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Towards Circular Social Housing: An Exploration of Practices, Barriers, and Enablers

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Abstract: The concept of Circular Economy (CE) and its application in the built environment is an emerging research field. Scholars approach CE from various perspectives covering a wide range of topics from material innovation to city-scale application. However, there is little research on CE implementation in housing stock, particularly that which is managed or owned by the social housing organisations (SHOs) and which offers opportunities to generate circular flows of materials at the portfolio level. This research focuses on Dutch SHOs and uses the Delphi method to examine CE practices in their asset management, as well as the main barriers to and potential enablers of its uptake. The analysis of two iterative rounds of expert questioning indicates that Dutch SHOs are in the early experimental phase in CE implementation. From the results, it is evident that organisational, cultural, and financial barriers are the most pressing ones that hinder the wider adoption of CE in their asset management. Building on the panel input, this study suggests potential enablers to overcome these barriers, such as CE legislation, best practice case studies, commitment and support from the top management, and the creation of a clear business case.

Keywords: Circular Economy; social housing; Delphi method; barriers; enablers; practices; built environment

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1. Introduction

The built environment is a critical sector in terms of its influence on the economy, society, and natural environment as construction activities are estimated to form about 9% of the European gross domestic product [1] and are the major consumer of natural resources [2]. Research suggests that this industry is responsible for 39% of global energy-related emissions [3] and 46% of the total waste generation in the European Union (EU) [4]. Thus, there is an urgent need for transforming the built environment to a resource-effective one to address these challenges.

The concept of Circular Economy (CE) has been embraced as an approach for minimising resource inputs and outputs by introducing cyclic principles [5], avoiding waste and pollution, and creating regenerative systems [6]. The concept gained traction in Europe in the early 2010s with the efforts of Ellen MacArthur Foundation (EMF) along with the introduction of the first Circular Economy Action Plan [7,8]. Indeed, many European countries [9], including the Netherlands [10], have developed several strategies and action plans, in which the construction sector takes a pivotal role as one of the main priorities in the transition towards a CE.

Research on CE in the built environment covers various dimensions, with some researchers focussing on the material innovation while others address CE implementation at city scale. For example, Marie and Quiasrawi [11] studied the properties of recycled aggregates that are reintroduced in the concrete life cycle multiple times, van Stijn and Gruis [12] proposed a circular housing retrofit strategy for modular building components, Eberhardt and colleagues [7] conducted a systematic literature review to determine which building design and construction strategies are associated with circularity for new buildings, and

Prendeville and colleagues [13] investigated how six European cities are implementing CE as a strategy. Furthermore, several researchers have proposed tools [14–16] and assessment methods [17] to support circular building processes, while others conducted systematic literature reviews to demonstrate the state-of-the-art of CE research [18,19] and identified barriers [20] for CE implementation in the built environment.

However, only a very few of the reviewed studies explicitly examines the circular transition of the housing sector, with a notable example [21]. This can be considered as somewhat surprising, given that the housing stock constitutes a significant part of the built environment. Moreover, especially in Northwestern Europe, a large part of the housing stock, varying from 3% to 30% of the total housing stock [22], is managed by professional institutes, social housing organisations (SHOs), with substantial portfolios that offer opportunities to generate circular flows of materials at the portfolio level. For a wider adoption of the CE in the built environment, therefore, understanding of SHOs' experiences with the circular practices is critical.

Sustainability of social housing is one of the five top priorities of Aedes, the umbrella organisation of Dutch housing associations [23]. Dutch SHOs own 29% of the national housing stock [24] and provide services to approximately 4 million low-income residents [25] which make them prominent actors in the Dutch construction sector.

Based on this background, this article aims to identify (1) circular practices of the early adopter Dutch SHOs; (2) main barriers that hinder CE implementation; and (3) potential enablers to address the most pressing barriers by conducting a Delphi study with 21 sector professionals across the Netherlands.

The remainder of this article is organised as follows. Section 2 presents the background of the study, discussing relevant literature on CE in the built environment, the main characteristics of Dutch SHOs, and CE implementation barriers and enablers in the construction sector. Section 3 demonstrates the execution of the Delphi method and elaborates on the data collection and data analysis phases. Further, Section 4 presents the research results highlighting priority issues, while Section 5 includes the discussion and concluding remarks.

2. Research Background

2.1. Circular Economy in the Built Environment

Circular Economy (CE) has emerged as a paradigm that originated from several theoretical backgrounds, such as Industrial Ecology and biomimicry [26,27] and has been interpreted in numerous ways by different players [28]. The literature review of Kirchherr and colleagues [29] resulted in 95 different academic and practitioner definitions of the concept, illustrating the conceptual confusion around the topic [29]. In a field where circularity is still in its infancy, only a limited number of scholars attempted to define CE for the built environment as reported by Benachio et al. [18].

Pomponi and Moncaster [30] conceptualised the building research from a CE perspective by proposing a research framework and made a brief definition of circular buildings: "*. . . a building that is designed, planned, built, operated, maintained, and deconstructed in a manner consistent with CE principles*" (p. 711). One of the limitations of this definition is that it does not elaborates on the circular principles to which it refers. Leising and colleagues [15], on the other hand, defined circular buildings from a broader perspective by incorporating ownership issues: "*A lifecycle approach that optimizes the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank*" (p. 977). They emphasize the importance of supply chain collaboration in closing the material loops throughout the lifetime of buildings.

Moreover, some non-academic actors such as EMF described a circular built environment as *modular* and *flexible by design* where resource loops are closed and human well-being is promoted [31]. Similarly, but more thoroughly, a comprehensive definition of *circular construction* is presented for the Dutch construction industry in the *Circular*

Construction Economy Transition Agenda as follows: " ... *the development, use and reuse of buildings, areas and infrastructure without unnecessarily exhausting natural resources, polluting the living environment, and affecting ecosystems. Construction in a way that is economically sound and contributes to the well-being of humans and animals. Here and there, now and later.*" [32] (p. 10).

For the implementation of CE, several strategies, frameworks and tools have been suggested by academicians, practitioners, and consultants. Ness and Xing [33] reviewed a wide range of resource efficiency principles and discussed whether these could be extended beyond industrial applications to the built environment. They concluded that industrial closed-loop strategies aiming for extending the lifetime of products could be translated for the building sector by strategies like *reuse*, *remanufacture*, and *maintenance* as well as by offering service models for building parts [33]. Indeed, some circular principles are assumed to be known already to the construction sector, particularly, the R principles. Recent research showed that "recycle" and "reuse" are the strategies that have been predominantly used [19], especially for recovering construction and demolition waste [34]. Arguably, the most extensive R framework is the one proposed by Potting et al. [35] for measuring the progress of CE transition (Figure 1), which is also applicable in construction processes.

