# Categorizing construction waste: Closing the gap between European waste regulation and management practices



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# Categorizing construction waste: Closing the gap between European waste regulation and management practices

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ABSTRACT

The European Union has proposed a comprehensive set of legislative measures and action plans aimed at facilitating the shift towards a sustainable future, however, the challenges of waste production and recycling remain an enduring issue, especially within the construction industry, which generates 800 million tons of waste annually in Europe alone. Given that waste management practices depend on how waste is categorized, this study delves into issues of waste categories and categorization processes highlighting their influence on how waste is handled. Drawing on an ethnographic case study and quantitative waste data, conflicting categorization processes that contribute to poor recycling practices and potentially erroneous waste data are uncovered. This includes 1) the existence of a grey zone in waste management for new build projects due to regulations only defining waste fractions for demolition activities, and 2) that the institutional setting has direct influence on waste categorization among different actors, which leads to erroneous waste data. This stresses a potential disparity in the comprehension of waste categories and resource management maintains fragmentation leading to substantial quantities of waste being incinerated rather than recycled.

## Introduction

Waste is an increasingly important global problem [1]. Construction and demolition waste (CDW) accounts for more than 30 percent of total waste produced in Europe [2], corresponding to more than 800 million tons per year [3]. In particular, waste from demolition projects has gained political attention as it accounts for 70–90 percent of the total CDW [4–6] and encompasses heavy waste fractions such as bricks, tiles, and concrete. Thus, efforts to manage demolition waste have garnered significant attention, with the primary objective being the proper treatment to maximize recycling potential [7]. At a European level, political attention has consequently been directed towards measures to reduce the amount of waste generated and to promote sustainable waste management practices [8–12]. Central in these measures is the creation of waste categories and a five-step waste hierarchy [13] to be applied by EU Member States to improve waste management. The waste hierarchy as outlined by Van Ewijk & Stegemann [14, p. 123] is a structured framework of preferred waste management options designed to minimize environmental impacts. It gives priority to prevention, reuse, recycling, and recovery over landfill. Due to its normative character [15], which assigns preferences and priorities for the efficient use of resources, the waste hierarchy has become an integral part of waste regulations at both European and national levels [16].

Despite the central position of the waste hierarchy, and the fact that compliance with it has increased over time [17], efforts to reduce CDW and embed CDW management practices in the construction industry are still lacking and studies have called for more research on European material flows [18] as increased recycling is linked to societal economic benefits and carbon emission savings [18,19]. On-site, the handling of CDW faces several challenges. The required sorting of waste for recycling or disposal is a task that demands extensive labour [20]. Moreover, there is a significant gap in knowledge and training among staff and managers regarding proper waste management procedures [21]. Space restrictions on-site further complicate the segregation and storage of waste materials [22]. Incorporating waste management into the already stringent project schedules poses another layer of difficulty [23], while the costs associated with these processes can strain budgets [24]. Challenges in the supply chain may hinder access to necessary recycling services or suitable disposal options [20]. Finally, altering the workplace culture to prioritize waste management is a task that requires persistent efforts and time investment [25]. Furthermore, studies have identified structural barriers that prevent the construction sector to improve such

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as market and regulatory barriers in the form of unfit building design standards and an under-developed market for reused CDW [26], low quality of CDW materials [24], lack of economic incentives [27], failure to translate sustainability into new economic values [25], and dis-alignment between product value and market value [28].

Gharfalkar et al. [29] tie these issues to the basic problem of unclear definitions of what constitutes waste. Without a clear definition of waste categories, it is thus deemed unlikely that the valuable resources contained in the waste can be effectively recovered [29, p. 306]. Similar arguments are found elsewhere in the literature where e.g., Teigiserova et al., [30] focusing on food waste prevention, and Ragossnig and Schneider [31], from a perspective of the circular economy in general, link the establishment of clearer categories in the waste hierarchy to the efficient minimization of waste. Gharfalkar et al. [32, p. 996] reinforce this argument and highlight the need for standardized waste categories that are universally acceptable to solve the problem of inefficient waste recovery. The question, however, is whether such aspirations can be met or, more so, are fundamentally possible to attain. From a sociological perspective, categories are thus not naturalized phenomena but social constructs that differentiate among entities, such as products and people [33]. Categories are according to Delmestri et al. [34] shared cultural concepts not changeable at will, and David et al. [35] argue that categories are embedded culturally and institutionally and, therefore, are imparted meaning by actors occupying different positions. In particular, Tunarosa [36] stresses the place-bound nature of categories arguing that specific places influence the meanings that become associated with a category. Such places might be geographically bound (nationally, regionally, etc.) but also organizationally delimited. The meanings attributed to a new accounting system or corporate policy may thus differ drastically between top managers and employees. Likewise, there may be major differences in how different nation states perceive and transpose European legislation as the consequences of various interpretations of the category systems among countries where local regulations, norms, codes, accreditations, market devices, etc. shape the category [37].

Building on such insights, this paper contributes to research on CDW and how to embed CDW management practices in the construction industry by addressing these three research questions: 1) How are waste practices and categories shaped in CDW regulation? 2) How does a construction company translate waste regulation into practice? 3) What factors influence waste data and recycling efforts on-site?

Drawing on an ethnographic study of on-site waste handling and statistical waste data from a contracting company, this study displays how efforts to reduce waste are influenced by different understandings of waste categories among a multitude of actors across different levels and locales of the industry. These differences in understanding categories have some indirect effects on the validity of waste data, that otherwise increasingly is becoming a foundation of sustainable investment and corporate transparency, countering greenwashing. Emphasizing the category of mixed waste, this paper illustrates how the mixed waste category is defined according to different category systems and discuss what consequences this has for the efforts to minimize waste and drive resource effectiveness as defined in the waste hierarchy.

## Theoretical framework: the notions of category and categorization

We draw on an institutional understanding of categories to identify and analyze how waste categories are mobilized and sometimes come in conflict with each other in the process of managing CDW. Institutional theory is a suited analytical framework to examine how social norms and different institutional settings shape practices and furthermore how these practices conform to regulation in different ways. This is particularly applicable when studying waste management, as it facilitates a nuanced understanding of the connection between regulation and organizational behavior. This help us understand how waste is regulated, defined, categorized, and managed in practice.

In institutional theory, the concept of category can be defined as a label or classification used to organize and make sense of the world and has been found to play a crucial role in shaping organizational behavior and outcomes [38]. Categories are interfaces of cognitive and normative agreement, which create a common reference or taken-for-granted impression that is useful in e.g., exchange of products [39]. They play a key role in imposing coherence on the social world by partitioning items into groups and help individuals to process large amount of information, to give meaning to current practices and make judgments about value and worth [40,41]. This system of meaning, ordering time and space is at the core of institutions by providing boundaries between categories, which structure the social order like for example with the notion of private or public [42]. Exploring categories as the results of social negotiation and enactment is particularly suited when accounting for varying goals, interests, and grievances of different actors, and for studying the impact this may have on how categories are conceived and used [43].

Ideally, there are three features defining categories: first they are mutually exclusive; second there is a consistent set of rules for assigning objects to categories, and third, the system provides a complete coverage of a specific domain via the categories and rules at hand [44]. In practice, however, defining categories may reveal considerable imperfection, arbitrariness, and ambiguity [45]. Focusing on categories, makes it possible to identify the features, commonalities and trade specificities attributed in different contexts to materials and processes [40]. This provides a valuable contribution to the extant waste management literature, where the notion of categories often is taken for granted and serves to define, organize, and model the hierarchy of material and processes.

