

Waste not, want not:
Valorizing Construction Waste for Sustainable Alternative Materials

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Abstract

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The construction industry is a major contributor to waste generation and resource consumption in Canada (Earle et al., 2014), detrimentally affecting our environment. Reimagining ways to reuse construction waste can foster more sustainable industry practices. This thesis investigates which construction waste materials have untapped potential and how they could be reused responsibly within the built environment and design. The research develops new material composites from construction waste for use as interior objects, demonstrating how waste can be revalued. By examining the socio-cultural, economic, and political factors shaping waste management and wasting behaviour in Canada and Montréal, and through interviews with stakeholders involved in local waste management and reuse, the study highlights the subjectivity of waste and its shifting value. A review of industry waste management practices and Montréal waste statistics identified gypsum and aggregate as underutilized materials. Collected through field work at local construction sites, these materials led to recycled gypsum, a potato starch-based construction residue biocomposite, and a SCOBY-based construction residue biocomposite prototypes. Supported by a theoretical investigation into how value is created and a critical engagement with waste's agency, the prototypes were used to create functional décor objects such as coasters, trays, a bowl, candle holders, and vases. A lamp shade and chess set were also made. Lastly, a group interview was conducted to assess, from an outside perspective, how well the materials were valorized.

Keywords: Repurposed materials; composite materials; construction waste; circular design; material agency; waste management; research-creation

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List of Acronyms

CBE – Circular built environment

CMM - Communauté métropolitaine de Montréal

CRD – Construction, renovation, and demolition

CR – Construction residue

CUCCR – Concordia University Center for Creative Reuse

ECCC - Environment and Climate Change Canada

MELCCFP - Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs

SCOBY – Symbiotic culture of bacteria and yeast

Chapter 1: Introduction

In 2022, Canada generated 36.5 million tonnes of solid waste (ECCC 2024). Only 9.9 million tonnes of that waste were recycled, recovered, or diverted from disposal, while 26.6 million tonnes were disposed of, even though a public diversion program exists for most of our waste stream.

Waste management negatively affects our environment through the production of greenhouse gases (GHGs) and the release of other harmful pollutants (UNEP, 2024). While Canada's total national emissions have been on a decreasing trend since 2015, the waste industry's emissions have remained relatively stable (ECCC, 2025). Landfills contribute the majority of the industry's emissions in the form of methane (ECCC, 2025), and in Canada, less than half of the methane generated is captured (ECCC, 2022). Landfills also pose a threat to their surrounding environment in the form of leachate, a substance produced when rainwater filters through landfills and accumulates harmful water-soluble materials emitted during the decomposition of waste (Ozbay et al., 2021; Danthurebandara et al., 2012). Most modern landfills are equipped with runoff capture systems, but these still bear a risk of failure. The leachate, GHGs, and pollutants produced by waste management pose threats to our air, water, and soil, disrupting ecosystems and harming human and non-human life alike (Danthurebandara et al., 2012; UNEP, 2024).

Waste and waste management are also connected indirectly to other environmental issues. By providing a place for our waste to go, the waste management industry feeds our rapid cycles of production and consumption. Through mining, deforestation, intensive agriculture, and farming, these activities further degrade the environment (Du Pisani, 2006).

The built environment is a major contributor to waste generation and resource consumption in Canada (Earle et al., 2014). Annually, Canada's construction industry generates around 12% of the country's solid waste stream (ECCC, 2021). In 2020, the national diversion rate for construction, renovation, and demolition (CRD) waste was only 18% (Goodland & Walsh, 2024). A 2008 report from the Commission for Environmental Cooperation stated that Canada's built environment was responsible for 50% of national natural resource consumption, and increased waste disposal can only lead to further resource consumption.

The construction industry also contributes significantly to national GHG emissions. While operational emissions contribute the majority of the built environment's share (Natural Resources Canada, 2025), the embodied carbon in building materials has a long-lasting impact, and these materials maintain the potential to become waste. Embodied carbon also receives less attention for research and development in comparison to operational carbon (UNEP, 2023). Improving how the industry uses resources and manages its waste would reduce demand for new materials, reduce the amount of waste going to landfills, and subsequently reduce emissions related to these activities.

The issue of CRD waste persists on the local scale. In 2020, 1.4 million tonnes of CRD waste were generated in the Communauté métropolitaine de Montréal (CMM), 27% of the region's total waste (CMM, 2023). Only 29% of CRD waste was recovered. The category of CRD waste in the CMM includes aggregates, wood, gypsum, asphalt shingles, and "others" (CMM, 2023, p. 64). The largest sub-category of CRD residual materials was wood, with 537,579 tonnes generated in 2020, 40% of which were recovered. The next largest sub-category was aggregates, which includes concrete, stone, gravel, and asphalt (CMM, 2023, p. 8); 203,064 tonnes were generated, 53% of which were recovered. Nearly 65,000 tonnes of gypsum residual material were generated in 2020, with just under 7% recovered, one of the lowest recovery rates in the CMM.

During my undergraduate education in architecture at the University of Waterloo from 2017-2022, I became acutely aware of the construction industry's environmental impact, which fostered a personal interest in sustainability and an ethical obligation toward the negative impacts of my chosen field. This research is driven by the belief that designers, due to the specialized skills and knowledge they possess, have a responsibility to recognize and understand the costs of their actions (Russ, 2010). Many design fields and related disciplines (e.g., architecture, landscape architecture, product, industrial, and fashion design, and engineering) have the opportunity to shape society, affecting our relationships with each other and the planet. Achieving sustainability will require systemic change, and designers should advocate for positive changes within their professions.

Approaches to sustainability in the built environment are broadening, but in my educational and work experience in the architecture industry, the primary areas of focus were energy efficiency, emissions, and technical solutions. These experiences fostered an interest in waste reuse, an area I perceived as being somewhat overlooked. This prompted me to pursue the Master of Design program at Concordia University with waste reuse as a focus. The Montréal context also influenced the decision to focus specifically on CRD waste. Before starting at Concordia, I moved into an apartment across from a construction site for the STM's blue line extension, where I was presented with an active construction site and its waste every day. Attending Concordia's SGW campus, located downtown, I also noticed the abundance of construction sites throughout the city. Combined with research into Montréal's waste stream, CRD waste became impossible to ignore.

1.1 Research Questions

This influenced the decision to pursue research focused on CRD waste reuse and ask the following research questions:

How can we valorize discarded CRD materials gathered from Montréal's waste stream through their re-composition into new materials and repurposing as interior objects?

How might our perception of and sensory engagement with waste change if we consider these materials for a new purpose?