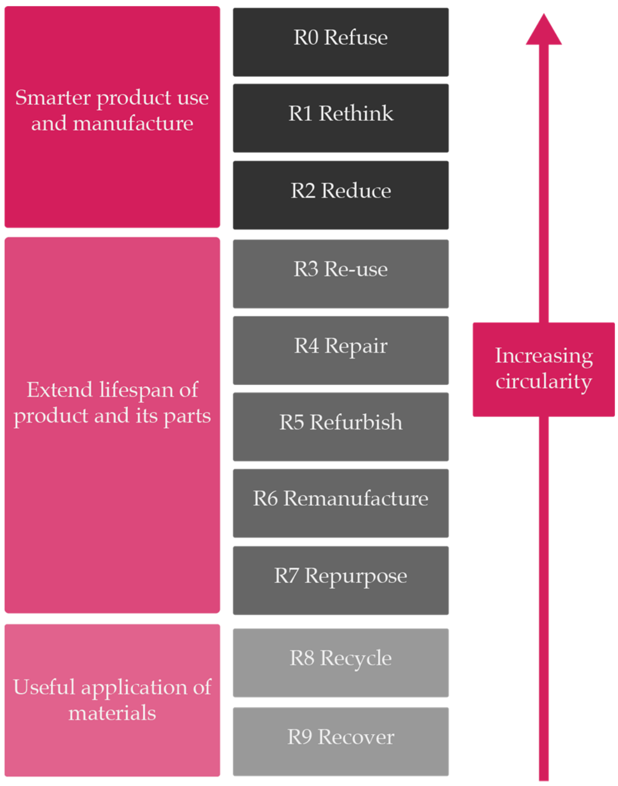

Figure 1. R framework proposed by Potting and colleagues [35]. Own illustration.

R strategies are also intertwined with the famous ReSOLVE framework of EMF [36]. Although developed for products and services in other sectors, the ReSOLVE framework is believed to be relevant for various spatial levels of the built environment [37]. For instance, *share* strategy can be applied to reuse reclaimed building products and to pool available assets in the cities such as cars and office spaces while with *optimise* strategy efficiency and performance of buildings can be increased during the design phase [37].

We used the R framework of Potting et al. [35] in this study as it is a well-known framework to the Dutch construction sector (see, e.g., a recent report of the Dutch circular construction economy transition team [38]), which made it easier to communicate the survey and collect data during the Delphi sessions amongst our respondents.

2.2. Dutch Social Housing Organisations

Dutch housing associations have a long tradition and are considered to be major actors in the Dutch construction industry [39]. The first housing organisations were established in the mid-1800s to construct labour houses, and they became critical during the post-war era due to the role they played in reducing the enormous housing shortage at that time [40,41]. They remain an essential part of Dutch housing provision to date. Aedes, the umbrella organisation of the Dutch housing associations, describes the Dutch SHOs as "*non-profit enterprises that pursue social goals within a strict framework of national laws and regulations by involving local government, tenants and other stakeholders in their policies and are accountable to the society*" [25] (p. 3). Their primary responsibility is to construct, rent, and manage social homes for the target group of low-income households as well as to maintain a good quality of homes and neighbourhoods [25,42].

When delivering these housing services, Dutch SHOs work closely with other market actors. Although some Dutch SHOs have an in-house maintenance department responsible for daily maintenance services, most of them outsource planned maintenance work. Typically design activities for renovation and new construction are outsourced as well. Over 10 years ago, Dutch housing associations began to develop supply chain partnerships in new-build, maintenance, and refurbishment projects [43]. In recent years, collaborative relationship models and partnering agreements for maintenance and renovation have been introduced, although traditional procurement processes are still used for the majority of projects.

The main characteristic of the Dutch social housing sector, compared to the other European countries, is the large share of the social rented segment within the housing stock which is the highest in Europe. As of 2020, approximately 2.3 million dwellings, constituting 29% of the national housing stock, are owned by the Dutch housing associations [24]. Currently, there are 312 SHOs actively operating in the Netherlands [44], some of them owning more than 50,000 dwellings [45].

In the past decade, energy transition, particularly, energy renovation of the existing housing stock, has been the central sustainability aspiration for the housing associations to contribute to reaching national climate targets of reducing carbon emissions by 95% by 2050 [46]. More recently, interconnected with the climate targets and also with the government-wide CE programme [10], CE is becoming a new sustainability paradigm in their agenda. In response to these developments, several SHOs across the country have started experimenting with circular strategies in pilot projects.

One such initiative, adopted by the province of Drenthe, is "Drenthe Woont Circulair" (Drenthe lives circularly). To generate affordable, repeatable, and scalable circular homes, six experimental projects, so-called proeftuinen (experimental "playgrounds"), have been developed that will result in 110 social rental homes [47]. Similarly, another circular proeftuin has started by employing a living lab approach in the province of Overijssel. This initiative involves many actors, from architects to a demolition company, to learn dismantling techniques and using biobased materials for increasing the reuse potential of the building components in future [48]. In the province of Limburg, as part of the Super Local Estate project, three circular homes have been constructed by reusing more than 90% of the materials from a 10-story apartment dating back to 1960s [49]. A few housing associations have gone beyond experimentation and announced ambitious targets in their policies to be carbon neutral and fully circular in coming decades [50,51].

2.3. Barriers and Enablers for a Circular Built Environment

Next to the conceptualisation of CE across the disciplines, scholars also focus on its operationalisation and interrogate factors hindering its wider adoption. For example, Geng and Doberstein [52] took an exclusive approach for identifying challenges associated with China's long-term CE program. Similarly, Kirchherr and colleagues [53] investigated the EU-wide barriers interrupting the transition towards a CE. In their comprehensive review, de Jesus and Mendonça [54] outlined the main CE barriers and enablers in a framework from an innovation studies point of view. Other researchers focused on the topic from supply chain [55–57], firm [58,59], and circular business models [60] perspectives.

The research on barriers and enablers of CE implementation in the built environment is limited. Current studies either focus on a particular country context or a specific subset of the building sector. Adams and colleagues [61] examined the industrywide CE awareness, challenges, and enablers in the United Kingdom. Their results showed that the most pressing barriers are *a lack of incentive to design for end-of-life issues, the lack of market mechanisms to aid greater recovery, and an unclear financial case.* On the other hand, *a clear business case, assurance arrangements for reused materials*, and *best practice examples* are seen as important enablers for the construction sector [61]. In another study [20], researchers address this issue in developing countries. In contrast, their findings reveal the absence of various social and regulatory aspects such as public awareness, financial resources, and support from public institutions as the key obstacles. Moreover, Jugend et al. [62] focused on a building component manufacturer and pointed out that the infrastructure systems might become a significant challenge on achieving intended circularity on the product level, meaning macro-level problems could hinder CE adoption on the micro-level [62]. In connection with that, the fragmented structure of the building industry and the complexity of buildings become critical obstacles when introducing innovative ideas. As pointed out by Leising and colleagues [15], successful supply chain collaboration might address these issues. Within the construction supply chain, architects are at the centre of the design processes. Kanters [63] investigated the barriers and drivers that architects and consultants encounter when designing circular buildings. His interview results showed that the absence of a definition of circular building design causes varying approaches within the sector. Furthermore, lack of flexibility in trying new methods alongside the limitations of current building codes, financing of buildings and high labour costs are identified as barriers for designers while the intention of the client towards circular building is seen as the main driver [63].

