and risks 117 or proactively by integrating sustainability in the firm. When addressing sustainable innovation 118 within a firm, the scope can vary from incremental optimization, like operational efficiency 119 schemes, to a fundamental shift in the purpose of the firm, thus also addressing organizational 120 change and the search for new market opportunities by creating shared value (Adams et al., 121 2016). The concept of shared value recognizes a move in defining markets from internal economic 122 incentives to societal needs. This requires internal actions, such as integrating sustainability in the 123 definition of the mission of a firm and in its decision-making, and external ones, such as taking 124 part in new forms of collaboration with stakeholders (Porter & Kramer, 2011). Furthermore, 125 Stubbs and Cocklin (2008) emphasized the importance of addressing both structural (e.g. 126 processes, structures and practices) and cultural (e.g. norms and values) attributes.

127 1.2 Circular business models for CDW

128 As a subcategory of sustainable business models (Geissdoerfer et al., 2018), circular business models embed circular economy principles in the core business strategy. Bocken et al. (2016) 129 130 proposed a typology distinguishing circular strategies that target slowing-, closing-, or narrowing 131 resource flows. Strategies that target narrowing resource flows aim at using fewer resources per 132 product, which in this paper are recognized as efficiency-targeted schemes. This type of strategy 133 usually does not imply a fundamental shift in business purpose, and thereby neither challenges 134 business as usual nor promotes radical innovation in construction and demolition. Business 135 models to slow resource loops focus on extending product use by extending the life of a product, 136 such as through PSS, refurbishment, improved durability and repair, and by encouraging 137 sufficiency and designs for long-life products. Business models for closing resource loops involve 138 activities like collecting and sourcing, establishing take-back systems, industrial symbiosis, and 139 design for cycling and reassembly. The target is to address innovation that promotes recycling and 140 thereby can secure a circular flow of resources.

As circular strategies in construction and demolition often require an implementation in multiple
phases, usually involving several stakeholders, along the project life (Nussholz & Milios, 2017), a
multi stakeholder approach is usually essential to succesfully recirculate building materials.
Furthermore, Nussholz and Milios (2017) discovered in a case study that developing new
resources and capabilities within firms is essential for circular business model innovation. To apply
circularity, they found that some firms had developed certification schemes to assure quality,
gained knowledge in reuse and recycling solutions, and had developed a new customer base and

148 supplier network to gain access to materials. They also discovered that some of firms acted 149 beyond their traditional position in the value chain, e.g. as retailers, to also operate in demolition. 150 Circular business models in construction and demolition can be embedded at various stages of a 151 building lifecycle, targeting different phases of the value chain, including i) material production, ii) 152 design, iii) constrution, iv) use and v) end-of-life (Adams et al., 2017; Wahlström et al., 2020). The 153 current practice in Europe is for most CDW to be used as backfilling (EEA, 2019). It is therefore 154 crucial for the transformation to a circular economy to develop business models that can assist the 155 looping of CDW back into the construction of new buildings rather than simply using as backfilling. 156 There exist only a few academic articles about circular business models for CDW (e.g. Nussholz & 157 Milios, 2017), and this article hopes to deepen the academic understanding of how such business 158 models can be organized. The business models presented in this paper therefore mainly represent 159 the end-of-life phase, focusing on the intersection between waste management and 160 transformation, albeit innovation in the material production phase is also partly targeted, as some 161 of the business cases seek to integrate a high amount of recycled content in material production. 162 As described in this paper, innovation in the end-of-life phase must target both demolition, waste 163 management and the transformation of resources, hence presenting the following value chain 164 (Figure 1):



183 interviews (Bryman & Bell, 2011). A pre-structured qualitative survey was thus conducted (Jansen, 184 2010) to be carried out by telephone interviews, to explore the diversity of the business model characteristics in emerging reuse schemes for CDW among the study cohort, followed up by semi-185 186 structured interviews for more in-depth discussions. 187 The study cohort comprised municipalities, public waste companies and private businesses 188 operating in Denmark, which were selected after a screening of the Danish waste sector and were 189 identified as companies and municipalities with systems for the direct reuse of CDW. Through a 190 web search, 18 companies were initially identified. Next, those with either no or too immature a 191 scheme, or who were not interested in participating in the study were excluded, leaving a total of 192 11 organizations, comprising six waste companies (owned by municipalities), three municipalities 193 and two commercial companies operating in the waste sector. An overview of the 11 respondents 194 is illustrated in Table 1.

195

Table 1 Overview of the respondents based on the type of organization.

Municipalities	Waste companies	Private companies
Albertslund	AVV	Solum
Bornholm	RenoDjurs	GenByg
Hedensted	ARWOS	
	Sønderborg Forsyning	
	ARC	
	AffaldPlus	

196

197 In the survey, a representative from each of the 11 organizations was interviewed over the

telephone and a short summary note of the interview was completed. The data from the

199 interviews were later codified and the results compiled in a table. Some of the 11 municipalities

and waste companies were additionally contacted by email afterwards and asked to clarify
potential misunderstandings and to supply additional data. The survey covered how their reuse
schemes were organized, the type of CDW covered by the scheme, the main suppliers and buyers
of the CDW, the economic transactions involved with the scheme, the quality of the CDW, the
environmental aspects associated with the handling of the CDW, and finally the capacity of the
reuse scheme. The findings from this survey were then used to synthesize four generic business
models for different modes of operation.

207 After the survey phase was completed, field visits were organized to five of the waste 208 companies/municipalities (Argo, Solum, Genbyg, AffaldPlus, and Albertslund recycling station). 209 The field visits were conducted to gain first-hand impressions of the types, quality and quantity of 210 the CDW collected and handled for reuse and the physical organization of the reuse systems. 211 Photos and notes were taken during the field visits. Also, during some of the field visits (Solum, 212 Genbyg, AffaldPlus and Albertslund recycling station), qualitative interviews were conducted with 213 key personnel involved in the direct reuse schemes. The qualitative interviews focused on 214 understanding why and how the systems had been established and what the key barriers had 215 been in terms of the legal aspects, market conditions (supply and demand), quality and 216 environmental issues, as well as more practical and organizational aspects of their established 217 business models. The research approach is summarized in Figure 2.