Waste, by definition, is something perceived as having no value (OED, 2023); if our perception of waste changes, so might our disposal practices. Broadening the extent to which waste is legitimized as a material resource would have the potential to divert more post-consumer products from landfills, reduce the amount of waste generated, and contribute to a circular economy. This research aims to expand the possibilities for material reuse by focusing on CRD waste materials that are currently ignored or underutilized. Based on the CMM waste statistics outlined above, wood, aggregates, and gypsum were selected as potential options for material exploration. Due to either their large volume in the waste stream or low recovery rates, these material categories require further investigation to learn why their reuse rates are not higher, and what potential they may have for reuse.

In order to address these questions, the research focused on investigating which types of CRD waste have untapped potential after their end-of-life and how they might be reused through the development of material composites. To demonstrate how waste can still have value after being discarded, the material composites were used in the creation of a series of object prototypes (fig. 1.1). They include: a coaster, a tray, a candle holder, and vase made from a recovered concrete, asphalt, and aggregate biocomposite; three candle holders, a vase, a tray, and a bowl made from recycled gypsum; a chess set using both aforementioned recycled materials; and a lamp whose shade is made from bacterial cellulose and recovered concrete, asphalt, and aggregate. Images of the object prototypes are included throughout the thesis. For larger images, see Appendix 1.



Figure 1.1 Final object prototypes created for the research. Image by Elizabeth Vince.

In addition to generating new uses for waste materials, this research investigates how our perceptions of and relationships to waste might change if we consider materials not for their monetary value but for their potential purposes. This goal is supported by critically examining what it means to waste and how power systems structure our relationships with waste. To support this adjustment in perspective, the term “residual material” is often used instead of waste to align with the provincial government’s terminology and avoid the negative connotations of “waste.”

1.2 Methodology: Integrating making and reflection

This thesis’s research questions, particularly in their relation to material engagement and aesthetic value, could not have been addressed without a creative component. This research-creation approach thus involved a constant back-and-forth between making and reflection. It considers the embodied knowledge emerging through creation (Chapman & Sawchuk, 2012) and leads to the critical or theoretical analysis of the creative work (FRQSC, 2023). More specifically, this research embraces Research through Design as a methodology, which emphasizes creating new knowledge through design work, as well as co-evolution of research and design, allowing the researcher to simultaneously learn and generate knowledge through making (Frankel & Racine, 2010; Godin & Zahedi, 2014). In this research, design work is used to develop alternative ways to think about and use waste, with the former being embedded in the latter.

The primary methods used in this research are literature review (Race, 2008), field research (Linstroth, 2008), interviews, and iterative prototyping (Sharp & Macklin, 2019). Additionally, a dedicated sketchbook was used to document progress, reflections, and inspiration. The reflection and analysis recorded in the sketchbook were synthesized and integrated into the thesis.

Field research involved visiting Montréal’s construction sites, collecting materials, and conducting interviews. Interviews were intended to contribute to a more thorough understanding of the Montréal waste context, including the range of actors involved in the local waste management system, how the system operates, and how citizens interact or engage with waste. To support this goal, local stakeholders and experts were recruited using internet searches and the CMM’s inventory of residual materials management facilities and organizations working in the management of residual materials (CMM, 2023, p. 151; p. 176). Three interviews (with Martin Bureau of environmental engineering firm Sanexen, Geneviève Dagneau of non-profit organization Mine Urbaine, and an anonymous Ecocentre employee) were conducted; however, only two revealed directly useful information for this research. Interviews were conducted in a semi-structured manner as this type of interview allows more flexibility for both interviewer and interviewee as the conversation progresses (Ayres, 2008). Discussion guides were prepared based on the literature review completed prior to the interviews; however, these were flexible in line with the semi-structured format. The conversations focused on the interviewee’s experiences related to CRD waste reuse and reduction, their observations of the socio-economic dynamics of waste

management, and their perception of residual materials. Interviews were audio- and video-recorded and transcribed. Transcriptions were analyzed informed by the coding strategies of initial coding and pattern coding (Saldaña, 2013). First, the transcripts were broken down into paragraphs, and each paragraph was examined to interpret its main idea. After analyzing the entire transcript, the codes for each paragraph were reviewed to determine commonalities, differences, and themes as they related to the topic of inquiry.

A group interview with two participants was also conducted to gather user feedback on the object prototypes, particularly to examine users' perceptions of the materials and how they engaged with them in comparison to CRD waste that had not been transformed (Barbour, 2018). The group interview was a means of examining how people's perceptions of waste might change, and for evaluating how successfully the residual materials were valorized. The approach taken to formulate group interview questions and the structure of the interview are described in greater detail in section 5.4. Participants were recruited from the university student body with the intention of including people with different backgrounds and interests. However, as information about the research was included in recruitment material, it should be noted that it is probable that respondents were already interested in sustainable design or related topics. The small number of participants should also be acknowledged, as this limited the diversity in comments, and their responses cannot be taken to represent a generalized opinion. However, the feedback was still productive. The group interview was audio- and video-recorded and transcribed. The transcription was analyzed using the same strategy as that used for the semi-structured interviews to break it down into its main ideas and identify themes. Additionally, the video recording was crucial in analyzing the group interview data as it allowed for observation of how participants interacted with the objects and for interpretation of non-verbal feedback based on their interactions.

Iterative prototyping was used to develop material prototypes and object prototypes. The prototyping process moved through cycles of conceptualization, creation, evaluation, and reflection, an adaptation of an iterative cycle as described by design researchers Sharp and Macklin (2019). Material prototyping focused on developing specific properties independently so they could be individually evaluated (Lim et al., 2008). The individual properties were then integrated into a more refined prototype. Object prototyping took a comparably more freeform approach to explore the capabilities of the materials and examine how I interacted with them as a maker. Different kinds of objects were created, as this allows for more opportunities to explore form, material properties, different ways of working with the material, how to elicit various affective qualities, and different ways that an end user could interact with the objects (see section 5.4). Exploring these qualities in a variety of ways created more possibilities for one or more of the final artifacts to elicit in a viewer a perspective shift on residual materials. Detailed records were kept for both material and object prototypes, tracking their composition, drying time, mold material, and other properties that were relevant to evaluation and reflection.

This research is driven by an understanding that what is classified as waste is subjective and contextual, drawing from the fields of discard studies, environmental studies, and anthropology. Through this framing, approaches to waste issues must also be contextual. The research is also informed by new materialist theories of agency and approaches to making to investigate how material can embody meaning and how a collaborative relationship with materials can be developed (Bennett, 2010; Ingold, 2013).