CE implementation strategies, barriers and enablers and their importance differ according to the stakeholders in the construction value chain. Thus, previously discussed factors might not be recognised by Dutch SHOs. Given their unique position in the Dutch building sector, it is timely to investigate their experiences with circular strategies in asset management. Therefore, this article aims to identify circular practices, as well as barriers and enablers associated with the CE implementation of early adopter Dutch SHOs. The next section elaborates on the Delphi study conducted with 21 sector professionals.

3. Delphi Method

Delphi is a method for aggregating opinions from a group of knowledgeable individuals for a wide variety of purposes including issue identification, concept development, group decision making, and forecasting future trends [64–66]. Early applications of Delphi concern forecasting in the military context; later, it became a popular method, both in academia and the corporate world, for reaching consensus, decision-making, or policy-making [67,68]. This technique is considered convenient for several scientific domains as many scholars applied it in social sciences [67,69,70], housing studies [71–74], and also in CE-related inquiries [54,75–79]. Furthermore, some researchers used Delphi technique, similar to this study, to determine barriers and enablers for implementing successful CE-based food supply chains [79] and for the application of sustainable purchasing and supply management [80].

The Delphi method has four key characteristics that made it suitable as the core method of this study. Based on the literature [64–68,81], these features can be summarised as follows: (1) *Anonymity*: During the execution, participants do not confer with each other as the facilitator controls the process. The aim is to reduce the impact of dominant individuals in group decision making. Additionally, anonymity allows respondents to express their opinions freely without feeling group pressure. (2) *Iteration*: The questioning of the participants occurs in several rounds of written questionnaires or interviews so that the panellists can adjust their opinions based on the feedback they get from the facilitator. Throughout the process, participants are actively involved in the debate and influence the questions and outcome. (3) *Controlled feedback*: The facilitator regularly transfers information between panellists. After each Delphi round, facilitator delivers feedback in a summary of the statistical values of the group judgements. (4) *Statistical group response*: At the final stage of the process, participant responses are formulated statistically and presented numerically, graphically, or sometimes qualitatively to indicate the degree of consensus or disagreement.

We performed a two-round Delphi study between December 2019 and October 2020, comprising three overarching phases, as shown in Figure 2. The preparation phase concerned the panel recruitment and the preparation of a list of barriers and enablers. The execution phase dealt with the data collection through interviews and questionnaires, and the final phase dealt with the analysis of the collected data.

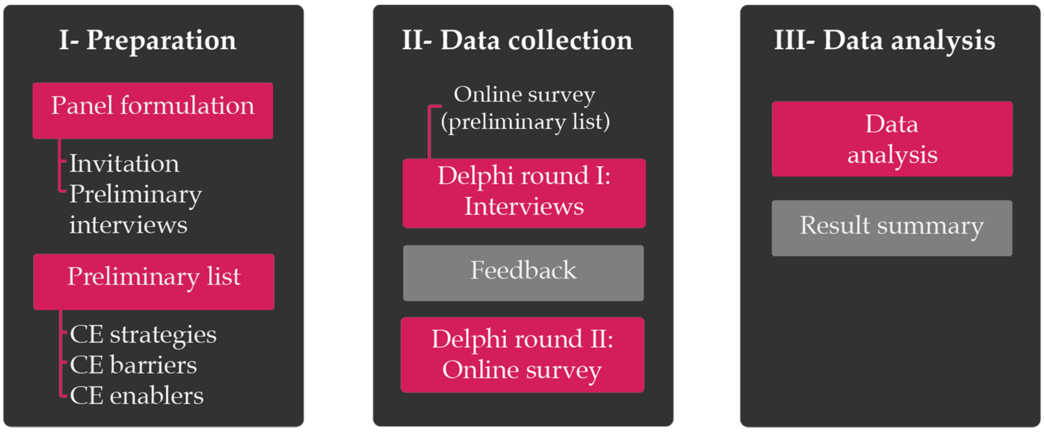

Figure 2. Three phases of the Delphi study.

3.1. Preparation

3.1.1. Panel Formulation

Scholars stress two crucial aspects of the panel formulation in Delphi surveys: expertise of the panellists and the size of the panel. The former is related to the selection of experts who have sufficient knowledge and experience in a specific domain [82], whereas the latter concerns the ideal number of participants in a Delphi panel. Sossa and colleagues [83] observed a tendency towards using a fewer number of panellists in academic research. Although there is no unique rule for the panel size, it is suggested to keep the participant number between 5 and 20 [82].

At the beginning of the study, we sent invitations to 64 sector professionals across the country who work for the forerunner SHOs that have explicit ambitions to implement circular principles, and preferably have conducted pilot projects in which they have experimented with circular construction approaches. The selection of forerunner SHOs was made based on reviewing professional journals and sector-related websites, our own knowledge, and the snowball technique. In return, 26 of the invitees responded to our call positively, a response rate of 40%. Following a round of introductory conversations, a panel was formed with 21 professionals, representing 19 different housing association owning approximately 21% of the social housing stock in the Netherlands. The size and locations of the participating SHOs are shown in Table 1 and Figure 3, respectively, and the overview of the panel members is presented in Table 2.

Table 1. The size of represented social housing organisations (SHOs).

SHO	Size (Dwellings Owned)
1	35,800
2	43,000
3	50,000
4	69,400
5	55,800
6	15,000
7	25,000
8	33,000
9	4500
10	4000
11	56,000
12	4000
13	28,200
14	9000
15	11,000
16	15,200
17	4100
18	11,000
19	15,000
Total dwellings	**489,000**

Figure 3. The locations of the represented social housing organisations (SHOs).

Table 2. Overview of the panel members.