Most of the academic production builds on the waste hierarchy and its categories with a few national adaptations regarding the material. And so does waste management regulation, which prioritizes practices ranging from waste prevention to disposal [46]. But what is considered as waste is according to Amasuomo & Baird [47] to large extent subjective in meaning, as a substance can only be regarded as a waste when the owner labels it as such. This is particularly true, the authors insist, as one individual may regard a substance as a waste, while another may view the same substance as a resource. Moreover, the literature identifies that the waste hierarchy in its current form is an insufficient foundation for waste and resource policy to achieve absolute reductions in material throughput and suggests that waste should be redefined and associated collection and handling practices reshaped accordingly [14]. With this in mind, we seek to open the black box of waste categories and explore the role they play in CDW management. We do so by analyzing the application of waste hierarchy principles at a construction site. Furthermore, we delve into how various stakeholders within the value chain employ different categories of the same waste and explore the potential ramifications of these divergent approaches.

## Method

Methodologically, the paper adopts an interpretive approach building on the concepts of categories and categorization [39]. We draw on data from documents on European Union and national waste legislation and an ethnographic case study of organizational and on-site waste management practices in a Danish context.

### *Study of EU and national waste legislation*

To examine how categories of waste are shaped in relation to waste handling and their classifications, it was essential to grasp the context in which these activities occur. To achieve this, we conducted an in-depth examination of both EU and Danish regulations and industry directives regarding the sorting and handling of waste. This approach enabled us to trace and analyze the origins, local adaptations, and dissemination of waste labelling and hierarchization systems. The review of documents published between 1975 and 2023 (see Table 1) allowed us to explore the relationship between waste handling practices, the categorization of waste and the regulatory environment in which these processes are taking place.

*Ethnographic case study*

In addition to the study of categories in legislative and administrative publications, we conducted an in-depth case study [48] to document the handling of waste as it occurs on-site. This qualitative study, grounded in an ethnographic approach [49], integrates a variety of sources such as field observations, interviews, corporate social responsibility (CSR) reports, waste data, invoices, and photographic records of containers at construction sites. Building on an ethnographic approach enables a comprehensive understanding of on-site activities through immersive observations capturing the nuanced practices and viewpoints of the different stakeholders. It moreover allows for uncovering hidden knowledge and informal or even illicit practices that might not be revealed through interviews alone. Furthermore, the ethnographic approach makes is possible to comprehend the specific activities occurring on-site alongside the viewpoints of all involved, ranging from workers to managers. Finally, this approach also allows for an examination of how the prevailing organizational culture within construction sites influences the practices and strategies of waste management [50].

**Table 1**
Inventory of documents in the study.

| Data type | Quantity | Document specification |
|---|---|---|
| EU regulation & directives | 12 | Directive 75/442/EEC, Regulation (EC) No 2150/2002, Directive 2008/98/EC, Directive 2014/95/EU, Directive 2014/955/EU, Council Directive 1999/31/EC, Directive (EU) 2018/851, Regulation (EU) 2019/2088, Regulation (EU) 2020/852, Regulation 2021/2178, Directive (EU) 2022/2464, Directive 2014/95/EU |
| Danish regulation | 8 | LBK nr 1441 af 14/11/2022 (Årsregnskabsloven), LBK nr 2580 af 13/12/2021 (Lov om Klima), BEK nr 2512 af 10/12/2021 (Affaldsbekendtgørelsen), BEK nr 1536 af 16/12/2022 (Affaldsaktørbekendtgørelsen), LBK nr 5 af 03/01/2023 (Miljøbeskyttelsesloven), BEK nr 939 af 20/06/2022 (Affaldsregisterbekendtgørelsen), BEK nr 282 af 18/04/1997 (Bekendtgørelse om selektiv nedrivning), Klimaplan for en grøn affaldssektor og cirkulær økonomi (2020) |
| EU action plans | 10 | Action Plan: Financing Sustainable Growth (2018), The European Green Deal (2019), Circular economy action plan (2020), A Renovation Wave for Europe (2020), Financing the green transition: The European Green Deal Investment Plan (2020), 'Fit for 55′ (2021), 2030 climate target plan (2020), A Renovation Wave for Europe (2020), EPA 8 – Environment action programme to 2030 (2020), Closing the loop (2015) |
| Danish action plans | 9 | Handlingsplan Cirkulær Økonomi (2021), National strategi for bæredygtigt byggeri (2021), Klimapartnerskabet for bygge- og anlægssektoren (2020), Klimahandlingsplan (2020), En Grøn og Bæredygtig Verden (2020), Ressourcekortlægning af bygninger (2018), Projekt om selektiv nedrivning (2017), Bæredygtighedskriterier for affaldsforebyggelse og ressourceforbrug i det bæredygtige byggeri (2016), Danmark uden affald II Strategi for affaldsforebyggelse (2015) |
| Other documents | 12 (28) | Eurostat waste statistics (2020), EEA Report No 11/2021, IPCC (2022), CRG (2023), Global Status Report for Buildings and Construction (2022), Emissions Gap Report (2022), EU Construction & Demolition Waste Management Protocol (2016), Klimarådets Årsrapport (2022), Cirkulær økonomi i byggebranchen - i praksis (2018), Materialeatlas (2016), CSR reposts (2014–2022), Affaldsstatistik (2015–2022) |

The case study has been chosen by means of convenient sampling [51]. Convenience case studies are selected based on the ease of access to the data. This is particularly important when sensitive data need to be accessed, and the accessibility ensures that the research can be conducted efficiently and within the available means [51]. The company profile also qualifies the case as a representative case study as it exemplifies the situation of similar large contractors in Denmark [50]. The case study is conducted in one of five subsidiaries (referred to as "the Contractor") of a large Danish contracting company (referred to as "Holding"). In total, Holding has a workforce of around 3.000 employees and achieved an annual turnover of €1.16B (2022). The Contractor, specializing in renovation projects, contributes approximately to one third of Holding's overall revenue (i.e., €380 M) and employs 700 persons. The core activities center around renovation, including refurbishment, demolition and new build projects serving public, private, and social housing clients. In 2022, the Contractor's portfolio consisted of 176 projects varying in sizes and scopes. From this portfolio of projects, we selected four construction sites as potential candidates for the observation study.

The selection of sites was based on specific project criteria including duration, progress, scale, cost, and accessibility. To effectively differentiate between the types of waste, the projects needed to be structured into two distinct phases, clearly demarcating the demolition phases from the new construction one. One of the sites, constituting our main case, involves the expansion of a day-care facility for a public client under the municipality' control with a budget of approximately €12 M. The project encompasses both the renovation of an existing building and the construction of a new. The project started in spring 2022 and was in its final stages during the summer of 2023. During the demolition phase, approximately 1.150 tons of waste were generated, while the new construction activities produced approximately 80 tons of waste, constituting 7 percent of the total waste generated throughout the whole project. We retained the three other sites as references cases to ensure the validity of our observations and mitigate the danger of over-interpreting isolated events.

*Observations*

To gain practical insights into waste related activities, we conducted ethnographic on-site observations, focusing on the daily tasks and interactions of construction workers. The observation spanned a total of 107 h over a 12-month period (see Table 2).

Our observations enabled us to gather data related to waste handling during mundane activities on-site. Observations are a constructive way to gather empirical insights from everyday practices that reflect e.g., activities on construction sites. Rather than only relying on statements describing activities (e.g., from interviews), observations are a way to create a narrative based on behavior, interactions, and activities [52]. During each visit, we conducted inspections of the waste containers and their contents, which provided valuable insights into sorting practices and concrete applications of the categories. To document these observations, we made use of photos to trace the journey of the containers. We could then compare the contents of these containers with the formal reports, statistics, and other invoices produced by the various actors

**Table 2**
Inventory of observations conducted.

| Observations | No. of visits | No. of hours |
|---|---|---|
| Main case - Construction site (1) | 15 | 45 |
| Secondary case - Construction site (2) | 10 | 27 |
| Secondary case - Construction site (3) | 8 | 18 |
| Secondary case - Construction site (4) | 8 | 16 |
| Total | 41 | 107 |

within the waste management chain.

Besides, numerous informal conversations were held with the people on-site, especially with the management team. These conversations contributed to gain in-depth information on the routines, norms and practices associated with on-site waste handling. Additionally, by accompanying one of the transporters during the pickup and drop-off of containers, we gained a vivid illustration of how different actors perceived waste categories and hierarchies while handling the same containers and their contents.