Guided by the methodological approach taken in this research, the connections between these theoretical ideas and the creation portion are continually explored throughout the entirety of the work. Exemplifying theories and methods through practice reinforces their links, as well as the links between thinking and making.

1.3 Chapter Overview

The next chapter addresses how socio-cultural, economic, and political systems influence waste management and wastefulness as a Canadian cultural norm (Hird, 2021; Liboiron & Lepawsky, 2022). These ideas are then contextualized by investigating the waste management context in Montréal. Lastly, interviews with two individuals involved in waste reuse in the local context are detailed. This chapter serves to deconstruct the idea of waste as a homogenous, ambiguous category, instead establishing it as contextually situated (Douglas, 2003; Liboiron & Lepawsky, 2022; Strasser, 2000).

The third chapter examines current waste management practices in the construction industry, future strategies that could increase the effectiveness of its waste management, and the barriers impeding progress. This chapter also includes a review of existing research and practical examples in the areas of waste reuse and sustainable material development. These reviews situate this research within existing work, while also highlighting CRD waste reuse as being primarily limited to architecture and infrastructure applications, and rarely extending into the fields of industrial, furniture, and object design. These investigations are used to finalize which waste sources will be pursued for reuse.

The fourth chapter details the residual material collection process and associated construction site visits. The history, properties, manufacturing process, and uses of each residual material are also investigated to inform the material prototyping process. The process of prototyping a recycled gypsum composite and two biobased construction residue composites is then detailed, focusing on exploring material compositions and their properties.

The fifth chapter explores the object prototyping process and the factors that informed it. It examines how value is ascribed to goods to support the valorization of waste through transformation. How people form attachment to possessions from a consumer and business studies perspective (Belk, 1988; Richins, 1994) is also examined, informing the decision to make

functional décor in the object prototyping process. The prototyping process draws from a critical engagement with material agency (Bennett, 2010) and embodied cognition (Nimkulrat & Groth, 2024). Developing a relationship with the materials is explored as a valorization strategy, as it allows them to take on an influential role in the design and making process. Lastly, a user feedback session is detailed, which explored how perceptions of waste might change after interacting with the object prototypes.

Chapter 2: Contextualizing Waste

While waste has many definitions, it is generally understood as an object or material perceived as having no use or value (OED, 2023). This research-creation project aims to shift perspectives around waste and responds to discard studies scholars Max Liboiron and Josh Lepawsky's (2022) invitation to defamiliarize waste. This involves interrupting the normalized and expected ways in which we perceive waste and wasting systems. To do so, this chapter examines how contextual understandings of waste are shaped and follows Liboiron and Lepawsky's strategy of investigating waste's normalization within broader socio-cultural, economic, and political systems.

The reflection first draws on the work of anthropologists Mary Douglas (2003) and Joshua O. Reno (2009; 2015), historian Susan Strasser (2000), and interdisciplinary scholars Myra J. Hird (2021) and Kate O'Neill (2019) to explore how socio-cultural, economic, and political systems shape wasting behaviour and the cultural narratives surrounding it. It examines how capitalism influences waste management decision-making and traces the development of modern understandings of waste in relation to shifting socio-economic conditions and the rise of mass consumption and disposability. Finally, it explores the politics of waste management, showing how systems are structured to conceal waste and its harmful effects while reinforcing the notion of waste as an individual responsibility.

The second part of the chapter delves into Montréal's waste management system and how it is affected by the municipal and provincial social, economic, and political systems. The responsibility of various levels of government and related stakeholders is investigated, along with the legislation and guidelines that govern the city's waste management. The movement of waste throughout the city and surrounding territory is also examined to demonstrate the industry's complexity.

Lastly, the final section details the results of two interviews conducted with stakeholders involved in CRD recovery and recycling: an engineer at a private company recovering a byproduct of the CRD waste sorting process, and a former Ecocentre employee. These interviews contributed to a better contextual understanding of the city's waste management. They provided information about logistical operations, while also contributing to an understanding of how economic and political factors shape waste management systems and inform individual relationships with waste.

2.1 Waste and relationships to socio-cultural, economic, and political systems

In her influential 1966 book *Purity and Danger*, Douglas argued that our perception of something as dirt or dirty is the result of "a systematic ordering and classification of matter" (2003, p. 44) to make our environment conform to an idea, and what we classify as dirt are the rejects of the organizational scheme. Douglas argues that humans are naturally inclined toward pattern making,

which helps us understand and organize our environment. When something does not fit into our classification system, it either must be rejected or the criteria for classification must be changed. Dirt, then, is something perceived as being “recognizably out of place, a threat to good order” (Douglas, 2003, p. 197), and as such must be removed from the environment it is disrupting. In the process, it is reclassified as garbage, where it is perceived to belong.

Following Douglas’ (2003) argument, scholars in discard studies, history, anthropology, and environmental studies examine the subjective, ambiguous, and arbitrary status of waste. As Strasser aptly puts it in her 1999 book *Waste and Want*: “what counts as trash depends on who’s counting” (p. 3). Liboiron & Lepawsky (2022) also argue that the way we as individuals go about understanding and categorizing waste is contextual; it is influenced by where we live, our jobs, our economic status, the social and cultural groups we belong to, and our life experiences. Waste is thus difficult to define because it means different things at different scales and to different people. Similarly, the way that society interacts with and manages waste is not just the manifestation of our collective desire for organization; waste management is entangled with and shaped by broader socio-cultural, political, and economic systems, and it can shape these systems in turn (Hird, 2021; Reno, 2015).

2.1.1 Waste as a cultural category

Douglas asserts that culture is an extension of individual classification systems on a larger scale. Culture provides “public, standardised values of a community [and] mediates the experience of individuals” (2003, p. 48). When these systems are shared or adopted by a group, they become culturally accepted values. The assent of a larger group strengthens these categories, making them more rigid and harder to change. The expectation of agreement from community members further limits individuals’ ability to adjust their own perceptions.

Cultural categories, like individual ones, must contend with anomalies and ambiguities. This can be done by redefining categories. For example, in 20th-century North America, food scraps shifted from livestock feed to waste as urbanization and industrialization advanced (Strasser, 2000). New categories, such as recyclables, can be created. Rejects can also be physically contained through sorting centers and landfills.