Profession	Professional Experience (Years)	Delphi Round 1	Delphi Round 2
Advisor	34	x	x
Advisor	7	x	
Advisor	24	x	x
Advisor	22	x	
Advisor	22	x	x
Director	25	x	x
Director	25	x	x
Director	36	x	x
Innovation manager	10	x	x
Program manager	18	x	x
Program manager	20	x	x
Project leader	15	x	x
Project leader	16	x	
Project leader	18		x
Project manager	30	x	x
Project manager	20	x	x
Project manager	14	x	x
Real estate manager	7	x	x
Real estate manager	25	x	
Real estate manager	20	x	x
Real estate manager	20		x
Total participants		**19**	**17**

3.1.2. Extensive List of Barriers and Enablers

Prior to the first Delphi round, we prepared an initial set of CE implementation barriers and enablers, based on the relevant literature [53,54,58,61,84–87], to stimulate the discussions with the panel members during the interviews. Similar issues identified by different scholars were merged and sometimes adapted to the context of this study. For example, we combined "Limited awareness across the supply chain" [61], "Lack of interest, knowledge/skills, and engagement throughout the value chain" [84], and "Lack of awareness, understanding, knowledge, and experience with environmental issues" [87] into "Lack of awareness, knowledge, and experience with the CE." A total of 56 issues were grouped under six categories, namely, *social and cultural*, *organisational*, *financial*, *sectoral*, *technical and technological*, and *regulatory*.

3.2. Data Collection

3.2.1. Delphi Round I

The purpose of the first Delphi round was to explore the CE implementation issues that early adopter housing associations experience with their pilot projects. Before the online interviews, panellists were sent a list of barriers and enablers in a questionnaire format and asked to score each of the matters by importance on a 5-point Likert scale, 1 being "not important at all" to 5 being "extremely important".

As outlined in Table 2, 19 panel members out of 21 responded to the online questionnaire and participated in the online interviews. At the beginning of the interviews, panellists were asked open questions regarding circular practices in their organisations. Following this, barriers and enablers in each category were refocussed, and panellists' initial ratings were discussed in-depth. In the meanwhile, panellists reflected on their responses and supplemented additional points that were not covered in the list. These points were then mentioned in the subsequent interviews to validate whether they were relevant to be brought to the second round. Further, panellists were given a chance to adjust their answers upon discussions before the interviews ended. Upon completion of the first round, a summary of the first cut results, demonstrating the mean scores, the highest, and the lowest ratings, and additional notes of the panellists were reported to all participants.

3.2.2. Delphi Round II

There were two underlying objectives of the second Delphi round: (1) to determine circular principles used in business-as-usual practices and circular pilot projects and (2) to prioritise barriers and identify enabling factors. For the former, we used the R framework proposed by Potting and colleagues [35] and asked panel members to indicate which of the R principles apply for both their regular activities and circular pilot projects. For the latter, panel members ranked 13 barriers, chosen from the previous round, in line with the priority given by their organisations. The selection of these barriers was made according to the top-rated two scores per category, including an additional issue raised by the panel members ("The building code, rules and regulations hinder reusing building materials"). The reader must note that some of the barriers from the first round were combined to keep the list concise. For instance, "High purchasing costs of new circular materials" and "High purchasing costs of recycled materials" were combined into "High purchasing costs of circular materials (new and recycled)." Finally, participants were requested to propose enablers to address the top 5 barriers they ranked. With this, we aimed to build meaningful correlations between the most pressing five barriers and potential enablers.

3.3. Data Analysis

For the first cut summary, a quantitative analysis was performed to summarise the panel ratings by calculating minimum, maximum, mean scores, and standard deviation values. Standard deviation was used to demonstrate the distribution of responses, in other words, the degree of consensus. A lower standard deviation value indicates a higher consensus. We did not seek a consensus among panel members, but focused on exploring CE implementation issues. Therefore, a consensus criterion was not defined when analysing the results. Similarly, for analysing the second-round results, mean and median scores of the rankings were used to measure central tendency, and standard deviation and interquartile range were calculated for quantifying the amount of variation in rankings. After finalising the data analysis, a summary of the results was reported to all panellists.

4. Results

4.1. Circular Economy Practices of the Dutch Social Housing Organisations

4.1.1. Current State of the CE Implementation

The analysis of the Delphi rounds reveals that CE is a new topic for the Dutch social housing sector, and its implementation is in an experimental phase. As presented in Figure 4, none of the represented housing associations has completed a circular project up until now. However, almost 80% of them are currently carrying out first circular pilot projects, which are expected to be completed in a short period of time. The majority of the panel members regard these projects as the first experimental steps to generate practical knowledge, or as one panellist put it, "*learning by doing*." In addition, we found that two-thirds of the SHOs have implemented a few circular strategies in renovation and demolition activities. These include the collection of old building components, for instance, bathroom fixtures, reusing them upon cleaning, and repairing in another location; using biobased insulation materials in energy renovation projects; reusing the old roof tiles in roof renovation. Moreover, the majority of the represented organisations have incorporated CE in their policy documents or explicitly expressed it as one of their long-term sustainability targets.

Figure 4. The current state of the CE implementation in 19 early-adopter Dutch SHOs.

4.1.2. CE Strategies and Business Models

In the second Delphi round, participants were asked what circular strategies are used in their business-as-usual activities, and in what ways circular pilot projects differ from them. Figure 5 shows the total counts of the responses on each R strategy. "Repair" is the dominant approach in both business-as-usual and circular operations, as maintaining a good quality of homes is one of the core tasks of the SHOs as mentioned previously. Particularly in demolition projects, "recycling" is a norm as there is a lack of urban mining experience among social housing associations. One of the panel members elaborated on this: "*We are not aware of the value that could be captured from the existing buildings. We do not have the tools to measure it. Therefore, we prefer to recycle building components instead of seeking for upcycling options.*"

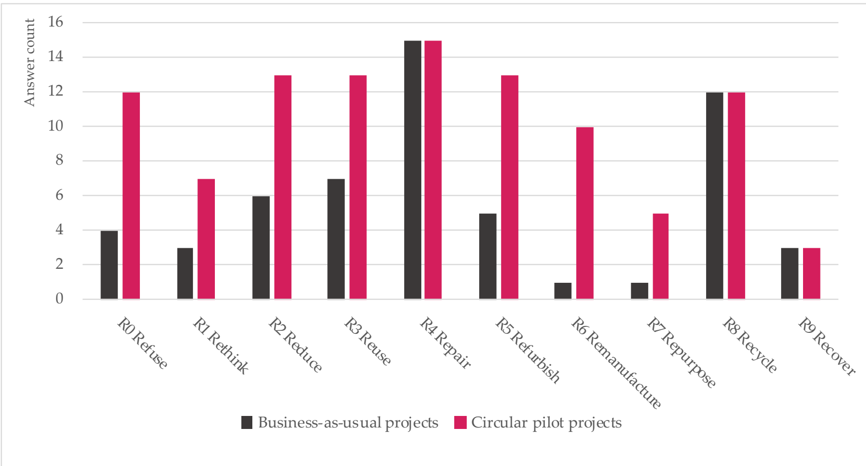

Figure 5. Response counts on R strategies [35] by 19 participating Dutch SHOs.