*Interviews*

To understand how rules, decisions, and rationales behind the decisions taken during the sorting and handling of waste, we conducted a total of 37 interviews (see Table 3). 19 interviews were held with respondents from Holding and the Contractor. 18 interviews were held with other actors of the industry involved in processes relevant to waste procedures and practices.

We conducted all interviews using a semi-structured interview guide tailored to the roles of the respondents allowing us to steer the conversations towards the issues specifically related to waste. Prior to the interviews, we clearly communicated the aim of study to the respondents and assured them of anonymity to encourage open and free dialogue while safeguarding the richness of the information [50]. All interviews were fully transcribed and analyzed according to the themes

**Table 3**
Inventory of interviews conducted.

| # | Respondents - Role / title | Company | Duration min. |
|---|---|---|---|
| 1 | Project Manager | Demolition company | 22 |
| 2 | Head of Sales | Waste transport company | 72 |
| 3 | Sales Coordinator | Waste handling facility | 63 |
| 4 | Head of Administration | Waste handling facility | 63 |
| 5 | Environmental Inspector | Municipality | 85 |
| 6 | Chief Consultant, sustainability | Municipality | 67 |
| 7 | Chief Consultant, construction | Municipality | 57 |
| 8 | Sustainability Consultant | Danish Building Agency | 70 |
| 9 | Environmental Technician 1 | Danish Environmental Agency | Mail |
| 10 | Environmental Technician 2 | Danish Environmental Agency | Mail |
| 11 | Consultant on Sustainability | Financial consultant company | 49 |
| 12 | Head of Administration | Construction client 1 | 56 |
| 13 | Construction Director | Construction client 2 | 56 |
| 14 | Project Development Director | Construction client 3 | 50 |
| 15 | Senior ESG analyst | Construction client 3 | 66 |
| 16 | ESG Manager | Investment company 1 | 47 |
| 17 | Head of ESG Denmark | Investment company 2 | 72 |
| 18 | Consultant on Sustainability | Consultant company | 75 |
| 19 | Board member | Holding | 54 |
| 20 | CEO | Holding | 56 |
| 21 | Technical Sustainability Manager | Holding | 83 |
| 22 | Head of Sustainability | Holding | 77 |
| 23 | Head of Sustainability | Holding | 42 |
| 24 | Financial Controller | Holding | 50 |
| 25 | Head of IT | Contractor | 68 |
| 26 | Chief Marketing Office | Contractor | 30 |
| 27 | Construction Manager 1 | Contractor | 49 |
| 28 | Construction Manager 2 | Contractor | 34 |
| 29 | Construction Manager 3 | Contractor | 63 |
| 30 | Department Director | Contractor | 37 |
| 31 | Carpenter | Contractor | Mail |
| 32 | Department Manger | Contractor | 77 |
| 33 | Head of Sustainability | Contractor | 53 |
| 34 | Head of Sustainability | Contractor | 50 |
| 35 | Business Area Director | Contractor | 38 |
| 36 | Head of Project 1 | Contractor | 42 |
| 37 | Head of Project 2 | Contractor | 40 |

developed in iteration with the theoretical framework on categories and the existing literature on waste management. These themes served as background data contributing to create a coherent narrative throughout our study.

*Data analysis*

To conduct our analysis, we followed a five steps model of qualitative analysis developed by Taylor-Powell and Renner [53]. These steps encompass: (1) *Familiarizing with the data*: in the initial step we immersed ourselves in the data by reviewing it several times to develop a deeper understanding; (2) *Identifying key questions or topics*: this included a readthrough of regulatory waste definitions and how waste categories have been shaped over time. Furthermore, we aligned the implications with the use of waste hierarchy principles in practice and structured identification of how waste categories have been used by Holding and on construction projects. Next, we chunked the data and identified key questions and topics as they appeared across the various transcriptions, observations, and conversations to provide a structure to the analysis; (3) *Categorizing information by themes and features*: this involved clustering the different topics and creating categories and themes, which consist of grouping and assigning abbreviated synonyms to similar topics across transcription and observation notes. This included processing the respondents' statements from the Contractor and grouping all statements according to key topics identified in step 2 e.g., waste definitions, sorting challenges, or how to accommodate the company's recycling aims; (4) *Identifying patterns and connections within and between categories*: in this step we analyzed the newly created categories to identify similarities or differences across our interview data and observations notes. We e.g., acknowledged that almost no one at the Contractor were familiar with Holding's recycling objectives and that different definitions were used among our respondents when speaking about mixed waste content. And finally (5) *Interpretation by attaching meaning and significance to the analysis*: in this step we connected all our data aiming at getting clear overview of the research categories and themes by making general assumptions and provide an overall meaning to our findings. This was done by creating key themes that additional could be unfolded from our theoretical framework of analysis and provide a basis for discussion.

The results and interpretations of the different methods of gathering data have been triangulated [54]. Furthermore, they also were discussed among the researchers conducting the project. By bringing together sources from different contexts, timeframes, and people and by building on several methods of enquiry, we were able to integrate multiple perspectives on the study topic, enhance our understanding, and provide additional knowledge [55]. Thus, we achieved triangulation between methods and between different types of data to ensure trustworthiness of our results [54].

## Findings

The findings are presented in three sections. We begin with an exploration of how waste is categorized according to the waste hierarchy through EU regulations. This section sheds light on how such regulation frames and prioritizes the waste categories across different category systems in different industry settings and how distinct regulation targeting CDW impacts different streams of waste. The second part of our findings delves into the strategic waste policies and specific targets at the level of the Contractor. Here we explore their endeavors to influence waste management practices and, consequently, the recycling statistics generated from their construction sites. We furthermore demonstrate how industry norms and regulations inadvertently lead contractors to publish potentially inaccurate waste data and recycling statistics. In the final part of the findings, we illustrate how construction waste is handled and prioritized on-site and investigate waste statistics and categorization events leading to, and maintaining, large amounts of mixed waste.

### *How waste practices and categories are shaped in CDW regulation*

In this first part of the findings, we illustrate how categorizing waste according to the waste hierarchy has become a political ambition and a central element in European recycling targets and emphasize the wider legislative efforts aimed at promoting sustainable data practices. The implications of this wider regulatory push is highlighted with implications for practice and impact on the on-site management of construction waste. We also delve into different waste streams originating from demolition and new build projects and examine how regulatory categories, which are primarily shaped by demolition practices, introduce a degree of ambiguity when being used to handle waste in the context of new build projects.

#### *European legislation and the waste hierarchy*

The European Union has supported waste handling in many years with a variety of legislations and action plans promoting uniform categorization of waste fractions and improved resource preservation. The impact from EU has created a pressure on national legislation and local businesses stemming from recycling targets and increased documentation requirements. National waste legislation can thus be seen as a combination of integrated EU-framework and national choices converted from EU directives to national rules and local settings e.g., from the *European Waste Codes* (EWC), that categorize waste numerically, and a subsequent hierarchization of the different categories [56]. In 2008, the Waste Framework Directive [11] outlined the waste hierarchy, prioritizing various waste handling methods and establishing specific reduction targets within the hierarchy e.g., for construction aiming at 70 % reuse, recycling or recovery by 2020. Many countries successfully met these targets, as some reports indicating more than 90 % compliance in these categories [2]. However, these numbers reveal a fundamental issue in relation to the ambiguity of categories as e.g., recovery hitherto has been placed under the recycling category in Danish waste statistics [7]. Subsequently, this category was revised, leading to a significant reduction in waste categorized as recycling from 68 % in 2017 to 45 % in 2018. This shift is particularly pertinent to the construction sector, which, since 2018, has seen over 50 % of its waste placed in the material recovery category. Particularly, this category primarily consists of heavy materials such as concrete, tiles, and bricks. However, categorizing waste according to EU's hierarchy principles is causing other practical dilemmas. As the waste hierarchy constitutes a generic framework of preferred waste management options applicable across different national and industrial settings, its use is not sensitive to the particularities of local category systems, giving rise to practical dilemmas when used in context of CDW [14]. Furthermore, demolition waste is not separated from new build waste in the hierarchy, which leads to a grey zone when handling waste on new build projects as elaborated further below.