Our cultural definition of waste reflects collective judgements about what is valuable and what is worthless (Liboiron & Lepawsky, 2022). Waste mirrors us, both individually and collectively (Hird, 2021). As culture evolves, so do our definitions of waste. For example, contemporary Western notions of dirt and hygiene were shaped by the 20th-century understanding of pathogens (Douglas, 2003; Strasser, 2000). The association of dirt with illness made cleanliness and hygiene morally desirable, and by extension, disposal came to signify moral good when it removed matter

seen as threatening hygiene (Strasser, 2000). Disposal thus materializes moral judgements against things perceived as disgusting or valueless.

Our present culture reinforces wastefulness, yet this behaviour is learned rather than inherent (Liboiron & Lepawsky, 2022). The cultural construct of waste is deeply bound to capitalism, which prioritizes maximizing economic value. When something lacks or no longer maximizes such value, it is defined as waste (Hird, 2021). This is no accident—our industrial economy’s focus on high productivity necessitates excess and makes waste an inescapable, normalized part of life (Lyle, 1994).

2.1.2 The rise of mass consumption and disposability

In North America, marketing tactics encouraging mass consumption emerged in earnest in the early 20th century (Monod, 1996). Before this time, Strasser (2000) argues, people purchased fewer goods and typically used clothes, tools, and objects until they no longer served their function. It was also common to reuse, repair, recycle, sell, or donate goods. As industrialism increased in the late 19th century, producers “had the ability to produce far more than they were selling” (Monod, 1996, p. 106). Manufacturers realized they could shape markets and encourage people to buy more by changing the way products were advertised and targeting specific groups (Monod, 1996; Strasser, 2000). Consumption became associated with convenience, while technological advances and fashion trends rendered older products obsolete even if they still functioned.

Following the Second World War, the global economy expanded, and many people became more affluent (Strasser, 2000). Wartime innovation led to the development of new technologies and products, bolstering mass consumption. A major shift occurred in the plastics and packaging industries, as producers realized that by making their products disposable and framing this as convenience, they could ensure constant demand (Liboiron & Lepawsky, 2022). This approach soon extended to other consumer goods. However, people had to be taught how to waste after years of wartime resource scarcity (Strasser, 2000). Advertisements and packaging included step-by-step instructions for new uses of products, encouraging faster consumption and one-time use. Convenient and disposable goods made household management easier, and disposability became desirable because it represented “the freedom of modernity from the drudgery of old-fashioned life” (Strasser, 2000, p. 268). The profitability of disposability drove increased consumerism and waste generation, changing our relationships with material goods and waste, while advancing the idea that humans are inherently wasteful (Liboiron, 2013). As disposability became culturally accepted, definitions of waste shifted, and people began discarding items they once would have kept for future use.

2.1.3 The economics of modern waste management

The normalization of mass consumption and mass disposal supported the continued development of the waste management industry. Municipal waste collection services in North America and Europe, resembling those we have today, date back to the late 19th century (O'Neill, 2019). Throughout the 20th century, waste was generated in increasing quantities, and environmental concerns grew, leading waste management to become more complex. Many local governments no longer had the expertise or budgets to manage their waste independently (Gandy, 1994). Today, the highly profitable Canadian waste management industry involves a combination of private and public actors (Gandy, 1994; Hird, 2021) and is dominated by a handful of multinational corporations (O'Neill, 2019). This privatization transformed waste from a common resource into a commodity whose market fluctuates according to shifting policies and the whims of buyers.

Canada's waste is managed according to the waste hierarchy, developed in line with political priorities as environmental issues gained prominence in public consciousness (Hird, 2021). The hierarchy outlines preferred approaches to waste management, ranked from most to least desirable for reducing environmental impact. Commonly referred to as the 3Rs (reduce, reuse, recycle) in media and advertising, it follows the order of prevention, reduction, reuse/repair, recycling, recovery, and finally, disposal (ECCC, 2021). Beyond national waste management plans, this hierarchy also shapes municipal policies (Hird, 2021). However, the increasing involvement of private contractors in the waste management process carries economic and political implications that influence whose interests are prioritized. As a result, rather than focusing primarily on addressing environmental concerns, waste management decisions are often driven by profit maximization.

Disposal, whether in landfills or through energy recovery, is one of the primary waste management strategies employed today (Hird, 2021), as it is less complex and more profitable than those higher up the waste hierarchy. By providing a place for our waste to disappear, private, municipal, and governmental waste management stakeholders benefit from this system. For example, contractors or municipalities are paid to collect and transport waste, and in Québec, the operators of landfills, incineration facilities, and transfer stations must pay the government a fee of \$34 per metric ton of residual material they process, excluding materials that are recovered (MELCCFP, 2025b). When approaches to solving waste and environmental issues rely on technological solutions and emphasize diversion and disposal strategies, they indirectly encourage consumption and additional waste generation. The waste industry continues to benefit from this because there remains waste to manage, unlike with prevention strategies (Hird, 2021).

Recycling, another primary waste management tactic, became common practice for diverting municipal solid waste from landfills in the mid-20th century (Gandy, 1994). It has continued to dominate waste management since then, due to its profitability and its "green reputation" (Liboiron

& Lepawsky, 2022, p. 70). Recycling allows us to continue producing disposable products and generating waste under the assumption that it will not negatively affect the environment. In reality, recycling is the least environmentally friendly of the 3Rs (Hird, 2021). The process requires new materials and energy while generating emissions, pollution, and waste (Liboiron & Lepawsky, 2022). Moreover, not all recyclables are actually recycled; when municipal waste streams become too costly to sort effectively, they are often sent to landfills instead (O'Neill, 2019). Like landfilling, recycling reinforces rather than disrupts the “circuits of capitalist production and consumption” (Hird, 2021, p. 38). It also allows manufacturers to externalize the costs and responsibilities of managing the waste associated with their products onto municipalities and individuals (Hird, 2021). For example, plastic manufacturers produce and market their products to consumers, while municipalities, funded by taxpayers, are left responsible for managing the resulting waste. Although consumers do not actually “make” waste, they are assigned responsibility for its management (Liboiron, 2013).

2.1.4 Waste governance, individual responsibility, and invisibility

The individual’s responsibility for managing waste has been amplified by government regulations and messaging as environmental issues intensify. Campaigns continue to emphasize post-consumer waste and recycling, even though most waste is produced during extraction and manufacturing, and recycling has failed to reduce production and consumption (Hird, 2021). Consumers are targeted as both a “point of blame and unit for solution” (Liboiron & Lepawsky, 2022, p. 47) for waste and climate problems, despite the mismatch between the scales at which waste is generated and those at which individual actions can have an impact. Individual behaviour changes—such as curbside recycling—do not reduce the number of disposables produced, even when widely practiced. Presenting recycling as a solution to individual waste generation, Liboiron and Lepawsky (2022) argue, allows our waste management system and culture of consumption to remain largely unchanged and profitable.