Maybe the most apparent trend in circular practices is the growing attention to the pre-use phase-related strategies (*refuse*, *rethink*, *and reduce)* that aim to reduce, and if possible, to eliminate resource use when designing buildings. Another remarkable finding is that SHOs consider applying new circular strategies during the use phase of buildings, such as *remanufacture* and *repurpose*.

The typical business model of the Dutch SHOs has several links with the circular business archetypes defined by Bocken and colleagues [5]. For example, Dutch SHOs own the properties in their housing portfolio and provide rental services to their tenants, which corresponds to the "Access and performance model" [5], and also their housing stock has a long lifespan thanks to the regular repair and maintenance activities, which can be linked to the "Classic long-life model" [5]. As for the circular pilot projects, there have been a few experiments with the new business models: Only one participating SHO applied material-as-a-service model and two of them tested sharing economy and take-back guarantee models.

4.2. Barriers and Enablers for the Dutch Social Housing Organisations

In the first round, panel members were asked to rate and discuss 56 barriers and enablers, sub-divided into six categories. The scores were given on a 5-point Likert scale, 1 being "not important at all" to 5 being "extremely important." The analysis of the ratings is demonstrated in minimum, maximum, mean, and standard deviation values in Table 3. Following sections discuss these findings in depth and present the mean scores of the barriers and enablers in brackets.

Table 3. The extensive list of CE implementation barriers and enablers, based on [53,54,58,61,84–87] and authors' interpretations, and the summary of the first-round ratings on a 5-point Likert scale.

Category	Barriers and eEnablers	Min	Max	Mean	Std dev	Mean Category
Barriers						
Social and Cultural Barriers	Lack of awareness, knowledge and experience with the CE	2	5	3.84	0.87	3.27
	Resistance from stakeholders	2	5	3.42	0.94	
	Tenant preference for new building products	2	4	3.32	0.8	
	Lack of willingness to collaborate across the supply chain	1	4	3.26	0.85	
	Lack of consumer (tenant) awareness and interest	1	4	2.53	0.88	
Organisational Barriers	Giving higher priority to other issues, e.g., energy transition	3	5	4.11	0.72	3.62
	Operating in a linear system	2	5	3.68	0.8	
	Limited top management commitment and support for circularity	1	5	3.58	1.23	
	Lack of time and human resources	2	5	3.47	0.99	
	Insufficient technical training and education on circularity	1	5	3.26	1.02	
Financial Barriers	High purchasing costs of new circular materials	3	5	4	0.46	3.8
	High purchasing costs of recycled materials	2	5	3.95	0.69	
	Unclear business case	2	5	3.95	0.94	
	High upfront investment costs	3	5	3.89	0.72	
	High costs for collecting, dismantling, urban mining	2	5	3.84	0.59	
	Limited funding for circular projects	1	4	3.16	0.93	
Sectoral Barriers	Conservative and uncooperative nature of building industry	2	5	3.79	0.95	3.42
	Lack of standardisation	2	5	3.68	0.86	
	Uncertainty in building end-of-life issues	2	5	3.42	0.82	
	Long product life-cycles	1	5	3.37	1.13	
	Poor partnership formation with supply chain	2	5	3.26	1.07	
	Complexity of buildings	2	5	3	0.92	
Technical and Technological Barriers	Lack of an information exchange system	2	5	3.68	0.86	3.5
	Lack of circular design guidelines	2	5	3.53	0.82	
	Lack of relevant tools for material reuse	2	4	3.47	0.68	
	High costs of implementing new technologies	2	5	3.32	0.8	
Regulatory Barriers	Circularity is not effectively integrated in regulations	2	5	3.68	0.8	3.51
	Limited circular procurement	2	5	3.68	0.8	
	Uncertainty regarding future legislation	2	5	3.42	0.82	
	Lack of global consensus on CE	2	5	3.26	0.91	
Enablers						
Social and Cultural Enablers	Leadership	3	5	4.21	0.61	3.84
	Collaborating with other social housing organizations	3	5	4.05	0.6	
	Circular economy training, education and workshops	2	5	3.84	0.67	
	Social awareness and shifting tenant preferences	3	5	3.79	0.61	
	Awareness raising events	3	4	3.32	0.46	
Organisational Enablers	Commitment and support from the top management	3	5	4.58	0.59	4.09
	High priority on circularity within the organisation	2	5	3.95	0.89	
	Collaboration of internal teams	2	5	3.74	0.64	

Table 3. *Cont.*

Category	Barriers and eEnablers	Min	Max	Mean	Std dev	Mean Category
Financial Enablers	Clear business case for CE	3	5	4.05	0.83	3.91
	Lower costs for circular materials	3	5	4.05	0.6	
	Financial incentives to use secondary materials	2	5	3.84	0.93	
	Lower costs for collecting, dismantling, urban mining	2	5	3.84	0.87	
	Sufficient funding for circular projects	2	5	3.79	0.83	
Sectoral Enablers	R&D and innovation	3	5	4.05	0.69	3.99
	Best practice case studies	3	5	4	0.56	
	Better collaboration with sector parties	3	5	3.95	0.6	
	Development of standards	2	5	3.95	0.83	
Technical and Technological Enablers	Development of enabling technologies	3	5	3.95	0.6	3.87
	Development of tools and guidelines	2	5	3.84	0.74	
	Development of digital marketplaces for secondary material	2	5	3.84	0.93	
	Development of circular procurement systems	2	5	3.84	0.81	
Regulatory Enablers	Incentives for CE	2	5	4.11	0.72	3.96
	Circular economy legislation	3	5	4.05	0.69	
	Policy support	3	5	3.95	0.51	
	Waste management directives	2	5	3.95	0.83	
	Global agreement on circular economy	2	5	3.74	0.85	

4.2.1. Social and Cultural Barriers

Our results indicate that panellists identified “Lack of awareness, knowledge, and experience with CE” as the most influential cultural barrier (with an average score of 3.84), while “Lack of tenant awareness and interest” was considered the least important (2.53) in this category. The panel unfolded the reason behind this distinction: “*Tenants are not involved in the project development phase. Thus, their knowledge and awareness in CE would not influence the way we develop housing.*” However, “Tenant preference for new building products over reclaimed ones” considered moderately necessary (3.32) as some of the participants experienced resistance from their clients in situations where reclaimed toilet components from an old hospital were thought to be unsanitary. Moreover, another panel member pointed out that tenant acceptance could be an essential obstacle when initiating new circular business models. She further explained: “*Tenant acceptance becomes a major issue when we want to introduce laundry rooms since tenants need to say goodbye to their personal washing machines and adopt a new behaviour. This is more difficult than accepting reclaimed materials in their homes.*”