#### *A waste management grey zone*

Construction waste has by EU been categorized uniformly under the label construction and demolition waste (CDW) without differentiating between waste streams by separating construction waste from demolition waste. Instead, both are included under a single umbrella as defined in Directive 2014/955/EU [57] notwithstanding that waste from demolition phases encompasses other materials than waste from the construction phases.

Before a construction project can start in Denmark, the client must apply for a building permit to get the project approved. If the project has demolition activities that are expected to exceed one ton of waste, the client must make a waste notification that must be approved by the local municipality. The notification is used as a communication tool, to categorize waste, and make sure that materials from the demolition activities are handled correctly. The first step in getting the notification approved is for the client to perform a screening of the building's existing materials in search for toxic exposures e.g., from PCBs, chlorinated paraffins, PAHs, asbestos, or other environmentally harmful substances. If the screening shows any signs of hazardous materials that exceed the municipality's limits, the client must include a detailed mapping of the location of the hazardous materials and a treatment method in the notification. In addition to the hazardous waste, all other materials from the demolition activities must also be included in the notification and categorized according to the EWC system. The EWC system marks material fractions with a universal code and categorizes them according to their recycling potential e.g., as hazardous, or non-hazardous.

When the municipality has approved the notification, it also specifies which waste handling facility to be used and gives the different waste fractions a tracking code making it possible to follow the waste all the way to the handling facility. Non-hazardous waste with recycling potential, must be sorted on-site in minimum 10 fractions, such as bricks, concrete, tiles, insulation, plasterboards, and other common materials from demolition activities. However, the regulation only specifies that a client must notify the municipality of demolition, renovation, and maintenance activities. This means that waste generated on new build projects does not necessitate screening, mapping, or notification approvement by the municipality, which otherwise provides the means to track the waste to a waste handling facility as illustrated in Fig. 1.

As mentioned earlier, the regulation only specifies industry specific waste fractions (the 10 recyclable fractions) from demolition activities. Common spillage or leftover materials from new build activities do not necessarily conform to the 10 recyclable fractions defined for demolition works. Rather, recycled waste from new build projects is categorized into general non-industry specific fractions (e.g., glass, metal, plastic, paper etc.). This means that waste fractions not explicitly categorized as recyclable are left unspecified, leading to a potential grey zone in waste management during new build projects. In such cases, non-specified waste tends to be categorized based on local industry category systems or norms rather than regulatory guidelines. The absence of regulatory notification mandates for waste generated in new build projects poses a multitude of challenges, encompassing issues related to tracking, control, documentation, and validation. These challenges, which correspondingly cast doubt on the reliability of a contractor's waste statistics, will be elaborated further below.

### *How a construction company mediate policy and practice*

In this second part of the findings, we examine how a construction company works with waste and waste data. We show how different category systems employed by various actors in the industry challenges the company's efforts to meet specific reduction requirements with implications for the reporting and documentation of waste fractions.

#### *Drivers of waste reduction and CDW management in a construction company*

It is not only waste legislation that influences waste practice within the construction industry. Other measures, such as corporate social responsibility, legitimization, and supply and demand for circular solutions also play a role in relation to the categorization and hence the management of waste. Documentation for waste handling is e.g., becoming a necessity for many construction companies and several reporting initiatives have been launched as part of the European Green Deal [58,59]. This includes an updated version of the Non-Financial Reporting Directive (NFRD) [60] that from 2024 will be replaced with the Corporate Social Reporting Directive (CSRD) [61], which establishes mandatory waste reporting criteria for large companies. Other regulation also promotes more efficient recycling e.g., Regulation (EU) 2019/2088 [62] and the EU taxonomy Regulation (EU) 2020/852 [63] which represent an opportunity for large companies to differentiate them from others with measurable sustainability indicators and to attract interest for improved recycling and waste handling. These

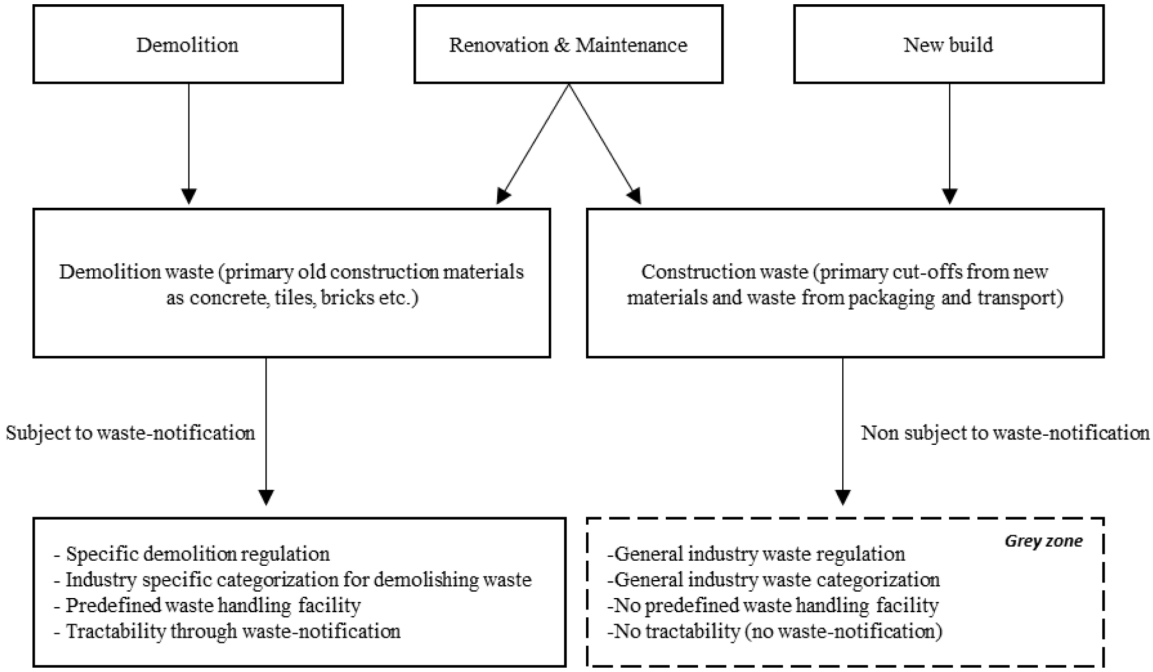


**Fig. 1.** Waste streams from demolition and new build projects.

initiatives specifically target internal operations as companies have a legal responsibility for preparing CSR reports (in compliance with the NFRD) to communicate their green profile to investors, clients, and other stakeholders.

The increased focus on sustainable data prompts an increased demand for documentation that affect organizations in different ways. In our case, Holding is heavily reliant on e.g., recycling performance measurements to produce their CSR reports. Holding therefore needs to ensure performant data streams with its subsidiaries to trace the waste production and ensure that the overall corporate targets are met. Holding documents the entire company's waste performance and produces waste statistics by collecting data from all the subsidiaries. Since 2014, Holding has published CSR reports with waste information on waste fractions, totals, and recycling percentages. Of the company's total waste, 25–30 % has been labelled as mixed waste, which corresponds to more than 6.500 tons per year. This means that the need for engaging in initiatives aiming at minimizing the mixed waste fractions, especially ensuring compliance with the EU taxonomy, is imminent.

To comply with the EU taxonomy, Holding needs to achieve a minimum of 70 % recycling of its materials. The regulation criteria of the EU taxonomy specify that energy recovery is not part a of the 70 % recycling, as opposed to material recovery. For Holding, data management is an unavoidable element in producing the waste statistics. Holding, however, depends on the subsidiaries performance as it does not have direct influence on-site waste management practice. This results in Holding directing its efforts towards adapting the local category system provided by its subsidiaries, with the aim of increasing recycling percentages, rather than changing or improving waste management and on-site practices.