Hird (2021) and Liboiron & Lepawsky (2022) contend that by structuring waste management around recycling and individual responsibility, governments and producers frame waste as a technical issue, obscure waste’s entanglement with broader political, economic, and social systems, and reinforce the belief that waste problematics can be solved through technoscientific means rather than through socio-cultural, economic, or political change.

As attitudes shift toward more sustainable waste management and governments recognize that individual responsibility alone cannot solve the waste crisis, both Canada and Québec have introduced extended producer responsibility programs. These programs make producers accountable for collecting and recovering post-consumer products, relieving individuals of some waste management obligations (ECCC, 2017; MELCCFP, n.d.). In Québec, current extended producer responsibility regulations require producers to fund collection and recovery for

packaging, printed paper, beverage containers, and some hazardous household materials. In some cases, producers are also required to prioritize sustainability in product design (Éco Entreprises Québec, 2024; MELCCFP, n.d., 2025c).

The city of Montréal is also taking steps to re-politicize its waste management by seeking public feedback at multiple stages in the development of its waste management plans. However, the city still determines the terms of participation, and citizens must engage on their own time.

Controlling public participation in waste management decision-making is part of the broader goal of waste management infrastructure to make waste disappear, both physically and from public awareness (Hird, 2021; Reno, 2015). Waste is transported to facilities located on spatial margins (Liboiron & Lepawsky, 2022), while landfills isolate it from society, “maintaining their contents in a state of suspended animation” (Reno, 2015, p. 563) and preserving it for future generations to manage. The hidden nature of waste and its management reinforce the status quo, and our constant participation in these practices has normalized them. This invisibility also makes the environmental and social costs of waste management easier to externalize onto people and places with less socioeconomic power (O’Neill, 2019). Conversely, waste’s visibility or proximity comes with social stigma (Liboiron & Lepawsky, 2022; Reno, 2009, 2015). For example, the areas where waste is managed are seen as less desirable, and landfills negatively impact health, nearby land, and housing value due to the hazards associated with them (Danthurebandara et al., 2012).

Current waste management strategies primarily address waste that has already been generated. To effectively tackle the waste crisis, upstream strategies are needed to target the broader factors influencing wasting behaviour, including lifestyle and economic relationships to profit (Hird, 2021; Liboiron & Lepawsky, 2022). As strategies like the circular economy become more popular and waste volumes grow more difficult to manage, contemporary policies increasingly view waste as a material resource (Reno, 2015). This shift requires reframing waste in media, public communication, and public understanding from a pollutant to potentially beneficial materials.

The extent to which innovative waste management strategies, material reuse, and salvaging can be promoted, Reno (2015) argues, is limited if waste is viewed as pollution. This research hopes to demonstrate this shift in framing in action by reflecting on my own relationality to and perceptions of waste as I work with it. In seeking to valorize discarded CRD materials, I am forcing myself to adjust my internal filtering mechanism that, based on past experiences and influenced by larger systemic factors, automatically wants to classify certain materials as waste.

Following Douglas (2003), who argues that we classify something as dirt when it does not fit into any of the mentally constructed categories we use to order our environment, this section examined how waste can be understood as an arbitrary, subjective, and contextually situated category. By recognizing waste as a subjective category and deconstructing how factors such as advertising,

mass consumption, disposability, capitalism, and governmental decision-making influence contextual understandings of waste, this preliminary contextualization begins to defamiliarize waste so that new interpretations of its potential can be further developed.

2.2 Montréal's waste context: A complex system informed by multiple actors

Defamiliarizing waste also involved making visible the actors involved in Montréal's waste management and examining the political responsibilities held by various levels of government, logistical responsibilities, geographic movements of waste, and the interplay between public and private sectors. This section explores how the systems discussed in section 2.1 impact the Montréal context. Investigating how waste is managed and how CRD waste is or is not addressed by the city's efforts to transition towards a circular economy also bolsters the argument that CRD waste management is an area in need of improvement and exploration.

2.2.1 The interplay of governmental actors in Montréal's waste management

The management of Montréal's waste is a collaborative effort between municipal, provincial, and private actors, in line with governmental regulations (Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020b). Their interactions are synthesized in Figure 2.1 and described below.

At the highest level, the provincial government develops the Québec Residual Materials Management Policy through a collaboration between provincial ministries and internal organizations (MELCCFP, RECYC-QUÉBEC, and Bureau d'audiences publiques sur l'environnement) (MELCCFP & RECYC-QUÉBEC, 2019). The provincial government also consults various levels of government, Montréal and Québec Metropolitan Communities, Indigenous nations, and citizens to develop action plans and strategies to achieve the goals set out in its Policy (Bureau d'audiences publiques sur l'environnement, 2022). In recent governmental plans, the industrial, commercial, and institutional and CRD sectors were singled out as needing improvement to support the province in meeting its goals for a circular economy and waste reduction.

The Communauté métropolitaine de Montréal (CMM) is a planning, coordination, and financing organization that includes 82 municipalities in the area surrounding Montréal and 48% of Québec's population (CMM, n.d.). The CMM has devised its own *Plan métropolitain de gestion des matières résiduelles* to guide the region's waste management, in accordance with provincial guidelines.