220 3 Current Danish Waste Management System

In Denmark, CDW accounted for approximately 40% of all waste in 2019, amounting to a total of 5

222 million tonnes (Danish Environmental Protection Agency, 2020); of which, 5% of the CDW was

deposited at landfills, 7% was incinerated, 36% was recycled and 52% was used as backfilling.

224 Although Denmark complies with the objective of the EU Waste Framework Directive

225 (2008/98/EC) by reaching at least 70% recycling by 2020, the current recycling practice implies

that the majority of CDW is downcycled and used as road base and filling material (i.e. backfilling),

instead of being reused for its original purpose in the construction of new buildings – similar

228 practices can be found in most European countries.

229 The legal Danish framework for handling CDW is based on the EU Waste Framework Directive

230 (WFD), which includes the so-called waste hierarchy, which indicates the preferred way to prevent

and handle all types of waste. The hierarchy is divided into five levels based on priority: 1)

prevention, 2) preparation for reuse, 3) recycling, 4) other recovery, including energy recovery,

and 5) disposal, including landfill.

234 For this study, it was essential to clearly distinguish between levels 2 and 3, i.e. preparation for 235 reuse and recycling. Preparation for reuse according to the WFD includes activities such as 236 checking, cleaning and doing minor repairs to construction materials to enable their reuse without 237 further processing, where reuse is defined in this context as a process in which the construction 238 material is utilized for the same purpose for which it was originally created. Recycling, as level 3, 239 includes processes where construction materials are processed into new products, materials or 240 substances that can be used for the purpose they were originally intended or for other purposes. 241 The responsibility for waste management in Denmark is split between several levels of 242 government. The national government is responsible for waste prevention, while the 98 243 municipalities in Denmark are responsible for waste management. Source-separated industrial 244 waste is liberalized in the sense that private companies, for example in construction, can choose a 245 private waste contractor to handle their CDW. The government's Executive Order on Waste (BEK 246 nr 2159 af 09/12/2020) determines that construction projects generating less than 1 tonne of 247 waste can use municipal recycling stations without the waste needing to be reported to the local 248 authority. This allows small-scale contractors in the construction sector (e.g. carpenters, 249 bricklayers and plumbing companies) to use public recycling stations, whereas large-scale 250 construction companies typically must use private contractors instead. 251 In Denmark, there are around 400 recycling stations, where citizens and private companies can 252 hand in bulky waste for recycling. The recycling stations vary in size and design and in the number 253 of fractions they handle and how they handle those waste fractions. Most of the waste managed 254 at the recycling stations is recycled, while a smaller part is incinerated, and a minor part is

deposited at landfill sites. Only very limited amounts of the waste at recycling stations are reused
(Winkler & Nyborg, 2021).

257 The quality (understood as the ability for the materials to be reused or recycled without adding 258 significant amounts of labour and energy) of these fractions varies, but it is likely that some part of 259 these waste materials will have the potential for reuse. Moving waste from recycling to reuse, 260 however, often requires different waste handling processes, including its preparation for reuse 261 (Dalhammar et al., 2021). Recently, several Danish recycling stations have established reuse 262 schemes for CDW, but so far only limited knowledge about these systems has been compiled 263 (Milios & Dalhammar, 2020; Moalem et al., 2022). The Danish government reached political 264 agreement for a plan covering also the structure of the future Danish waste management system 265 in June 2020 and as part of this, all recycling stations must implement reuse schemes (Danish 266 Government, 2020).

267 4 Results from the Survey and Interviews

The following section presents the results of the study following some general qualitative considerations from the respondents surveyed in the study. These considerations cover the collected fractions, their potential and how they are handled, as well as some reflections on how the different reuse schemes are organized. The data from the survey is summarized in Table 2.

Organization	Albertslund Municipality	RenoDjurs	ARWOS	AffaldPlus	Sønderborg Utilities	AVV	Bornholm Regional Municipality	Genbyg	Hedensted Municipality	Solum	ARC
Туре (1—4)	Swap system (1)	Swap system (1)	Retailing at waste company (2)	Retailing at waste company (2)	Retailing at waste company (2)	Retailing at waste company (2) /commercial retailer (3)	Reuse through commercial retailer (3)	Reuse through commercial retailer (3)	Reuse through commercial retailer (3)	Reuse through commercial retailer (3)	Recycling via the material's producer (4)
Waste fractions	Insulation materials, wood products, doors, roofing tiles, vapour barriers	Paving stones, doors, windows, wood products	Paving tiles, stones, wood products, sanitation, interior doors, insulation materials	Wood products, paving stones, windows, doors, sanitation, insulation materials, metal products	Wood products, windows, doors, insulation materials	Wood products, tools, paving tiles, tiles, windows, interior doors, sanitation, furniture	Wood products, bricks	Doors, windows, lamps, electrical items, wood products, flooring, tiles, paving tiles, bricks roofing tiles, sanitation	Wood products	Interim wood	Wood products, luminaires, concrete
Suppliers	Private users (primary) and SMEs (minor)	Private users (primary) and SMEs (minor)	Private users (primary) and SMEs (minor)	Private users (primary) and SMEs (minor)	Private users (primary) and SMEs (minor)	Private users (primary), SMEs (minor) and bricks from demolition contractors	Demolition contractors	Demolition contractors	Demolition contractors	Contractors	Demolition contractors
Buyers	Consumers	Consumers	Consumers	Consumers	Consumers	Consumers (bricks to business)	Businesses (start-up phase)	Consumers and SMEs (minor)	SMEs	Consumers and businesses	Businesses (internal experiment)
Organizational structure	Managed by the municipality without extra employees	Managed by RenoDjurs without extra employees	Managed by ARWOS w/ separate account and employees	Managed by AffaldPlus w/ separate account and 14 employees	Managed by SF w/ separate account and 2–3 employees	Managed by AVV w/ separate account. Social enterprise for bricks	Storage at the recycling station. Establishing value chain	Contractor managing store and webshop with 12–14 employees	Facilities and storage for entrepreneu rs managed by the municipality	Distribution and sales by retailer. Sorting and packing by Solum.	Project managed by ARC
Economy	Financed through waste fees (no sales)	Financed through waste fees (no sales)	Financed through sales. Generates savings from reduced treatment fees	Financed through sales. Generates savings from reduced treatment fees. Profit used to balance waste fees	Financed through sales	Financed through sales. Generates savings from reduced treatment fees. Profit used for new initiatives	Projects not yet commercializ ed	Free access to materials via soft stripping	Financed by the municipality and entrepreneu rs	Value capture shared between the value chain partners	Projects not yet commercializ ed
Fees	Private users: public fee. For businesses: €31/vehicle	Private users: public fee. For businesses: €27/visit	Private users: public fee. For businesses: €30/visit	Private users: public fee. For businesses: fee exemption for reuse	Private users; public fee. For businesses: €27/visit	Private users: public fee. For businesses: depends on yearly visits	not relevant	not relevant	not relevant	not relevant	not relevant
Quality	No special assessment	No special assessment	No special assessment	No special assessment	No special assessment	CE-certified bricks	Resource screening	No special assessment	No special assessment	No special assessment	Concrete class assessment
Environment	Pragmatic assessment	Pragmatic assessment	Pragmatic assessment	Pragmatic assessment	Pragmatic assessment	Pragmatic assessment	Mandatory screening	Mandatory screening	Mandatory screening	Visual screening	Mandatory screening
Capacity	Small barn allocated at the recycling station	5 open shipping containers	Small extension to secondhand store at the recycling station	1000 sqm decentralize d store	Store at the recycling station	180 sqm store at recycling station	3 shipping containers at the recycling station	6000 sqm total in store and decentralize d storage	1000 sqm facilities and storage	National retailers central storage	not relevant