*Shifting hands, shifting waste categories*

Even though the Contractor govern its construction projects, it does not handle its own waste, and is thereby dependent on external sources to transport, and potentially recycle its waste. Furthermore, distinct regulations govern materials and data in separate realms. Consequently, for contractors, adhering to these regulations involves separate processes. When materials are dispatched for sorting, they must follow waste sorting guidelines, whereas data received from the handling method is employed for reporting and aligning with data reporting regulations. Fig. 2 visually delineates the distinct pathways for materials and data.

As illustrated, the contractor passes on the materials to a transport company that handles and transports the waste to a handling facility. The waste handling facility then redistributes the waste, either for recycling, incineration, or other purposes. The waste handling facility is required to update the waste notifications (on construction waste subject to notifications), with the actual weight of the containers. This information makes it possible to trace the waste from demolition activities to the specific waste handling facility and control where the waste is delivered. However, the handling method attributed the notification in the screening phases is not controlled after the waste handling facility receives the waste. This prevents insights into what happens with the individual waste fractions when it subsequently leaves the waste handling facility.

The challenge of ensuring data validity becomes even more pronounced when dealing with waste from new build projects. As waste from new build projects is not subject to waste notifications, the handling method is not specified, reported, or confirmed anywhere. For both the client and the contractor, this means that they cannot track the waste after it has been passed on to the transporter nor control if their waste is recycled. This furthermore limits the possibility to create precise waste statistics. Nevertheless, the contractor receives data from the transporter including waste fraction, weight, EWC codes, and handling methods. However, it is important to acknowledge that this data may not always be accurate, as the waste handling facility sends invoices to the transporter solely based on weight and waste fractions. This approach might, for instance, group all waste with recycling potential into a unique recycling category, or classify all mixed waste for energy recovery. But this does not always correspond to realities as not all waste with recycling potential is recycled nor all mixed waste incinerated. Consequently, the choice of handling method is decided at different local settings associated with different category systems that fit with their practices. As in the case of the waste handling facility, waste containers are often re-categorized and subdivided prior to delivery. As the Head of Administration for a waste handling facility explains: *"It is never the transporter that decides how we treat the waste […] many times, we*

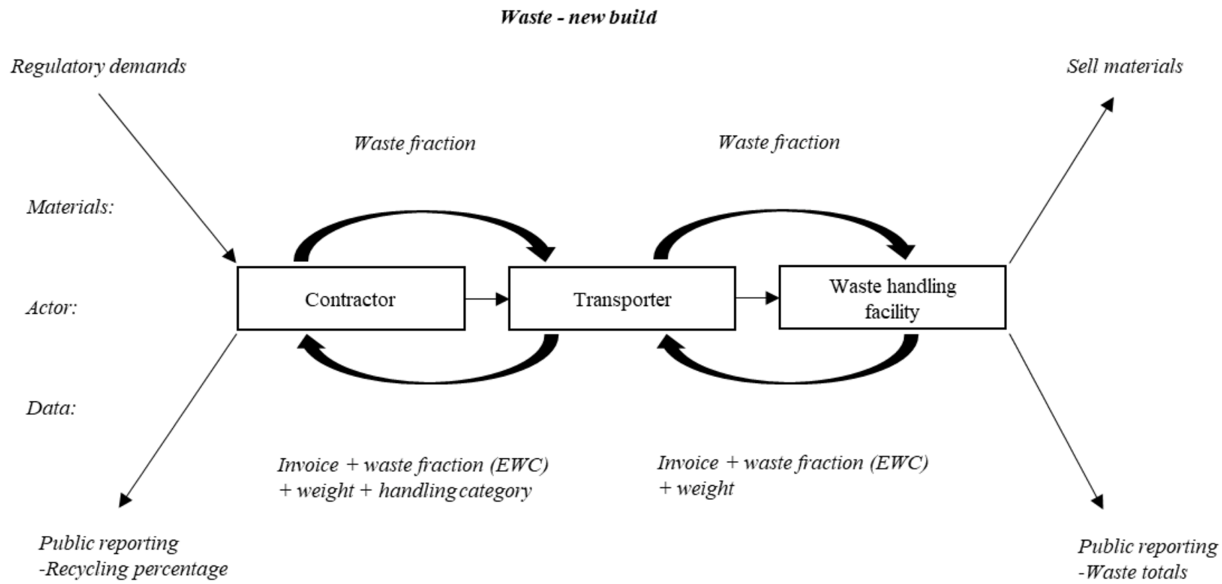


**Fig. 2.** A schematic overview of pathways for materials and data.

*subsequently find other materials [than stated] in the containers, and then we subsequently re-categorize the fraction" (Head of Administration, waste handling facility).*

This can cause validation issues for a contractor's recycling claims, as the contractor builds the waste statistics on the transporter's category system, which is based on categories reflecting their own concerns in relation to waste transport, and not what happens at the waste handling facility or on-site. Taking insulation as an example, all insulation waste handled by the transporter is classified as recycled, and without questioning the validity of this classification, the contractor uses these claims in its statistics irrespective of whether the transporter can substantiate them. Further exacerbating this issue, not all waste can be recycled as some waste handling facilities do not have recycling options for e.g., insulation. This problem, among other, stems from monopoly agreements between different waste handling facilities and materials producers that buy insulation waste and use it in production of new insulation. However, as producers may have limited capacity and can only take limited amounts back into their production, some producers have made agreements with waste handling facilities to ensure the recycling of their insulation waste, consequently leaving others out. As the Head of Administration of the waste handling facility explains: *"We inform our customers that we do not have a solution [to recycle insulation] and we shouldn't take their insulation. Unfortunately, this is due to the monopoly agreement [with other waste handling facilities]" (Head of Administration, waste handling facility)*

Without knowing whether the insulation waste ends up at a waste handling facility without recycling agreements, the Contractor, nevertheless, forwards its waste statistics (including categorizing all insulation waste as recycled) based on the transporter's data to Holding. This adds insecurity and validation issues to Holding's waste statistics and recycling percentages, and furthermore compromises the intentions of the categories.

*How construction waste is handled on-site*

In this section, we focus on the project level to study the practical categorization of waste and provide statistical insights in the on-site practices and influences of different actors' categorizations in the construction waste supply chain. This is relevant as it also highlights the connection between on-site practice and the political attention towards different waste streams and the consequences of aligning and categorizing waste streams under a single legislative umbrella, which is elaborated below.

*Waste awareness and handling on-site*

In contrast to demolition waste, waste from new build projects primarily consists of spillage and cut-offs from new and uncontaminated construction materials with high recycling potential. Nevertheless, the materials from the demolition activities, according to our data sample, perform better in relation to the hierarchy definitions than materials from new build project (see Fig. 3).

To understand, why this is the case, and how waste on new build projects is handled, we draw on data from a renovation project (our main case) of a day-care institution that has both demolition and new build activities. Being aware that different construction activities may use different category system, which potentially makes it difficult to compare waste from demolition and new build projects, the question is whether the low recycling percentages on new build projects arises from a lack of on-site awareness or if it is a result of different uses of categories. At our early visits at this project site, it was apparent that the project and construction managers were unaware of Holding's ambitions and recycling targets. A construction manager explains: *"There are probably some targets […] but I'm not sure what Holding's strategy is […] I don't know what happens higher up in the system, I focus on what happens out here on-site" (Construction Manager, Contractor)*

Nevertheless, the managers are, to the best of their knowledge, following the waste regulation and have created a large container area at the construction site to manage the different waste fractions. The containers contain different waste materials, such as spillage from production (e.g., pieces of plasterboard or insulation), packaging and transport leftovers, which all are varying in scope during the different construction phases. Management has categorized and labelled the containers in collaboration with the transporter, which has resulted in the following waste fractions being sorted: metals, plasterboards, cement base plasterboards, insulation, plastic, cardboard, wood, and mixed / burnable waste.