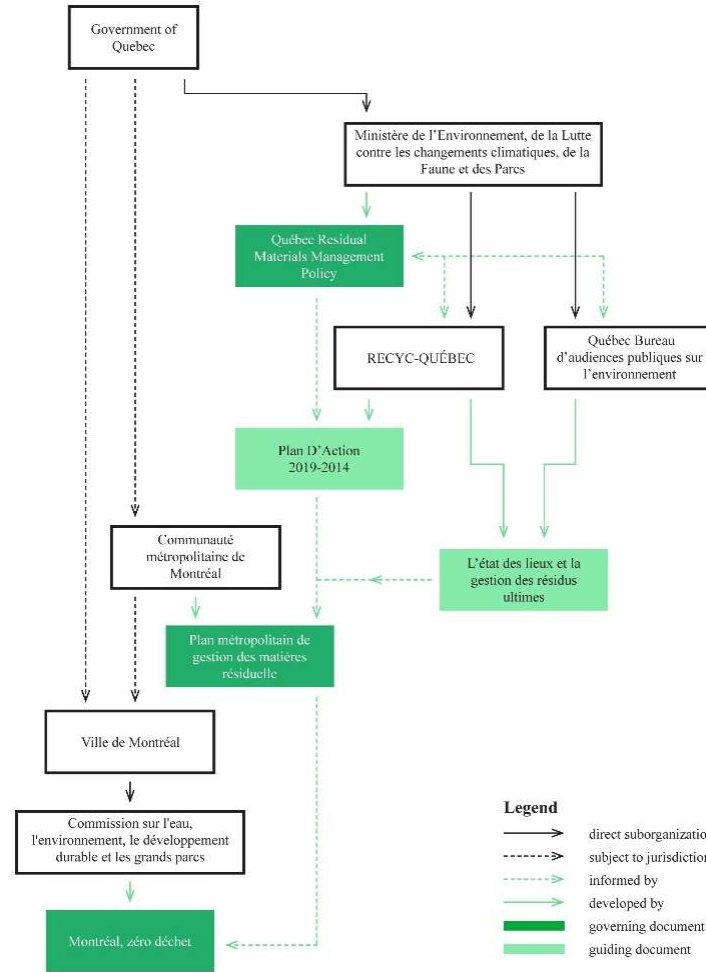


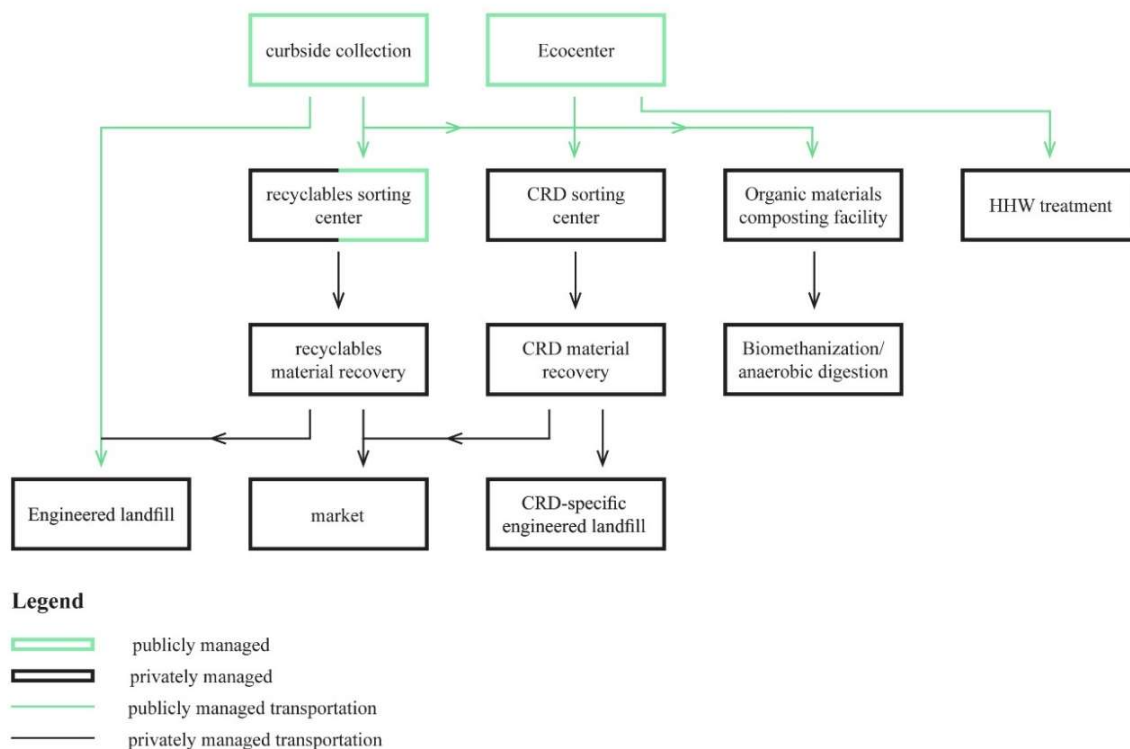
Figure 2.1 Diagram of the hierarchy of actors involved in waste management from the provincial to municipal level.

Image by Elizabeth Vince.

Finally, at the municipal level, the City of Montréal is responsible for implementing the measures set out by the CMM, infrastructure planning, and the management of contracts with private companies for the collection, transport, treatment, and disposal of Montréal's municipal waste (CMM, 2023). The City of Montréal has also developed its own master plan titled *Montréal, zéro déchet*, which outlines localized strategies to achieve recycling, reduction, and diversion targets and to implement steps toward a circular economy in the Montréal agglomeration. It focuses on technical strategies to improve waste collection, management, and valorization, upstream interventions to reduce waste generation, measures to stimulate citizen participation and behaviour changes, and economic incentives to support circularity (Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020a, b). While the typical neoliberal approach to waste management is to focus on waste as a solely technoscientific issue (Hird 2021), it is clear in the recent Montréal and CMM plans that they recognize and are interested in addressing the broader upstream issues connected to wasting and waste management in Montréal.

2.2.2 Montréal waste collection

The City of Montréal is responsible for the collection and transportation of residential residual materials and materials generated by industrial, commercial, and institutional sources that are similar in quantity and category to residential residual materials (CMM, 2023). Figure 2.2 outlines the path taken by municipal solid waste collected by the city, also described below. Curbside collection is divided into five different collection services: recyclables, organic food waste, green waste, household waste, and bulky/CRD waste (Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020b). The city also operates seven Ecocentres, where residents can drop off various categories of materials and objects that can be reused, which might otherwise have gone to landfill. The materials from these collections and Ecocentres are then transported to various sorting centers, organic composting centers, CRD processing sites, and landfills, which are both municipally and privately operated. Materials from the sorting centers and Ecocentres are further transferred to private companies that recycle, reuse, or repurpose these products to be introduced back into the material economy.



Note: this diagram is simplified and does not include transfer/transshipment stations because not all MSW goes through these stations

Figure 2.2 Diagram of the movement of waste through the Montréal management network.

Image by Elizabeth Vince.

For waste generated by industrial, commercial, and institutional and CRD sources that exceed the municipal collection limit, the producers of the waste are responsible for its collection and management, although they must comply with municipal and provincial standards (MELCCFP,

2025a). Beyond adhering to government standards, private companies are not required to disclose the amount of waste generated or how it is managed. This can make data collection and understanding how the industry operates difficult. The web of CRD waste management becomes even more complex when it is broken down into its constituent categories, which include not just sorting centers and landfills, but container companies, construction and demolition contractors, waste transportation companies, and the companies that specialize in the recovery and reuse of specific materials. The distributed responsibility for waste management also broadens the range of waste management strategies that are used. The variety of actors involved in waste collection and management increases the complexity of the system and creates hindrances for initiatives hoping to improve the industry's sustainability.