274 SF: Sønderborg Forsyning; w/: with; w/o: without. SME: small and medium-sized enterprise. CE: Conformité Européenne

275 4.1 Waste fractions

276 The CDW collected by recycling stations can be divided into two main flows: 1) new and unused 277 construction materials that become waste during construction projects and 2) used construction 278 materials that typically result from demolition processes or are generated as a by-product from 279 construction or renovation processes. Construction materials submitted at the recycling stations 280 must be source separated, but the specific fractions differ between recycling stations. In 281 Copenhagen Municipality, for example, CDW for recycling must be sorted into 14 different 282 fractions (Copenhagen Municipality, 2022). 283 CDW handed in at recycling stations owned by waste companies are typically recycled at private 284 companies for the production of new materials and products. The usability and economic value of 285 the fractions vary significantly. Establishing a scheme for reuse therefore depends on which 286 fractions potential users assign value to. The respondents in the study mainly pointed to wood 287 products as the type of materials with the highest demand and value potential. Typically, wood 288 products include different types of planks, laths and plywood that originate both from 289 construction projects and demolition projects. Some recycling stations remove nails and the like 290 from wood products to increase the value of the waste, but such procedures can require 291 substantial effort and labour. Based on the survey, the following CDW materials were identified as 292 the main products that would be most likely suitable for reuse:

• Wood products

• Insulation materials

• Newer windows and interior doors

• Tiles, paving stones and bricks

• Sanitation products

The selection and prioritization of CDW fractions vary between the surveyed waste companies. For example, the reuse scheme established by AffaldPlus receives both new and used construction materials, while in Albertslund Municipality, a swap scheme (without sales) has been established, focusing mainly on unused construction materials that have been turned in as waste at the recycling station.

Most of the studied reuse schemes receive construction materials from private enterprises involved in the construction sector. Five of the surveyed systems receive CDW for reuse from larger demolitions, but in most cases, this is done on a project basis and they have not yet developed sustainable business models to cover such flows. The Solum and Genbyg cases are the only ones in the surveyed schemes where formal agreements have been made with several construction and demolition companies.

309 4.2 Organization

The surveyed reuse schemes are organized in different ways, with some using shop facilities, swap schemes or systems based on a collaboration between waste companies and private retailers and/or private material producers. Among the 11 companies surveyed, two have organized reuse schemes based on a swap system. For example, the waste company RenoDjurs has set up five shipping containers at the recycling station and designed a special area dedicated to reusing building materials, furniture and the like. Meanwhile, 4 of the 11 surveyed schemes have organized shop facilities for reuse. In this type of scheme, a shop is set up at the recycling station.

317 At the waste company AVV, a warehouse has been established to host a 180 sqm reuse shop 318 facility. Meanwhile, the waste company AffaldPlus invested in the renovation of an old 319 commercial property to host a 1,000 sqm construction market (including furniture sales and 320 workshop facilities). The property also hosts a facility for textile recycling, where textiles are 321 sorted and packed. In total, 8 of the 11 surveyed systems have established (or are in the process of 322 establishing) schemes for the reuse of construction materials handed in as waste. 323 The survey also identified some reuse schemes exclusively organized by private waste companies. 324 The private construction goods retailer Stark and the waste company Solum have entered into a 325 collaboration for the reuse of interim wood. Interim wood is used at construction sites for various 326 purposes, such as railings, shields, stairs. Often wood products come in standardized sizes and 327 quality. In this collaborative scheme, Stark organizes the transport and sales, while Solum is 328 responsible for the sorting and packaging to ensure a uniform quality. 329 The waste company Amager Resource Center (ARC) is working on several projects focused on the 330 recycling of CDW in collaboration with private material producers. These activities include projects

for the recycling of crushed concrete, where, after an environmental and quality screening

procedure, the concrete is transferred to the producer, via a waste handling company, where the

recycled concrete is treated, to then be used in the production of new concrete.

334 5 Business Models for the Direct Reuse of CDW

The previous section presented some general considerations according to the organization of different types of schemes for the direct reuse and recycling of building materials. It was concluded that these schemes can be organized in many ways. Based on the analysis of the

surveyed reuse schemes, we synthesized the findings into four generic business models for the direct reuse or recycling of construction materials. By synthesizing the data presented in Table 1 in accordance with Richardson's (2008) representation of a business model, the four generic models illustrate how the proposed value can be distributed and captured in the value chain, what resources and capabilities are needed to establish and run the business models, and what societal value can be gained through the schemes.