During our site visits we witnessed several pickups by a waste transport company. The pickup process starts with the on-site management noting that a container needs to be emptied. The manager then contracts the transport company to schedule a pickup. When the driver arrives at site, management is usually not present, and the driver loads the container singlehandedly. If the driver detects that the content of the container is not in accordance with the order (e.g., wood material in a container for plastic) the driver then, in collaboration with the transport

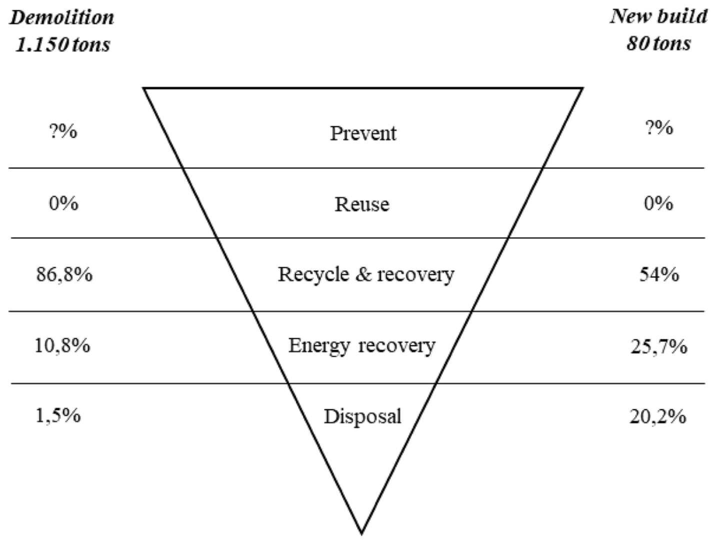


**Fig. 3.** Recycling percentages on sample project (construction site 1).

company's headquarters, re-categorizes the container, so the category fits the content. If e.g., a container for plastic waste contains wooden materials the container is classified as a mixed waste container and can either be directed to the scheduled plastic facility and be sorted or be send to an incineration facility for energy recovery. Even though the transporter company claims that on-site management is informed if containers are re-categorized, management denies receiving information of containers being re-categorized.

*Out of site, out of mind*

Once a month, the transporter sends invoices to the management for approval and payment. The invoice contains information on all the pickups from the previously month, and if e.g., a container for plastic have been re-categorized to mixed waste / burnable the invoice only includes the re-categorized information. This prevents the management from knowing, which containers have been re-categorized, as they do not focus on what happens after the container leave the site. As they say: "*out of site [sight], out of mind*" *(Construction Manager, Contractor)*. And as the management do not keep their own track of containers leaving the site, they are unaware of the many re-categorized containers. The Head of Projects explains: *"We do not control what they drive away with. We just trust that the transporter follows the rules, that's all we do" (The Head of Projects, Contractor)*

The lack of control furthermore makes it very difficult to back-trace the original content of a container as the re-categorized information replaces the old. And as the management are uninterested in waste statistics and only focus on what happens on-site by keeping the construction site functioning and staying within their budget, the many mixed waste containers stay under the radar. The statistics (see Table 4) from our case project shows that 19 out of 43 (i.e., 44 %) containers have been categorized for mixed waste / burnable. But since mixed waste is a common waste fraction on construction sites, it becomes difficult to separate the intended mixed waste containers with the unintended ones in the statistics.

*Aggregate consequences of recagorization*

The problem with the re-categorization of containers would be inconsequential if this was to happen only a few times on a few construction sites, but in general the Contractor pays primarily for mixed containers from all their sites, counting 1334 out of 4688 pickups in total (2022). This corresponds to 28 % of all pickups, and by weight the percentage is even higher with 35 %, as 2405 tons of the total 6927 tons (2022) has been categorized as mixed waste (See Fig. 4).

**Table 4**
Sample of contents from waste containers.

| Date | Intended handling | Category | Weight |
|---|---|---|---|
| 30–03–2022 | Energy recovery | Mixed waste / burnable | 0,40 |
| 30–03–2022 | Recycling | Metals | 0,32 |
| 30–06–2022 | Energy recovery | Mixed waste / burnable | 0,24 |
| 29–08–2022 | Recycling | Wood | 3,08 |
| 30–08–2022 | Recycling | Wood | 1,78 |
| 30–08–2022 | Material recovery | Rubble & ceramics | 6,76 |
| 02–09–2022 | Energy recovery | Mixed waste / burnable | 0,86 |
| 22–09–2022 | Energy recovery | Mixed waste / burnable | 1,56 |
| 06–10–2022 | Recycling | Metals | 0,18 |
| 06–10–2022 | Material recovery | Rubble & ceramics | 0,88 |
| 18–10–2022 | Energy recovery | Mixed waste / burnable | 1,22 |
| 25–10–2022 | Energy recovery | Mixed waste / burnable | 1,46 |
| 31–10–2022 | Energy recovery | Mixed waste / burnable | 1,08 |
| 01–11–2022 | Recycling | Metals | 0,48 |
| 04–11–2022 | Recycling | Metals | 0,62 |
| 18–11–2022 | Material recovery | Rubble & ceramics | 3,00 |
| 25–11–2022 | Recycling | Wood | 0,44 |
| 25–11–2022 | Energy recovery | Mixed waste / burnable | 0,30 |
| 25–11–2022 | Recycling | Insulation | 0,26 |
| 25–11–2022 | Recycling | Metals | 0,18 |
| 25–11–2022 | Energy recovery | Mixed waste / burnable | 0,36 |
| 01–12–2022 | Recycling | Wood | 0,24 |
| 01–12–2022 | Energy recovery | Mixed waste / burnable | 0,58 |
| 09–12–2022 | Energy recovery | Mixed waste / burnable | 0,28 |
| 09–12–2022 | Recycling | Wood | 0,22 |
| 19–12–2022 | Recycling | Insulation | 3,45 |
| 19–12–2022 | Recycling | Metals | 3,09 |
| 19–12–2022 | Recycling | Wood | 0,46 |
| 19–12–2022 | Energy recovery | Mixed waste / burnable | 0,36 |
| 19–12–2022 | Energy recovery | Mixed waste / burnable | 0,14 |
| 19–12–2022 | Recycling | Plastic | 0,20 |
| 09–01–2023 | Energy recovery | Mixed waste / burnable | 0,44 |
| 09–01–2023 | Recycling | Wood | 0,46 |
| 09–01–2023 | Recycling | Insulation | 0,52 |
| 11–01–2023 | Recycling | Wood | 1,44 |
| 11–01–2023 | Energy recovery | Mixed waste / burnable | 5,62 |
| 19–01–2023 | Energy recovery | Mixed waste / burnable | 0,10 |
| 19–01–2023 | Energy recovery | Mixed waste / burnable | 0,16 |
| 30–01–2023 | Recycling | Wood | 0,48 |
| 30–01–2023 | Energy recovery | Mixed waste / burnable | 0,84 |
| 31–01–2023 | Material recovery | Rubble & ceramics | 4,76 |
| 08–02–2023 | Energy recovery | Mixed waste / burnable | 0,16 |
| 08–02–2023 | Recycling | Plastic | 0,46 |