2.2.3 CRD-specific waste governance in Montréal

Governmental waste management plans at all levels include specific provisions to facilitate the increased reduction, recycling, and recovery of CRD waste; however, recovery rates for this category remain low (CMM, 2023). The city of Montréal, for example, is introducing clauses that will require a certain percentage (currently undetermined/undisclosed) of CRD material to be recovered when construction permits are given and prohibit the disposal of CRD residues for which a recovery program exists (Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020a). The city also plans to develop new local waste management infrastructure to divert more materials from landfills, and process and recover more residual materials without outsourcing (Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020a). These measures demonstrate an increasing awareness of the fact that CRD waste has a significant impact on our waste infrastructure and subsequently on the environment.

2.2.4 Geographic movements of CRD waste

The management of CRD waste takes place both within Montréal and within the broader territory of the CMM (fig. 2.3). Within the greater Montréal area, there are Ecocentres, sorting centers, and one engineered landfill, which all process CRD waste. Any construction waste that is either rejected from a sorting center or sent directly to a landfill will go to one of Québec's engineered landfills, one of which is within the CMM, or to one of the four CRD-specific landfill sites in Québec, all outside of the CMM (CMM, 2023).



Figure 2.3 Different types of waste management facilities in and around the CMM. Image by Elizabeth Vince.

Montréal's waste, therefore, is managed not just within Montréal; our waste system extends into the CMM, Québec, Canada, and internationally (RECYC-QUÉBEC, 2023). This combination of private actors and government involvement at various levels further complicates the movement of waste and widens the range of stakeholder interests. Due to the direct interconnected nature of Montréal's waste management with that of the larger CMM, and the more thorough data provided by the CMM, the statistical data collected by the CMM has been used as a guide for material selection in this research rather than that of Montréal alone.

Investigating the distributed nature of Montréal's waste governance, waste management, and waste statistics further contextualized waste in Montréal and supported the decision to pursue CRD waste reuse in this research. CRD waste has been identified in governmental plans from the provincial to municipal level as an area in need of improvement for the province of Québec to effectively transition to a circular economy. While the province is making efforts to bolster its waste management infrastructure and prevent the export of waste (Bureau d'audiences publiques sur l'environnement, 2022), our waste management system is not contained by any geographic boundaries, increasing its complexity and making it more difficult to understand how the system operates and to determine all the factors influencing it.

The CRD sector is a major contributor to the CMM's waste stream, accounting for over a quarter of the region's total eliminated materials, with a recovery rate of only 29%. Through a review of the elimination and recovery statistics of the material subcategories of the CRD sector, wood,

aggregate, and gypsum were identified as materials that, due to their high volumes in the waste stream or low recovery rates, warranted further investigation to determine if they could be explored for reuse in this research.

2.3 Field research: Stakeholders trying to shift perspectives around waste

To zoom in on Montréal's waste management system and explore initiatives trying to create change in the industry, two interviews with individuals engaged in local CRD waste management were conducted: Martin Bureau, engineer and Vice-President of Innovation at environmental management company Sanexen (Brossard, QC), who specializes in the recovery of construction and demolition waste fines; and an anonymous former Ecocentre employee. These conversations demonstrate concrete examples of how the systems discussed in section 2.1, particularly socio-economic systems, affect waste management and can either enable or hinder increased material reuse. The interviews also further contextualize the overview of Montréal's waste management given in section 2.2, contributing to a better understanding of the system's logistical operation. The interviews highlight the difficulty of navigating the complex waste management system, the need for more transparency and access in the waste management industry, and the importance of creativity regarding how the management of CRD waste is approached.

2.3.1 The unconventional value of C&D fines

Construction and demolition (C&D) fines are a byproduct of C&D waste sorting. When CRD waste is sorted, the process produces a residual mixture containing gypsum, plastic, wood, aggregates, and soil, as well as a range of contaminants that are difficult to treat and can contribute to the production of hydrogen sulfide and methane if landfilled. Due to the contaminants it contains, Bureau notes that landfills are reluctant to accept C&D fines and therefore charge higher tipping fees.

Roughly 500,000 tonnes of C&D fines are generated annually in Québec (Bureau, personal communication, 2024). C&D fines form an ambiguous category: they represent a large portion of CRD waste, result from waste management infrastructure, and remain invisible in official waste statistics. Provincial and municipal statistics do not include a category for "C&D fines," likely because data collection occurs through sampling at the start of sorting and management processes, before C&D fines are produced as a byproduct (RECYC-QUÉBEC, 2022).

Sanexen's process filters C&D fines into three categories: aggregates, materials high in biomass, and ultrafines, which remain after the first two categories are removed. The biomass-rich and aggregate materials can be used as cover for landfills, mining sites, and landscaping, or for energy generation. The remaining ultrafine material contains a mix of gypsum, organic matter such as paper, wood, and soil, small metal fragments, and contaminants. Sanexen applies a biotreatment

process that transforms the ultrafine material into compost. The treated compost can serve as cover material in landfills or as an additive for soil in landscaping and remediation. Sanexen also envisions future uses for the treated ultrafine material as an additive in construction materials such as insulating foam panels, polymers, and composites.

The high tipping fees for landfilling C&D fines make Sanexen's process economically viable, even without producing high-value products. If Sanexen or its licensed sorting centers charge a fee lower than landfill rates and apply their low-cost processing method, they can reuse, sell, or distribute the recycled C&D fines while still generating profit.

Sanexen's work demonstrates how a creative approach and a shift in perspective are key to valorizing waste. C&D fines, often seen as worthless debris produced by sorting, become valuable when viewed as both a challenge and an opportunity. Even the smallest remnants of drywall, wood, and aggregate can regain purpose when reimagined as resources rather than refuse.

2.3.2 The opaque logistics of public waste management: A portrait of an Ecocentre

Publicly available information about Ecocentre operation is limited, and the interview outlined and confirmed the opaque nature of the operations, even from the perspective of someone on the inside. This resonates with Hird's (2021) argument that waste and waste management are purposely kept out of sight to limit attention to the issues associated with waste management and maintain it as an apolitical issue.

There are two primary employee roles at the Ecocentres: those who work on the ground, directing citizens and helping to sort materials, and managers. The interviewee held the former role, which put them in regular contact with citizen users, residual materials, and the Ecocentre's partners¹.