4.2.2. Organisational Barriers

As mentioned in the previous chapters, increasing the existing building stock’s energy efficiency has been a critical task for the Dutch housing associations in the past decade. The panel confirms this tendency as “Giving higher priority on other issues” rated 4.11 being the most pressing organisational barrier. Although the represented SHOs are forerunners in circularity, they are operating in a linear way, which is found to be the second most pressing institutional barrier (3.68). A divergence in participant opinions is noted on the “Limited top management commitment and support for circularity initiatives”, which has the highest standard deviation among all questions (s.d. 1.23). Although the majority of the panel consider it as a significant obstacle (3.58), some of the panel members rated it “not at all important” by claiming that the higher management in their organisations has “*an innovative mindset and convincing them is not an issue for sustainability related matters.*”

4.2.3. Financial Barriers

Throughout the categories investigated, financial barriers possess a crucial place in the CE implementation. Five of the six financial barriers identified scored more than 3.80, meaning “very important.” High purchasing costs associated with new and reclaimed circular building materials are considered the most pressing economic barriers. One of the panel members reflected on this as follows: "*For social housing companies it is extremely difficult to realise new housing due to the high construction costs and the lack of good locations ... when extra material costs are added it may not be financially possible to deliver the desired number of homes.*" Furthermore, another panellist claimed that " ... *the value-added tax (VAT) on top of labour and storage costs makes secondary materials even more expensive. We should be exempted from the tax on the materials recovered from old buildings.*"

The second-most important financial factor appears to be "Unclear business case" (3.95) for the housing sector. Panel members expressed the need for experimentation to test and learn how circularity aids value creation with the supply chain partners. One panellist compared this process with the energy transition: "*A decade ago, during the experimental phase, solar panels were expensive, but now they became a part of our core business case. We have to find out ways for the circular materials as well.*"

Interestingly, "Limited funding for circular projects" was considered less important (3.16) than the other financial barriers. Although various institutions fund a large proportion of the pilot circular housing projects, some of the panel members believe that receiving funding is a short-term solution. Panellists express the importance of pilot projects in testing new ideas; however, concrete financial models are needed for the long-term implementation of CE.

4.2.4. Sectoral Barriers

Our results suggest that sectoral barriers related to the construction sector are the least significant within distinguished categories (3.42). The building industry is known for its fragmented and conservative characteristics that hamper innovation. In a field like CE, innovation is needed at an ecosystem level throughout the sector. Although acknowledging "Conservative and uncooperative nature of the building industry" as the most critical sectoral barrier (3.79), panel members perceive "Poor partnership formation with supply chain" as a reasonable obstacle (3.26). This could be explained from the dominant role of SHOs in the construction sector. As one panellist claimed: "*If one supplier does not agree with our approach, we will proceed with another interested innovative company. Our position in the market makes us an important player.*" Furthermore, "Lack of standardisation" especially for the design of buildings and end-of-life practices along with material passports is expressed as a significant barrier (3.68), whereas "Complexity of buildings" is considered less significant (3.0).

4.2.5. Technical and Technological Barriers

As noted in several studies [88–90], information management, in terms of data exchange between stakeholders regarding products' quality, quantity and location, is critical when applying circular strategies and introducing new business models. Indeed, interviews with the panel members made it explicit that there is a need for an information exchange system among SHOs and their stakeholders. Thus, "Lack of an information exchange system" is seen as the most critical technological barrier (3.68) in this category. Another significant technical barrier has been found to be "Lack of circular design guidelines" (3.53). During the interviews, we noticed that there is an immediate demand for guidelines, not only for design but also for implementation, management, and measurement of the circular construction, renovation, and maintenance projects. Lack of measurement tools to assess the circularity level was echoed in multiple interviews. Further, some panel members, although acknowledging the existence of several innovative technologies such as resource management platforms, material passports, and digital marketplaces, expressed the confusion around missing the "*time*" dimension in these tools: " ... *buildings have long life cycles; it is confusing how to keep material passports for 50 years.*" Another panellist commented: "*Current marketplaces fail to offer time arrangements for building parts that will become available from planned demolition sites. This hinders reusing reclaimed materials in design projects.*"

4.2.6. Regulatory Barriers

According to the calculated ratings, two of the identified regulatory barriers came forward in ratings. The first one is "Circularity is not effectively integrated into regulations", which scored 3.86. The major issue raised by the panellists was the strict building code, hindering the reuse of reclaimed building components in new construction projects. For instance, one panel member complained: "*We could not reuse a modular concrete staircase that we dismantled from an old building because the dimensions of the risers will not comply with the current building code. It was a lost opportunity.*" Likewise, many panellists shared similar practical obstacles when applying for a building permit for their circular pilot projects. The second barrier, which also scored (3.86) is "Limited circular procurement." According to the panel, there is a lack of understanding regarding the circular procurement procedures within the supply chain, which result in low demand and supply of circular products and services.

4.2.7. Social and Cultural Enablers

"Leadership" with a clear vision and commitment is believed to be the most driving cultural factor for the CE implementation (4.21). Following this, "Collaborating with other social housing organisations" to share knowledge and experiences scored as the second influential enabler (4.05). This enabler was echoed in multiple times during the interviews. One panel member who represents an SHO that has recently started the piloting process commented: "*We did not know how to start. Luckily, there are other housing associations that share their knowledge and experiences with us.*" Knowledge generation and distribution are not limited to collaboration with the companions as panel members pointed out the driving power of "CE training, education, and workshop" (3.84) for a well-informed ecosystem creation. Moreover, to stimulate a more extensive adoption of circularity, a shift in consumer (tenant) preferences and raising awareness in public are seen as essential enablers.

4.2.8. Organisational Enablers

Among all enablers throughout the categories defined, "Commitment and support from the top management" received the highest score (4.58). Some of the panellists mentioned that the organisational structure of the Dutch SHOs is still very hierarchical as one of the panel members put: "*If the top management is enthusiastic about circularity and open for innovation, we are one step closer towards achieving carbon-neutral housing stock; otherwise, we have to convince them for all the steps we are taking which, at times, is hindering the adoption of CE.*" As mentioned in previous sections, increasing energy efficiency of the existing stock or transformation towards natural-gas free homes have higher priority for Dutch SHOs at the current state. Along these lines, prioritising circularity is thought to be an essential enabler (3.95). In addition to the listed enablers, some panellists suggested "Creativity, openness for innovation, and new ideas" as an enabler.

4.2.9. Financial Enablers

Not surprisingly, "Lower costs for circular materials" is considered as the most crucial enabling factor (4.05) along with "Clear business case for CE" (4.05). During the interviews, we noticed that lowering material costs is linked with several elements discussed in other categories, for instance, R&D in biobased materials, market ecosystem creation for secondary materials, and policy support for lower taxes on reclaimed materials. Further, due to the labour-intensive nature of urban mining, dismantling building products becomes expensive. Panel members expect lower costs for urban mining to be a driving force for following a more circular business model. An additional enabler suggested by one panellist, "carbon tax on materials", was agreed to be a critical enabler by other participants. In addition, panellists scored "Sufficient funding for circular projects" (3.79) vital for CE implementation by acknowledging the need for a viable business model: "*Funding is essential during the experimentation phase. For the long-term implementation, we need a successful business case*".