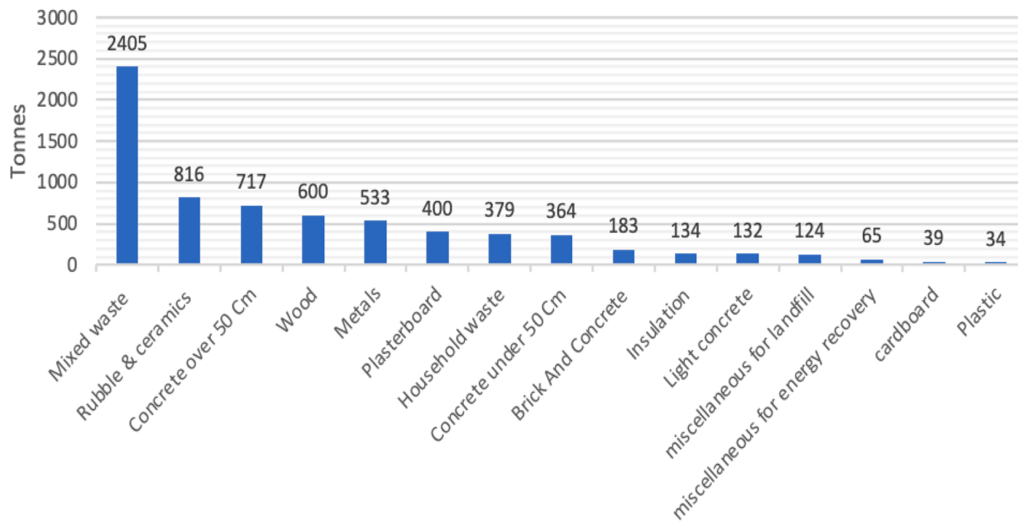


**Fig. 4.** Aggregate volumes of waste from all projects conducted by the Contractor.

Based on the statistics it is difficult to estimate how many containers have been intentionally re-categorized or accordingly due to bad sorting and how many that have been planned as mixed waste. But the economic consequences for the contractor are noticeable as the market price for mixed waste is much higher than for e.g., wood, plastic, or concrete. Approximately €100 per tons for mixed waste and €30 per tons for wood. In total the contractor has paid approximately €750,000 for waste handling in 2022 of which €340,000 were for mixed waste, corresponding to 45 % of the total waste expenses. Besides the economic significance for the contractor, the environmental consequences of not recycling construction materials and sending large amounts of waste towards incineration should be highlighted as it counteracts the political circular ambitions that e.g., are embedded in the waste hierarchy.

## Discussion

In the paper, we have taken the position that categories are normative and cognitive agreements [39] that actors use to create a common reference for their operations. Our study contributes to the understanding of construction waste and demolition waste and how different understandings and uses of categories influence waste practice data validity and, in some cases, result in reusable resources being classified as waste and incinerated. While categories may serve to create a common frame of reference, the fact that they are cultural concepts imparted meaning by actors occupying different positions means that they also are subject to negotiations and sources of conflict [39]. In the following discission, we will discuss the role of various cultural contexts in the shaping of categories and how the waste hierarchy prioritization of recycling over recovery can create ambiguity that may hinder rather than facilitate effective waste management. Additionally, we will examine the repercussions of the limited attention and failure to separate new build waste and demolition waste to achieve recycling targets and the practical implications from ambiguous regulation leading to potential incorrect waste reporting.

### *Waste hierarchy and categories, from policy to practice*

In light of the growing concerns surrounding resource scarcity [59] and the commitment to establish a climate neutral economy [58], EU has established a universal system [11,13,57] for the categorization of waste. Since the launch of the waste hierarchy, EU has strived to generalize its principles and create a reference frame for ranking waste treatment, which builds on the assumptions that the identification of the type of material is effortless, and its quality is intact [44].

The general categorization within the waste hierarchy facilitates a common understanding that arguably can be applied in many settings and create meaning to many local practices [40]. This is widely supported as scholars have argued that clear and unambiguous waste categorization must be established to solve issues related to insufficient waste handling [32], overlapping categorizations [29], and poorly defined end-of-waste criteria [31]. However, the link between political intention and operational practice is often weak with limited conceptualization of how to move from intention to implementation. This may result in non-compliance or decoupling [64–66] as illustrated in the findings where Holding tries to create corprate targes to increase the recycling percentages but with limited success as the individual projects engage in business-as-usual and avoid the criteria.

Consequently, while the waste hierarchy principles can be conceptually applied within a construction context, they were not specifically tailored for this purpose, which may account for the patterns observed. Experiences from other industries highlight great variance in the use of categories. Data from the Environmental Protection Agency [7] e.g., illustrates that waste material from the service sector and the household sector mainly falls into the recycling category with almost no waste in the recovery and deposit categories. These variances illustrate the point that differences in local or sector specific practices should be reflected in categories systems applied. Materials from different industries are thus subsumed under a uniform hierarchy system that may not fit local practices associated with the different industries. As previously highlighted, the construction industry displayed high recycling percentages prior to the adaptation of the recovery category. This could also be true for other sectors, as changes in waste statistics may reflect an adaptation to the waste hierarchy rather than a change of practice.

Moreover, as shown in the findings, the sorting of construction materials is influenced by different actors' assumptions and use of category systems associated with different practices, as transporter and contractor favors different use of the hierarchy. This enables local pitfalls that e.g., political bodies and regulators may struggle to address, particularly given the case of construction waste as its quality is often unpredictable and may need local adaptation or individual action that uniform regulation cannot unequivocally provide. Extant research has identified several best practice measures that may be used to address some of the challenges identified in the paper such as waste misclassification and a lack of awareness [67]. These include periodic checks on the use of CDW containers [68], coordination and review meetings about CDW [69], and mandating onsite staff to carry out reviews ensuring that on-site operations follow the agreed waste-management plan [70,71]. While, practically plausible, these suggestions nevertheless have certain shortcomings considering the understanding that waste categories are culturally agreed or institutionalized concepts. Efforts to implement best practices in CDW management may thus not succeed due to divergent interpretations of waste categories among stakeholders and the lack of flexible boundaries for categories within the existing waste management framework may hinder effective waste handling. This is discussed further below.

*Categories as cultural constructs*

Categories are culturally agreed or institutionalized concepts that can be anchored and stabilized by symbols (such as the waste hierarchy) to permit and facilitate interactions between producers and consumers [34]. David et al. [35] further argue that categories are shared representations of an agreement, or a common reference point for different actors. However, the context in which the category is established significantly influences the shaping of the category. Our findings illustrate that various actors hold distinct interpretations and applications of the same category. For example, we observe disparities in how the contractor, transporter and waste handling facility define when a material qualifies as e.g., recycled. This divergence can be attributed to two potential explanations. First, it may stem from symbolic distinctions deeply embedded in these categories by the actors employing them, given that the contractor, transporter, and waste handling facility exhibit different viewpoints on waste categories and the implementation of the waste hierarchy [36]. Second, this divergence may also arise from a lack of precise delineation and flexible boundaries within the categories. Yet, if treatment of waste is excessively rigid, it could potentially compromise the adaptability needed for purposeful handling. For example, the same type of material can have been exposed differently through its lifetime, which then determines which handling method or category within the hierarchy that is best-suited when classifying the material. On the other hand, the lack of clarity and ambiguity in the definitions of categories [45] introduces additional challenges. Our study highlights that the utilization of the recycle and recover categories is not straightforward among the involved actors. This is illustrated by the fact that the contractor, transporter, and handling facilities have preferences for different categories, particularly for the treatment of mixed waste. This choice is further reinforced by the financial benefits associated with categorizing waste for energy recovery.

The principles of universal hierarchization consequently categorize materials towards a universal and specific type of ranking, nonetheless in the case of construction, waste could have a variety of potentials. Moreover, within the hierarchy, recycling holds a higher ranking than recovery, making it favorable to categorize materials such as concrete under the recycling category rather than a recovery category. Although it could be advantageous, it also has drawbacks, as e.g., recycling concrete typically implies crushing the old concrete and using the crushed material as aggregate in the production of new concrete thereby replacing some of the virgin aggregates (sand and stone). This, however, moves materials away from the recovery category that typically consists of demolished concrete used as a bearing layer replacing stabilized gravel. Even though the purpose (end-product) is very different, the waste handling processes for recycling and recovery are almost identical and furthermore have similar indirect effect by substituting either stone, sand, or gravel mining. Furthermore, prevention assumes a paradoxical position in the hierarchy. As the prevention of waste take the highest position in the hierarchy, the contractor has little to no incentives to achieve this. As the contractor attempts to increase the recycling figures (e.g., in compliance with the EU taxonomy), the waste that is not generated (prevented) consequently stays outside the statistics, thus not influencing the recycling figures. The incentives for changing the category between recycling and recover could thus be higher than preventing or minimizing waste when focusing on reaching compliance criteria for recycling.