344 5.1 Model #1: Swap system

345 The first business model covers the direct reuse of construction and demolition materials as 346 organized at recycling stations through non-sale swap schemes. This business model is typically 347 organized as an integrated part of the conventional recycling station, as illustrated in Figure 3. It is 348 designed in such a way that users supply construction and demolition materials they consider 349 reusable and other users/customers can take the materials free of charge. This type of scheme is 350 typically financed by the municipal waste fee and does not require additional staffing. Thus, the 351 schemes can be operated by the existing staff at the recycling station. The staff guide users at the 352 recycling stations and carry out a simple quality control primarily aimed at avoiding the diffusion 353 of hazardous substances that may be in some construction materials placed in the swap system. 354 Signs at the recycling station guide users to the swap system, while the staff also encourage the 355 recycling station users with reusable construction and demolition materials to offer the materials 356 in the swap system instead of placing them in the otherwise designated recycling containers.

Figure 3 Illustration of business model #1 "Swap system", including the organizational resources, value capture, suppliers and
 buyers, and the potential societal value.

Reuse

357

360 The construction and demolition materials in this business model are typically supplied by private 361 users and smaller private companies that deliver volumes less than 1 ton, thus constituting 362 construction and demolition waste which is not subject to notification under the Danish Executive 363 Order on Waste (BEK nr 2159 af 09/12/2020). The smaller quantities of materials at these schemes 364 also mean that it is primarily the private users of the recycling stations that take construction 365 materials back that are targeted. Commercial projects require strict quality documentation in line with the Construction Product Regulation (305/2011) standards, which the organizations 366 367 operating swap schemes typically cannot provide. Thus, only a limited number of businesses can 368 use this scheme, usually for small renovations. Customized IT systems are rarely used in 369 connection with the swap schemes (ideally, such IT systems could be developed in the future), 370 although the schemes are typically communicated through social media (primarily Facebook). 371 Example of model #1: The main flow of waste is handed in for either recycling or energy recovery. 372 Operated as a side activity, materials for reuse are voluntarily placed by users in a reserved area

20

alue

373 and are sporadically assessed by the recycling station personnel - mainly for the removal of 374 suspected contaminated materials (e.g. lead in paint or polychlorinated biphenyl (PCB) in varnish 375 or grout). Thus, the personnel should receive some, even minor, training in pragmatic 376 environmental assessment. Private users have unlimited access to the recycling station included in 377 the basic waste management fee, while business users are charged approximately €30/visit. 378 Products for reuse are collected by users with no check carried out by personnel. Materials for 379 reuse are exempted the waste treatment fee for the waste company. Model #2: Retailing at the waste company 380 5.2

This type of scheme is shown in Figure 4 and has been established in connection with some recycling stations, but is primarily aimed at establishing a store for the commercial sale of construction materials. Thus, retailing waste companies operating this system require a higher degree of organization and logistics compared to the case with operating a simpler swap system (Model #1).

386 The economic costs of running the shops for the reuse of construction and demolition materials 387 are covered by the income generated from sales in the shops and therefore no waste fee is 388 included for the operation of the stores. Additional staff are typically hired specifically to operate 389 the stores, which in some cases creates social jobs. The number of additional staff varies, between 390 2–3 to 14 employees in our survey sample (Table 2), and some staff training is generally needed; 391 AffaldPlus spent €185 on training staff in 2019 (AffaldPlus, 2020). The stores are not really aimed 392 at generating profit, and any potential profit is utilized to stabilize existing waste fees or 393 reinvested in the scheme. To attract private businesses to supply CDW for reuse in the shops,

some of the systems offer 24/7 opening hours and free of charge disposal for private businesses to
encourage them to supply reusable construction and demolition materials to the shop. This
provides private companies a combined economic and practical incentive to engage with the
scheme, as the companies would otherwise have to use the fee-based, conventional recycling
option, which is also only open during office hours.



400 Figure 4. Illustration of business model #2 "Retailing at the waste company", including the organizational resources, value capture,
 401 suppliers and buyers, and the potential societal value.

399

To the waste companies that operate the recycling stations, there are additional indirect economic benefits associated with the reuse shops, as the abated recycling costs decrease. The establishment of reuse shops are in some cases also supported indirectly by the municipalities financing the buildings hosting the shops. As the sale of reusable construction materials through stores requires a higher degree of logistics compared to the swap schemes (Model #1), some of these schemes have an integrated IT system, where private companies are even offered a pick-up service for reusable materials. The primary customers in the shops are private citizens and to a lesser degree small-scale
companies in the construction sector. The fluctuating inventories and uncertainty of supply
considering also the material quality are still considered barriers to a larger scale business-tobusiness model.

413 Example of model #2: Like in model 1, the main flow of waste is handed in for recycling or energy 414 recovery. In 2019, AffaldPlus managed a total amount of approximately 194000 tonnes of waste, 415 of which 152000 tonnes were processed for recycling and 1800 tonnes were sold for reuse 416 (AffaldPlus, 2020). Operating as a store with a separate account, all products are handed in and 417 assessed by personnel for quality and pragmatically for preventing the diffusion of hazardous 418 substances before they can be placed in the store. Some materials require minor preparation for 419 reuse (e.g. the removal of nails). The separate store makes it possible for some schemes to offer 420 fee exemption to business users for reusable items and besides, the sales profit from the reused 421 materials also results in reduced treatment costs (e.g. Arwos saved approximately €90000 in 422 2019).

423 5.3 Model #3: Reuse through commercial retailers

Model 3 describes a business model where a system is established to loop targeted materials from
construction and demolition projects back into the construction sector via privately owned
retailers. The main difference between Models #2 and #3, as illustrated in Figure 5, is that Model
#2 is organized by the waste utility companies (typically owned by municipalities) and organized in
relation to the recycling stations, whereas Model #3 is operated by private retailers with no
affiliation to the recycling stations.