4.2.10. Sectoral Enablers

Our results suggest that "R&D and innovation" is a very significant sectoral enabler (4.05) to propose new ways of thinking for production and consumption systems in the sector. These could be in the form of introducing new circular materials, proposing new business models for closing the loops, or developing new technologies for ecosystem creation. "Best practice case studies" scored as the second critical enabler (4.00). Panel members echoed this driving factor frequently during the interviews. One interviewee claimed that "... *if there is a platform where the best practice cases and experiences are demonstrated, it could be beneficial for the rest of the sector.*" "Better collaboration with sector parties" is believed to be essential (3.95) to create a circular ecosystem where, as one of the panellists put, "... *all stakeholders from architects to suppliers sit at the same table* ... ." Last but not least, "Development of standards" for circular construction methods, circular procurement, and material passports is seen as a vital factor (3.95).

4.2.11. Technical and Technological Enablers

Many scholars agree that technology plays an enabling role in the implementation of circular strategies and business models [89,91,92]. Our results show that this is valid for the Dutch housing associations as well. Overall, by category, technical and technological enablers scored 3.87, where "Development of enabling technologies" is thought to be the most essential enabler (3.95). Exactly what "enabling technology" entails was an essential aspect of the discussions with the panel members: Data collection from the existing stock, data registration, measuring circularity, managing repair and maintenance operations, collaboration, and trading building components between the stakeholders were some of the qualities mentioned. In addition, tools and guidelines for circular design, implementation, deconstruction, and procurement are urgent requirements for the practitioners, according to the panel. In addition, panellists stressed the importance of digital marketplaces to stimulate the use of secondary building materials (3.84). Such platforms are not used primarily in housing projects as some of the respondents noted. Finally, circular procurement tools and associated databases are seen as being necessary when delivering circular building projects (3.84).

4.2.12. Regulatory Enablers

One of the frequently mentioned enabling factors was regulatory support from the policy environment for innovation and development of circular practices. In line with this, panel members stressed the driving influence of "Incentives for CE" (4.11). Especially, adapting the current building laws to circular strategies and creation of "CE legislation" (4.05) are considered essential for circular building projects. "Policy support" is another urgent aspect (3.95), which was mainly referred to tax and procurement issues by the panel members. For a better handling construction and demolition waste, strict waste management legislation is seen as a driving factor (3.95).

4.3. High-Priority Issues and Potential Enablers

In the second round of the Delphi inquiry, panel members were asked to rank 13 top-scored barriers according to their importance and requested to suggest enablers to overcome the most critical five barriers (see Section 3.2.2 for the selection criteria of the 13 barriers). Table 4 shows the calculated minimum, maximum, mean, median, standard deviation, and interquartile range values of the rankings and Table 5 presents the potential enablers. According to the results, the most pressing five barriers appear to be: (1) higher priority in other issues; (2) operating in a linear system; (3) lack of awareness, knowledge, and experience with the CE; (4) high purchasing costs of circular materials (new and recycled); and (5) unclear business case.

Table 4. Results of the second-round Delphi rankings. Lower numbers indicate higher priority.

Rank	High-Priority Issues	Min	Max	Mean	Std Dev	Median	Inter. Range
1	Higher priority in other issues, e.g., energy transition	1	9	3.60	2.50	3	4
2	Operating in a linear system	1	11	3.80	3.21	3	5
3	Lack of awareness, knowledge and experience with the CE	1	8	4.00	2.07	4	4
4	High purchasing costs of circular materials (new and recycled)	1	13	4.93	3.66	4	5
5	Unclear business case	2	11	5.53	2.55	5	4
6	Conservative and uncooperative nature of building industry	1	13	5.87	3.56	7	6
7	Lack of standardization in circularity	2	9	6.60	2.18	8	3
8	Lack of an information exchange system	3	13	8.67	2.44	9	3
9	Resistance from stakeholders	3	13	8.73	3.86	12	5
10	Lack of circular design and implementation guidelines	6	13	9.20	2.10	10	4
11	The building code, rules and regulations hinder reusing building materials	4	13	9.33	2.98	10	5
12	Circularity is not effectively integrated in innovation policies	1	13	10.27	3.28	12	4
13	Limited circular procurement	8	13	10.47	1.26	10	1

Table 5. The top five high-priority barriers and potential enablers.

Rank	High-Priority Issues	Potential Enablers
1	Higher priority in other issues (Organisational)	Giving higher priority on circularity within the organisation CE Legislation Leadership in circularity Commitment and support from the top management Combining energy efficiency and CE targets *
2	Operating in a linear system (Organisational)	Best practice case studies Collaborating with other housing organizations CE Legislation Leadership in circularity R&D and innovation Better collaboration with sector parties Introduction of change management practices *
3	Lack of awareness, knowledge and experience with the CE (Social and cultural)	Best practice case studies Development of circular design and implementation guidelines Giving higher priority on circularity within the organisation CE training, workshops, education Making experiments with supply chain actors * Introduction of clear measurement methods for circularity * Lobbying for CE *
4	High purchasing costs of circular materials (new and recycled) (Financial)	Clear business case Development of enabling technologies to recover materials R&D and innovation CE Legislation Development of circular procurement systems Lower costs for circular materials CE training, workshops, education CO_2 tax on materials * Considering life-cycle costs * Making experiments with circular materials and products *
5	Unclear business case (Financial)	Clear business case Best practice case studies R&D and innovation Commitment and support from the top management Incentives for CE Development of circular procurement systems Development of standards CO_2 tax on materials *

* Additional enablers defined by the panel members.

The two top barriers concern the way housing providers shape their strategic priorities in terms of sustainability, where energy transition has been the central theme. Regulatory frameworks played an essential role in steering energy efficiency measures in the housing stock in the past decade. Similarly, panel members consider the introduction of a binding “CE legislation” as an important driver to give circularity more attention in their organisations. Additionally, panel members suggested combining CE with energy efficiency targets as an alternative solution.

Our findings show that the linear as one participant put "*hierarchical*" structure of the SHOs makes it challenging to introduce innovative thinking in strategic and daily activities. This could be addressed with the leadership and commitment from the top management. "Operating in a linear system", although we consider it as an organisational barrier in this study, is a systematic obstacle that impacts all supply chain actors. In that sense, engaging in a collaborative ecosystem with other SHOs and sector parties is very critical not only to steer circular construction models but also to create new business opportunities. In connection, previously mentioned "proeftuinen" (experimental playgrounds) play a key role in this, as many panellists expressed the importance of successful case studies in convincing top management of their organisations as well as other sector parties towards circular practices.