*Implications of categorization in practice*

Waste from new build projects in Denmark is estimated to comprise roughly 4–10 % of the total waste generated from construction [72–73]. This relatively smal proportion could explain why legislation has tended to focus on demolition in regard to categorizing recyclable waste fractions. The categories generated for demolition have thus been institutionalized over time, rooted in practice [35], and aligned with general waste handling criteria. On the other hand, waste from new build projects has not gained any specific regulator attention. This could be an explanation for the consequences, as our data samples show a much lower recycling percentages (waste placed in the recycling category) on new build than demolition projects, even though the materials from new build projects typically are clean non-hazardous waste fractions with high recycling potential [74]. Furthermore, demolition waste is regulated in such a way that it is possible to follow the waste from the project to the waste handling facility, allowing for insights into whether the waste reaches its intended destination or not. Conversely, waste from new build projects does not require any form of approval or notification, rendering it very difficult to trace once it leaves the construction site. This, in the end, has some consequences for the validity of waste statistics, which furthermore creates a void in the connection between the political efforts and practice.

As categories typically are created to generate a common reference, as a type of agreement that can be useful in the exchanges of goods [39], the consequences of an uncritical misalignment in the understanding of categories among various actors become evident in this context. The monopoly agreements between material producers and waste handling facilities make it impossible to e.g., recycle all insulation waste, which nevertheless is categorized and labelled for recycling even though this is not what happens with it in practice. The validity of waste data can consequently become a problem for the contractor, as reporting incorrect recycling figures could harm their businesses and, in some way, facilitate the greenwashing of improper waste handling, harming investors and other industry stakeholders. This issue is further compounded by the lack of corporate influence on waste handling on-site. Holding holds a unitary interest in improving the company's overall recycling statics, but due to the corporate structure, where compliance and reporting demands are situated centrally rather than at the project level, they find themselves out of influence on the on-site practice and the possibility to control the validity of data. And as new compliance demands are pressuring the contractor (e.g., 70 % recycling to align with the EU taxonomy), it may result in so-called category adaptation to ensure fit to the category system instead of improving on-site waste practices.

*Theoretical implications and recommendations for policy and practice*

This research illustrates that waste categorization processes and the categories embedded in the waste hierarchy give rise to divergent perspectives and interpretations among the actors involved in waste management. Focusing on the notion of categories as used in context of institutional theory has helped to identify the features, commonalities and trade specificities attributed to materials and waste management processes in different social contexts. We have shown that while different actors engage successively in the process of sorting and handling waste, their individual understandings and practices remain unchallenged by one another. The result hereof is an absence of a shared frame of reference, which reinforces the current fragmented waste management practice. If waste management and recycling practices are to be improved in the construction industry, it is necessary to find ways to bridge these different perceptions. As previously argued, seeing categories as thoroughly cultural constructs, however, precludes the possibility of doing so by harmonizing different perceptions or enforcing a universal definition to solves the issue. Rather, suggestions for improving practice must be sensitive to the multiplicity of place-bound practices and category systems that exist, while still being able to, in the aggregate, inform waste statistics with valid data. This has repercussions for policy as well as practice.

From a practical perspective, the issue of data validity in waste categorization and reporting is central. As shown in the findings, a crucial aspect hereof is the lack of disclosure and traceability throughout the waste stream or waste value chain, which have important implications for CDW management. First, it may reinforce illegal waste dumping behavior. Yuan et al. [75] identified a series of critical factors that influence the illegal dumping behavior of CDW, including institutional factors such as regulatory conditions and penalty levels. Adding to this, we find that a lack of data validity may accelerate this issue further, as the lack of transparency precludes the possibility of following the waste as it leaves the site. This may both result in subpar recycling percentages and increase greenwashing due to wrongful waste reporting. Several solutions to this can be envisaged, including technological, economic, and regulatory methods and processes. Technologically speaking, traceability can be ensured by implementing technologies and management systems that follow the waste throughout the entire handling process. Blockchain solutions have e.g., been identified as a promising avenue for improvements. Ma et al., [76] thus argue that the inherent characteristics of blockchains, such its tamper-proof and immutable records, can reduce data manipulation and improve waste management processes. Bekrar et al., [77] also highlight this aspect, arguing that it is possible to complete a waste management trading system that treats construction and demolition waste as a tradeable resource using blockchain technology.

From a perspective of economic sociology, the question of turning waste into a tradeable resource has also been discussed by Moalem and Kerndrup [28] in a study of the role of waste companies in transforming waste streams to value streams. It is argued that knowledge information and documentation work play an important role in creating a distinct value for the waste product. Such a process of conferring value upon waste includes valorizing aspects of waste in term of more than externalities. This requires extensive coordination between buyers and sellers mediated by market devices [78–79] in the form of assay tools, procedures, etc. that enable different actors to agree on a price and trade to take place. This allows for more transparency in relation to how waste may shift between being attributed to different categories and with what consequences for the different actors throughout the waste handling process.

From a regulatory perspective, we have demonstrated the existence of a waste management grey zone and illustrated that the lack of approvals or notifications for waste from new build projects makes it difficult to trace the waste once it departs from the construction site. Implementing corresponding regulations and requirements for demolition waste may thus also alleviate the issues reported. Seeing waste management from a perspective of valorization also bears political implications. Moalem et al., [80] argue that directing waste practices away from recycling implies a range of challenges, including the development of partnerships between different stakeholders. This means that policymakers should prioritize the development of policies based on deliberative and participatory processes. This may involve engaging with construction companies, waste management firms, local communities, and environmental organizations to collectively address challenges related to waste practices. Such collaborative governance could involve both the design of incentive structures to motivate stakeholders to actively participate in sustainable waste management practices as well as educational initiatives and awareness programs to inform stakeholders about the benefits of waste categorization and recycling.

On this basis, we recommend that future research aiming at enhancing waste management should place more emphasis on how different institutional settings shape categorization practices and how industry and governance structures can be established in support of collaborative efforts to improve waste management practice.

## Conclusion

Waste is a global problem and waste from construction activities account for one third of the total waste generated in Europe. The political incentives to reduce the waste streams through different regulatory initiatives are increasing with particular focus on anti-greenwashing and supply and demand mechanisms for recycling figures. Better waste management and higher recycling percentages is thus becoming a competitive advantage for many companies. Furthermore, EU has strived to refine the principles of waste hierarchy and created unambiguous categories and waste definitions.

This study sheds light on the intricate relationship between construction waste, different category systems, and its practical implications for waste management on-site. The research has demonstrated that waste categories are not static, universally understood concepts but subject to interpretation and local adjustments by different actors. Different areas within the construction sector, such as contractors, transporters, and waste handling facilities, hold distinct views and uses of category system in their handling of waste. This can be attributed to both symbolic distinctions and institutionalized practices. The study furthermore highlights that the regulatory focus primarily is on demolition waste, and we have explored the implications of this in the context of new build. There clearly exist a lack of oversight and traceability for new build waste that create challenges for trustworthy waste statistic. Moreover, the misalignment in the understanding of waste categories among various actors (contractor, transporter, and waste handling facility) lead to inaccuracies in recycling figures, potentially harming businesses and encouraging and maintaining improper waste handling. This disparity in the comprehension of waste categories and resource management maintains fragmentation and results in substantial quantities of waste being incinerated and thus the degradation of resources. Addressing this will be essential in the context of growing concerns about resource scarcity and the need for a climate-neutral economy in the future.

## CRediT authorship contribution statement

**Andreas de Gier:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Stefan Christoffer Gottlieb:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Martine Buser:** Writing – original draft, Methodology, Formal analysis, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

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