430 The empirical data for this article suggest there are two main approaches to establishing reuse 431 through a commercial retailer: a) a broad strategy focused on items generated from the soft-432 stripping phase of demolition projects (e.g. items taken out of buildings prior to demolition, such 433 as doors, windows, electrical equipment or sanitation) and b) a strategy focused on one specific 434 fraction. The first approach typically involves items that are considered easily marketable among 435 private consumers. This type of building materials is usually relatively difficult to include in 436 standardized quality control systems due to the large variety in design, quality and function (doors 437 and windows for example often differ in design, shape, and material composition, etc.). Businesses 438 in the construction sector therefore tend to prefer new construction products, which are covered 439 by standardized quality control systems, over these types of reused items. Value capture across 440 the value chain is secured indirectly for the demolition contractor through a cost reduction 441 associated with the soft stripping, while at the same time providing free access to materials for the 442 retailer. The retailer generates profit through sales.

				Costs	Value - Material
ective demolition - Pre-demolition	Revenue - Cost reduction				
audit (shared)				Costs - Item price	Value - Material - Branding
Preservation of re	source quality	Reuse Social jobs		Encourage suffic Use value	iency

444 Figure 5. Illustration of business model #3 "Reuse through commercial retailers", including the organizational resources, value
445 capture, suppliers and buyers, and the potential societal value.

446	The second approach is most often used in relation to a specific type of material, such as bricks,
447	construction wood or interim wood. Focusing on a specific (and simpler) material simplifies quality
448	assessment and makes it possible to apply standardized quality control systems and associated
449	labelling systems (such as CE). CE certification has, for example, been used in association with the
450	reuse of bricks. By building a quality control system (e.g. factory production control, FPC) for
451	reused bricks, it is possible to prepare an European Technical Assessment (ETA) and an European
452	Assessment Document (EAD) to describe the overall technical specifications (for example, for
453	documentation of the product's performance) for enabling them to achieve CE certification. This
454	makes it easier for private businesses in the construction sector to apply such bricks in the
455	construction of new buildings where certification is needed.

Most of the surveyed companies who market construction and demolition materials through a
commercial retailer do not screen for environmentally hazardous substances themselves, but use
data from the legal statutory environmental screening conducted during pre-demolition.

459 Example of model #3 based on the flow of bricks: In the second approach, to preserve the quality 460 of materials during demolition, the contractor performs a pre-demolition audit identifying the 461 quantities, qualities and possible hazardous substances prior to a selective demolition (European 462 Commision, 2016). Hoang et al. (2022) identified the combined cost for labour and machinery for 463 dismantling such materials with a sorter grab to be approximately \$10/tonne more than in a 464 conventional demolition process; however, the potential resale value increases by almost the 465 same amount - some materials even have a potential profit factor of two times, e.g. bricks 466 (Christensen et al., 2022). To ensure quality, the bricks are manually cleansed for removing excess 467 mortar and assessed at an ETA approved facility for CE certification before they can be sold at the 468 store.

469 5.4 Model #4: Recycling via the material producers

The fourth business model targets the large quantities of construction materials generated from
demolition projects (such as steel or concrete) that are typically unsuited for direct reuse.
Covering recycling processes (as opposed to Model #3 that covers reuse processes), this business
model focuses on demolition materials that can be recirculated back into new constructions
through a private material producer, such as a concrete producer. To ensure quality in this type of
business model, it is imperative that a proven practice is established, including well-defined
workflows for selective demolition. This process can be strengthened and secured through

477 certification. In a report from the Danish Environmental Protection Agency, Dansk Byggeri's
478 Demolition Section suggests that an ISO 9001 certification can support quality management in
479 relation to selective demolition (Golder Associates A/S et al., 2017). High quality in recycling
480 processes may, however, not always be achieved and recycling processes therefore need to be
481 evaluated and differentiated according to the end-use requirements.



Figure 6. Illustration of business model #4 :Recycling via the material producers", including the organizational resources, value
 capture, suppliers and buyers, and the potential societal value.

485	The flow of materials and logistics can be organized in several ways, e.g. off-site through
486	stationary recycling stations or mobile stations operated onsite. On a general level, Silva et al.
487	(2017) found that stationary recycling stations tend to ensure the highest quality. However, the
488	stationary recycling of, for example, concrete often implies more transportation, making it more
489	complicated to ensure and guarantee the quality when the concrete is moved and more partners
490	are involved at several sites. For this type of business model, it is crucial to secure close
491	collaboration between the actors, as illustrated in Figure 6, and so value capture as well as risk
492	management must be clearly negotiated. This can be organized through forming a consortium

493 between the contractor, treatment company and manufacturer in the tender offer. The business 494 represented in Figure 6 is in this case the construction client. Considering the case of the flow of 495 concrete: Like in model #3, the concrete is first demolished and crushed either on site or at a 496 facility, screened for soil and then separated into fractions by grain size to secure clean aggregate 497 fractions for application (fine grain for sand aggregates and coarse for stone and gravel). The 498 concrete is assessed to provide a performance declaration for CE certification based on drill tests 499 prior to demolition, aggregate tests prior to manufacturing and sample tests after manufacturing 500 (Kellermann et al., 2021). The recycled concrete must be purchased before manufacturing and 501 matched for the right type of application in terms of the quality. Thus, the recycling of concrete is 502 still performed on a project-to-project basis.

503 6 Discussion

As presented in the four business models, several factors must be addressed to successfully operate the reuse and recycling schemes, including the development of new organizational resources. To further scale circular business models for CDW, it is crucial to engage the supply and demand conditions, quality assurance and control of hazardous substances. These factors are discussed in the following.