"Lack of awareness, knowledge, and experience with the CE" was ranked as the third most significant barrier. In terms of attainment of skills and experience for circular construction methods, successful "Best practice case studies", where alternative circular strategies and business models are tested, is considered essential. Such experiments are critical not only for SHOs but also for their stakeholders in the supply chain. In relation to this, the need for circular design and implementation guidelines was thought to be necessary particularly for the new starters. Furthermore, measurement methods and standardisation of circular processes and materials are believed to be very crucial for catalysing a wider adoption of the concept in the housing sector.

The fourth and the fifth most pressing CE implementation barriers are related to the financial constraints: the high costs of circular materials and ambiguity around a viable circular business case for the housing sector. A few solutions were proposed for the former, including introducing CO_2 tax on construction materials, developing circular procurement systems, and considering lifecycle costs in financial calculations. Among them, the CO_2 tax on construction materials gained considerable attention by the panel members, reflecting the ongoing discussions regarding the demand for a structural shift for taxing labour, raw materials, pollution, and emissions for the construction sector in the Netherlands [93]. We noticed that generating a viable business case has connections with lowering circular material prices as well; however, it is not limited to it. A few of the participating SHOs have experimented with product-service models by taking an innovative approach. Similar experimentations with circular business models showcased in "Best practice case studies" are assumed to be an essential driver for the CE implementation in the sector.

Overall, to address the most urgent CE implementation issues in Dutch social housing sector, four enablers come to the forefront: First, "CE Legislation" for the introduction of new tax schemes on construction materials and for construction methods; second, "Best practice case studies" to demonstrate successful experimentations with circular construction strategies and new business models; third, "Commitment and support from the top management" to make circularity a priority item on SHOs' agenda; and finally, "Clear business case" to boost the market for a wider adoption of the CE concept.

5. Discussion and Conclusions

Despite the emerging body of literature in CE in the built environment, existing research has mostly overlooked the housing stock, especially the one managed or owned by the social housing organisations (SHOs), while this offers tremendous opportunities to generate circular flows of resources in the built environment. This article sheds light on the CE practices of the early-adopter Dutch SHOs and presents the main barriers and enabling factors associated with implementing circular principles, employing a Delphi study with 21 sector professionals.

Seen from a wider implementation of CE approaches in their maintenance, renovation and construction activities, our findings indicate that Dutch SHOs are at the early stage of development in which they experiment with new circular strategies by involving sector stakeholders from the beginning of the construction process. In doing so, we found a tendency to apply higher level circular strategies, such as "refuse", "rethink" and "reduce" in pilot projects.

From the circular business models perspective, Dutch SHOs are "service providers" who keep the ownership of the housing stock they operate and offer rental properties to their tenants. This system coincides with "Access and performance model" of Bocken et al. [5], which was interpreted differently by Eikelenboom et al. [21] as delivering all-inclusive service package to the tenants through a single contract. They argue that such model could cause extra burden on low-income households. SHOs also regularly repair and maintain their housing stock, slowing the resource loops by offering long-lived buildings, as in "Classic long-life model" [5]. Therefore, elements of a CE are already implicit in their business operations. However, there is a noticeable gap in new business model creation in circular pilot projects. Among 19 represented SHOs, only two of them employ the take-back system, and one of them tests a materials-as-a-service model with a supplier.

Our Delphi research has identified five critical barriers for a wider implementation of CE in the Dutch SHOs, namely, (1) higher priority in other issues; (2) operating in a linear system; (3) lack of awareness, knowledge, and experience with the CE; (4) high purchasing costs of circular materials (new and recycled); and (5) unclear business case.

In general, the main barriers that Dutch SHOs encounter are closely related to their organisational structure and company culture. This finding coincides with the Kirchherr and colleagues' EU-wide study [53]. According to their results, other businesses also suffer from "Hesitant company culture" when introducing CE as a strategic goal in their organisations. On the other hand, Adams and colleagues [61] discuss organisational issues mainly from the sectoral perspective. Their study with the UK construction industry indicates that the sector's fragmented nature hinders the application of circular principles throughout the supply chain. The panellists also acknowledged this view in the first round of our Delphi survey. However, we have not observed a direct relationship between the sectoral and organisational barriers.

Similar to our study, several studies highlight that developing a viable business case for circular construction processes is challenging [61,94] and high costs of circular materials hamper the CE implementation [62,95]. Challenges for new business model creation have ties with the traditional ownership models in the building sector. Several scholars discuss the need for a shift in the way of ownership of buildings and its components are structured for the circular flows of resources [30,61,63,96]. As discussed previously, Dutch SHOs retain the ownership of their building stock and deliver services to their tenants, which correspond to circular models. However, for renovation and newly built projects, there is a room for experimentation with other circular business models to increase the level of circularity.

Many reviewed studies identify lack of awareness as one of the most critical barriers for CE implementation [20,53,61,62]. Consistent with the literature, our study also found this barrier very important; however, there is a marked difference in our findings that panel members consider lack of "tenant" interest and awareness as a minor issue, whereas other studies, e.g., Kirchherr and colleagues [53] found "Lacking consumer interest and awareness" as the most pressing barrier in the European context (see Section 4.2.1 for panel arguments on this topic).

Several enablers are proposed to overcome these key obstacles. These include a binding CE legislation allowing innovation in circular construction practices and reforming existing tax schemes on construction materials, systematic exchange of best practices, development of enabling technologies and circularity measurement tools, a more prominent role for leadership and priority setting at top-management level, and clear business models for SHOs and their supply chain partners. Particularly for new starters, development of CE design and implementation guidelines and collaborating with other SHOs are important enabling factors.

Overall, our study shows that, although the Dutch SHOs may have been dealt a good hand in terms of their fundamental business model and societal objectives, they also face significant barriers for a wider implementation of CE principles. The main challenge now seems to be setting in place the enablers that will allow circular asset and construction to become common practice.

When interpreting our findings, it must be kept in mind that the Delphi panel members were chosen from SHOs that have explicit goals for the CE. Other SHOs, who have no explicit CE goals yet, may be expected to face similar barriers and enablers when they do start to adopt CE goals, but this cannot be stated with absolute certainty. Moreover, as CE in the construction sector itself evolves over time, the experienced barriers and enablers are likely to shift as well.

This article contributes to the rapidly expanding field of circular built environment research by providing insights from the SHOs, who own a large part of the housing stock, particularly in Northwestern Europe. Our work appears to be one of the first attempts to examine housing associations' CE practices thoroughly and lays the groundwork for future research into CE implementation in the sector. This study's findings will be used in further research on the development of a framework to address identified barriers through enabling digital technologies.

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