509 6.1 Market conditions: supply and demand

510 CDW for reuse covers many different categories and inventories at the reuse schemes, with 511 significant fluctuations. The goods in the reuse markets can therefore change, and the reuse shops 512 are thus unable to offer the same stability as conventional construction markets. These 513 fluctuations in supply make the reuse schemes in their present form less attractive to commercial

514 buyers. The majority of the surveyed reuse schemes are owned and operated by municipalities. 515 They are not allowed to earn a profit but only aim to cover the costs to operate the scheme; 516 hence, the fluctuating flows of different construction and demolition materials are not considered 517 an economic barrier to operate such a scheme. However, based on the data from the survey, it 518 can be concluded that the fluctuating flow of materials has a negative influence on the shops 519 ability to attract commercial customers, who would prefer conventional construction markets with 520 more stable supply and inventories. Thus, to increase B2B sales, it is necessary to establish a more 521 stable flow of construction materials, as private companies will otherwise not find it worth their 522 effort to drive to the reuse shops at the recycling stations. In addition, a web-based marketing 523 system would likely create a better overview of the assortment available, and create more security 524 for business customers according to the availability of goods.

525 Some of the waste companies have implemented a fee exemption for business customers at the 526 recycling stations to encourage them to use the reuse scheme instead of the recycling scheme. 527 This economic carrot is intended to discourage companies from throwing CDW in large containers 528 and instead encourage them to use the slightly more labour-intensive reuse scheme. However, 529 this type of reuse scheme requires additional staffing at the recycling stations to manage the 530 incoming materials. The waste company RenoDjurs operates a swap scheme and points out that 531 fee exemption can risk compromising the quality of the materials submitted in the reuse scheme, 532 since companies will have an incentive to hand in all materials regardless of its quality. The study 533 therefore finds that fee exemption is best paired with a business model based on commercial 534 retailing, since this model can generate income, which can pay for additional staff to monitor and 535 select materials for the reuse scheme based on quality.

536 6.2 Quality assurance

537 Of the 11 surveyed schemes, 8 responded that they performed no special quality assessment of 538 the construction materials, and that it is up to the customers themselves to assess the quality of 539 the materials. Quality assurance is to an extent less vital for private citizens, but this is considered 540 critical for the sale of used building materials to commercial customers. As Gálvez-Martosa et al. 541 (2018) points out, quality assessment and the classification of materials is a factor that can 542 increase the confidence in used building materials, by creating transparency and providing the 543 possibility for them to comply with market standards. Professionals are obligated to comply with 544 the standards laid down in the Construction Product Regulation (305/2011), hence quality 545 assurance creates an incentive for the industry to utilize reuse schemes. Bornholm's Regional 546 Municipality has established systems for the quality screening of building materials, as their 547 project aims to establish a value chain based on commercial customers; however, the municipality 548 does not guarantee the quality of the reused construction materials in strictly legal terms. 549 To establish a market for secondary materials, it is important to address the risks in legally 550 guaranteeing material quality. This requires new agreements between the value chain actors, 551 preferably early on in the process, specifically in terms of who guarantees the material quality 552 (supported by CE certification) and how the risks are shared (Lauritzen, 2018; Wahlström et al., 553 2020).

554 6.3 Environmentally hazardous substances

A wide variety of construction materials contain environmentally hazardous substances, such as
PCBs, asbestos, chlorine paraffins, lead and other metals. Materials considered a risk are

separated from the other reused materials at the recycling stations to avoid the diffusion of
environmentally hazardous substances. At most of the surveyed schemes that include recycling
stations, the environmental assessment is based on a pragmatic assessment performed by an
employee at the recycling station.

561 Formal environmental screening for hazardous substances is exclusively carried out in cases where 562 the material supply comes from demolition projects, as environmental screening is mandatory in 563 that case. For example, Bornholm's Regional Municipality aims to establish a value chain for 564 reused/recycled construction materials through a series of demolition projects, by creating a 565 network of actors from the construction sector (Christensen, 2021). During the demolition 566 projects, samples are taken to test them for potential environmentally hazardous substances and 567 resource mapping is performed to assess the quantity and quality of the materials prior to demolition. 568

Regarding the environmental assessment of direct reuse materials, generally no special training
for personnel is undertaken beyond the general qualification, but at AVV, for example, simple
environmental screening principles have been developed in relation to the risk of PCBs, mercury,
etc.

573 7 Conclusion

574 The majority of CDW is presently recycled as backfilling, but since construction materials often are 575 energy intensive to produce in the first place, there are potentially substantial environmental 576 benefits associated with efforts to push materials up in the waste hierarchy. The present study 577 analyzed the potentials and barriers in different business models based on the reuse and recycling

578 of CDW, and identified the main barriers related to the economy, organization, quality and 579 environmental issues.

Based on a survey of reuse schemes established in Denmark, the study identified diverse ways to
organize closed-loop systems for CDW. Based on these diverse experiences, four generic types of
business models for the reuse and recycling of CDW were synthesized: 1) Swap system, 2)
Retailing at the waste company, 3) Reuse through commercial retailers and 4) Recycling via the
material producers.

The study identified the main elements of the business models for end-of-life CDW and the four proposed business models illustrated in abstract terms the resources needed and the cost incentives needed to establish reuse and recycling schemes for CDW. Moreover, the study contributes to an identification of the main challenges to scale-up business models for the reuse and recycling of CDW for future research, including market engagement and value chain collaboration, quality and environmental assessment, and the relation between the waste sector and the construction sector.

The direct reuse of construction materials is a relatively new area for municipalities and waste companies. The current reuse schemes in municipalities and waste companies typically cover a high diversity of fractions, but only cover a small proportion of the total accumulated waste from construction and demolition, since the larger companies in the Danish waste sector typically use private contractors for handling and recycling their CDW. Based on the findings in this study, some perspectives for future research can be provided in terms of meeting the discussed barriers and further developing elements of the presented business models.

599 The study finds that a vital precondition for upscaling the studied schemes is an improved 600 collaboration between private and public partners. Five of the studied schemes engaged in 601 dialogue with demolition companies to increase the purity and quality of materials, including the 602 development of selective demolition procedures. Additionally, collaboration across the value chain 603 is a necessary condition for the development of the supply and demand for reused and recycled 604 CDW. Future research on value chain collaboration related to risk assessment, the distribution of 605 responsibilities and the development of organizational resources is crucial to commercialize 606 secondary construction materials.

607 The studied schemes primarily target private costumers (private citizens who reuse CDW) and a 608 further upscaling of the schemes to cover companies in the established construction industry 609 would require the development of standardized quality systems and certification schemes. Future 610 research on how to develop systems for the quality assessment of secondary construction 611 materials is important. This would likely necessitate a targeted strategy for selected waste 612 fractions as quality assessment procedures and certification are time consuming and economically 613 expensive. Furthermore, research on the relation between the waste sector and the construction 614 sector regarding legislation, and the key actors and processes is urged with an aim to transform 615 the waste sector into a resource sector. A framework condition to comply with the quality criteria 616 in the Construction Product Regulation (305/2011) is to develop national or international 617 standards for End-of-waste criteria (2008/98/EC).

618 8 Funding

619 The research was funded by the Zealand Region's Regional Council Development Funds.

620 9 Acknowledgements

621 Thanks to all the project partners in the project Cirkulær Sjælland who contributed to this study.

622 10 References

- Adams, K. T., Osmani, M., Thorpe, T., & Hobbs, G. (2017). The role of the client to enable circular
 economy in the building sector. *Proceeding of the International HISER Conference on*
- 625 Advances in Recycling and Management of Construction and Demolition Waste, June, 118–
- 626 121.
- 627 Adams, R., Jeanrenaud, S., Bessant, J., Denyer, D., & Overy, P. (2016). Sustainability-oriented
- 628 Innovation: A Systematic Review. International Journal of Management Reviews, 18(2), 180–
- 629 205. https://doi.org/10.1111/ijmr.12068
- 630 Affaldplus. (2020). *Årsrapport 2019*.
- 631 Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business
- 632 model strategies for a circular economy. Journal of Industrial and Production Engineering,
- 633 33(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124
- Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to
- 635 develop sustainable business model archetypes. *Journal of Cleaner Production, 65,* 42–56.
- 636 https://doi.org/10.1016/j.jclepro.2013.11.039
- 637 Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models
- and economic performance: An overview. *Journal of Cleaner Production*, 45, 1–8.
- 639 https://doi.org/10.1016/j.jclepro.2012.08.013

640	Bringezu, S., Ramaswami, A., Schandl, H., O'Brien, M., Pelton, R., Acquatella, J., Ayuk, E. T., Chiu, A.
641	S. F., Flanegin, R., Fry, J., Giljum, S., Hashimoto, S., Hellweg, S., Hosking, K., Hu, Y., Lenzen, M.,
642	Lieber, M., Lutter, S., Miatto, A., Zivy, R. (2017). Assessing global resource use: A systems
643	approach to resource efficiency and pollution reduction. In United Nations Environment
644	Programme.
645	Bryman, A., & Bell, E. (2011). Business Research Methods (3rd editio). Oxford University Press.
646	Christensen, T. B. (2021). Towards a circular economy in cities: Exploring local modes of
647	governance in the transition towards a circular economy in construction and textile recycling.
648	Journal of Cleaner Production, 305, 127058. https://doi.org/10.1016/j.jclepro.2021.127058
649	Christensen, T. B., Johansen, M. R., Buchard, M. V., & Glarborg, C. N. (2022). Resources ,
650	Conservation & Recycling Advances Closing the material loops for construction and
651	demolition waste : The circular economy on the island Bornholm , Denmark. Resources,
652	Conservation & Recycling Advances, 15(July), 200104.
653	https://doi.org/10.1016/j.rcradv.2022.200104
654	Copenhagen Municipality. (2022). Sorteringvejledning ved nedrivning, renovering og nybyggeri.
655	Dalhammar, C., Wihlborg, E., Milios, L., Richter, J. L., Svensson-Höglund, S., Russell, J., & Thidell, Å.
656	(2021). Enabling Reuse in Extended Producer Responsibility Schemes for White Goods: Legal
657	and Organisational Conditions for Connecting Resource Flows and Actors. Circular Economy
658	and Sustainability, 1(2), 671–695. https://doi.org/10.1007/s43615-021-00053-w
659	Danish Environmental Protection Agency. (2020). Waste statistics.

- Danish Government. (2020). Klimaplan for en grøn affaldssektor. In *Klimaplan for en grøn affaldssektor og cirkulær økonomi*.
- 662 EEA. (2019). Construction and Demolition Waste : challenges and opportunities in a circular
- 663 economy. In *European Enviroment Agency* (Issue Briefing no. 14/2019).
- European Commision. (2016). EU Construction & Demolition Waste Management Protocol. In
 Official Journal of the European Union (Issue September).
- 666 Gálvez-Martos, J. L., Styles, D., Schoenberger, H., & Zeschmar-Lahl, B. (2018). Construction and
- 667 demolition waste best management practice in Europe. *Resources, Conservation and*
- 668 *Recycling*, *136*(April), 166–178. https://doi.org/10.1016/j.resconrec.2018.04.016
- 669 Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and
- 670 supply chains for the circular economy. *Journal of Cleaner Production*, *190*, 712–721.
- 671 https://doi.org/10.1016/j.jclepro.2018.04.159
- 672 Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and
- 673 benefits of a circular economy approach to the construction and demolition sector. A
- 674 literature review. *Journal of Cleaner Production*, *178*, 618–643.
- 675 https://doi.org/10.1016/j.jclepro.2017.11.207
- 676 GlobalABC, IEA, & UNEP. (2019). 2019 Global Status report for Buildings and Construction.
- 677 Towards a zero-emissions, efficient and resilient buildings and construction sector. In *Global*678 *Status Report.*
- 679 Golder Associates A/S, Teknologisk Institut, & Lauritzen Advising. (2017). *Projekt om selektiv*680 *nedrivning* (Issue 1962).

- Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global
- 682 economy?: An assessment of material flows, waste production, and recycling in the European
- union and the world in 2005. *Journal of Industrial Ecology*, *19*(5), 765–777.
- 684 https://doi.org/10.1111/jiec.12244
- Hoang, N. H., Ishigaki, T., Watari, T., Yamada, M., & Kawamoto, K. (2022). Current state of building
- 686 demolition and potential for selective dismantling in Vietnam. Waste Management,

687 *149*(February), 218–227. https://doi.org/10.1016/j.wasman.2022.06.007

- 588 Jansen, H. (2010). Forum, qualitative social research. Forum Qualitative Sozialforschung / Forum:
- 689 *Qualitative Social Research*, 11(2), 1–21.
- Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods
- 691 Research. Journal of Mixed Methods Research, 1(2), 112–133.
- 692 https://doi.org/10.1002/9781119410867.ch12
- 693 Kabirifar, K., Mojtahedi, M., Wang, C., & Tam, V. W. Y. (2020). Construction and demolition waste
- 694 management contributing factors coupled with reduce, reuse, and recycle strategies for
- 695 effective waste management: A review. *Journal of Cleaner Production, 263,* 121265.
- 696 https://doi.org/10.1016/j.jclepro.2020.121265
- Kellermann, K., Soja, H., Pedersen, A. D., Laugesen, P., & Arre, T. (2021). *Genanvendelse af beton*.
- 698 Fra håndholdt indsats til permanent praksisændring En vejledning til bygherrer.
- 699 Lauritzen, E. K. (2018). Transformation of structures and materials. In Construction, Demolition and
- 700 *Disaster Waste Management* (1st ed., pp. 27–54). Taylor & Francis Group.
- 701 https://doi.org/10.1201/b20145-2

702	Leising, E., Quist, J., & Bocken, N. (2018). Circular Economy in the building sector: Three cases and
703	a collaboration tool. Journal of Cleaner Production, 176, 976–989.
704	https://doi.org/10.1016/j.jclepro.2017.12.010
705	Lucon, O., Rge-Vorsatz, D., Zain Ahmed, A., Akbari, H., Bertoldi, P., Cabeza, L. F., Eyre, N., Gadgil,
706	A., Harvey, L. D. D., Jiang, Y., Liphoto, E., Mirasgedis, E., Murakami, S., Parikh, J., Pyke, C., &
707	Vilari~no, M. V. (2014). Buildings. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani,
708	S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen,
709	S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), Climate Change 2014: Mitigation
710	of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the
711	Intergovernmental Panel on Climate Change (Issue January, p. 101). Cambridge University
712	Press.
713	Lüdeke- Freund, F. (2010). Towards a Conceptual Framework of Business Models for Sustainability.
714	Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU Conference,
715	Delft, The Netherlands, 49(0), 1–28. https://doi.org/10.13140/RG.2.1.2565.0324
716	Magretta, J. (2002). Why business models matter. Havard Business Review, May 2002.
717	Milios, L., & Dalhammar, C. (2020). Ascending the waste hierarchy: Re-use potential in Swedish
718	recycling centres. Detritus, 9(March), 27–37. https://doi.org/10.31025/2611-
719	4135/2020.13912
720	Moalem, R. M., Remmen, A., Hirsbak, S., & Kerndrup, S. (2022). Struggles over waste: Preparing
721	for re-use in the Danish waste sector. Waste Management and Research.
722	https://doi.org/10.1177/0734242X221105438

- Ness, D. A., & Xing, K. (2017). Toward a Resource-Efficient Built Environment: A Literature Review
 and Conceptual Model. *Journal of Industrial Ecology*, *21*(3), 572–592.
- 725 https://doi.org/10.1111/jiec.12586
- 726 Nussholz, J. L. K., & Milios, L. (2017). Applying circular economy principles to building materials:
- 727 Front-running companies' business model innovation in the value chain for buildings.
- 728 SustEcon Conference, September, 0–11.
- 729 Nußholz, J. L. K., Nygaard Rasmussen, F., & Milios, L. (2019). Circular building materials: Carbon
- saving potential and the role of business model innovation and public policy. *Resources,*
- 731 *Conservation and Recycling*, *141*(August 2018), 308–316.
- 732 https://doi.org/10.1016/j.resconrec.2018.10.036
- 733 Osterwalder, A., Pigneur, Y., & Tucci, C. L. (2005). Clarifying Business Models: Origins, Present, and
- Future of the Concept. *Communications of the Association for Information Systems*, 16(May).
- 735 https://doi.org/10.17705/1cais.01601
- 736 Porter, M. E., & Kramer, M. R. (2011). Creating shared value. *Harvard Business Review*, 89(1–2).
- 737 https://doi.org/10.32591/coas.ojss.0201.04037b
- 738 Richardson, J. (2008). The business model: an integrative framework for strategy execution.
- 739 *Strategic Change*, *17*(5–6), 133–144. https://doi.org/10.1002/jsc.821
- 740 Rios, F. C., Chong, W. K., & Grau, D. (2015). Design for Disassembly and Deconstruction -
- 741 Challenges and Opportunities. *Procedia Engineering*, *118*, 1296–1304.
- 742 https://doi.org/10.1016/j.proeng.2015.08.485

- 743 Salama, W. (2017). Design of concrete buildings for disassembly: An explorative review.
- 744 International Journal of Sustainable Built Environment, 6(2), 617–635.
- 745 https://doi.org/10.1016/j.ijsbe.2017.03.005
- 746 Schaltegger, S., Lüdeke-Freund, F., & Hansen, E. G. (2012). Business cases for sustainability: The
- role of business model innovation for corporate sustainability. *International Journal of*
- 748 Innovation and Sustainable Development, 6(2), 95–119.
- 749 https://doi.org/10.1504/IJISD.2012.046944
- 750 Silva, R. V., de Brito, J., & Dhir, R. K. (2017). Availability and processing of recycled aggregates
- 751 within the construction and demolition supply chain: A review. Journal of Cleaner Production,
- 752 *143*, 598–614. https://doi.org/10.1016/j.jclepro.2016.12.070
- 753 Stubbs, W., & Cocklin, C. (2008). Conceptualizing a "sustainability business model." Organization
- 754 *and Environment, 21*(2), 103–127. https://doi.org/10.1177/1086026608318042
- 755 Wahlström, M., Bergmans, J., Teittinen, T., Bachér, J., Smeets, A., & Paduart, A. (2020).
- 756 Construction and Demolition Waste: Challenges and opportunities in a circular economy (Issue
 757 January).
- 758 Winkler, N., & Nyborg, J. H. (2021). Genbrugspladser i Danmark: En central del af den kommunale
- 759 infrastruktur på affaldsområdet.
- 760