Montréal's Ecocentres are managed and operated by the non-profit organization Groupe Pro-Vert. This organization is responsible for arranging contracts with recycling and material recovery firms for the management of the materials collected at Ecocentres, and for day-to-day operations. Despite Ecocentres being a municipal service, the city has little understanding of their processes because they do not directly oversee their management. This contributes to the barrier to citizen understanding. Commenting on this barrier, the interviewee said, "Yeah, it's as if they were keeping it secret. It's like that for us, too." They clarified that they did not think information was withheld from employees for any deliberate or malicious reasons, but rather that it just was not

¹ It should be noted that the interviewee worked at only one Ecocentre location, so the information provided about Ecocentre management is not necessarily reflective of all locations. The interviewee has chosen to remain anonymous, and as such, the location where they worked is not disclosed.

necessary for them to know. The interviewee described a wall separating us from the more specific details about how the residual materials are managed once they leave the Ecocentre.

The materials at the Ecocentre are separated by material categories (e.g., metals, cardboard/paper, wood, plastic, CRD materials, electronics, hazardous household waste, and green waste), after which private companies are contracted for their transportation and recovery. The Ecocentre had, in the past, established contracts to divert objects and materials still in good condition to resale organizations. These types of contracts, however, are time-consuming for the Ecocentre, as employees must inspect and carefully sort these objects as opposed to tossing them into bins based on material category, which is the typical practice. These contracts, for this reason, are not as cost-efficient and thus are not as long-lasting. The materials and objects that are still in good condition or could be easily repaired instead typically go into the recycling stream. The interviewee added, “It’s contrary to the base principle [of the Ecocentre], which is [...] to reduce waste.” From the interviewee’s experience, Ecocentres were more focused on traditional recycling than any other reuse or diversion tactics.

When discussing how their perspective of waste changed over their time working at the Ecocentre, the interviewee described the experience as “eye-opening.” Their appreciation for residual materials grew as they imagined how materials could be reused or transformed. “It’s almost in the spiritual sense unethical at some point,” they said, referring to seeing nice materials be disposed of, knowing they will likely be broken down and recycled when they could be reused as is. They added that all the materials are considered property of the city, so even if an employee wanted to take something for reuse, they could not. Having previously considered investigating if I could source waste materials from Ecocentres, this statement confirmed that it would be unlikely.

Together, the interviews provided insight into the different actors involved in Montréal’s waste management system. These actors demonstrate how working with waste in a hands-on manner can facilitate a different interpretation of its value as well as different strategies for valorizing waste through chemical and physical transformation.

The interviews also further contextualized the systemic issues affecting waste management discussed in section 2.1. They demonstrated how the economic and political confines of the waste management industry enforce a focus on maximizing profit rather than environmental benefit, obscuring waste and making it difficult for circular and reuse initiatives to gain traction if they are not extremely economically efficient. They also illustrate that it is more difficult to recognize, and therefore easier to ignore, the socio-environmental harm brought by our wasting habits and consumption patterns when we don’t see the waste. This makes it difficult for the public to organize around waste as a matter of concern when the negative effects associated with it are invisible.

2.4 Chapter summary

To effectively propose an alternative value for residual materials, it was necessary to understand current perceptions of waste and how these perceptions are formed. This chapter explored the factors that inform relationships with waste and the operation and governance of waste management systems in order to defamiliarize waste and support the argument for how it can be valorized through reuse. This was a fundamental step in determining which materials should be pursued for valorization. It was established that waste is an arbitrary category, rather than reflective of any inherent qualities of a thing. Everyone has a contextual relationship to waste that is impacted by deeply intertwined socio-cultural, economic, and political systems. These systems simultaneously work together to uphold our waste management system and cultural patterns of consumption and disposal, making it difficult to adjust any individual elements of waste management or waste governance to make concrete changes toward more sustainable practices.

The responsibility for waste governance and management, waste's geographic movements through Montréal, and the region's waste statistics were investigated in order to establish a contextual understanding of waste in Montréal. This investigation illustrated the complex nature of the city's waste management and demonstrated that CRD waste remains a prevalent issue in Montréal and Québec. While legislative and infrastructural steps are being taken to address it, they have not yet been implemented (CMM, 2023; Commission sur l'eau, l'environnement, le développement durable et les grands parcs, 2020a, b). This supported the decision to investigate CRD waste further and select materials from this category for experimentation and reuse.

The interviews further contributed to a local and contextual understanding of waste and waste management, particularly the hindrances created by its socio-economic dynamics. They also supported the understanding of Montréal's waste management as an opaque system that is difficult to navigate for those within and outside of the industry. The interviews also provided examples of how waste can be valorized, and how an individual person or company can create change by shifting their perception to view waste as something potentially valuable. These examples provide insight that is applied to the valorization efforts in this research.

Chapter 3: Waste Management and Material Reuse in the Built Environment

This chapter investigates the current state of waste management in the construction industry and examples of material reuse in the built environment. The built environment, in this context, refers to the architecture and construction industries, and interior, industrial, furniture, and object design.

CRD waste was selected as the research area of focus because of the construction industry's impact on the environment and the relatively low rates of CRD waste recovery in Montréal, particularly in the material categories of wood, aggregate², and gypsum (see Introduction for statistical overview). The first section of this chapter explores current waste management strategies employed in the Canadian construction industry and barriers preventing more effective strategies from being implemented. This is used to determine if low material recovery rates are indicative of industry-wide issues. Future strategies that could be applied to reduce waste generation and increase material reuse are also investigated. This review also demonstrates how our economic system shapes CRD waste management, as discussed in Chapter 2.

The second section provides an overview of practical examples of material and waste reuse in the built environment, emphasizing the limited scope of reuse applications for CRD waste, particularly in the fields of industrial, furniture and object design. This situates the research in the existing research context and while also informing the selection of aggregate and gypsum as the waste materials to be pursued for experimentation.

3.1 Waste management in the Canadian construction industry

There are a variety of waste prevention and management strategies currently employed in the construction industry, including landfilling, recycling, reuse, modular/prefabricated construction, and design for deconstruction. This section provides an overview of these strategies, including their prevalence and how much or how little they contribute to the construction industry's waste problem. The circular built environment (CBE) is also investigated as an approach that could improve the industry's sustainability, although more research, development, and collaboration are needed before it can become a reality. Lastly, the barriers inhibiting a CBE and increased material reuse are investigated, which primarily stem from economic and systemic factors. This investigation is used to identify gaps in research and practice with respect to certain materials and determine which materials are underutilized or rarely reused in the industry.

² Aggregate, in this case, refers to the CMM's statistical category of aggregate, which includes concrete, stone, gravel, and asphalt.

3.1.1 Current waste management strategies

As seen in the introduction and previous chapter, elimination via landfilling is still the most popular strategy for CRD waste management in Canada (Goodland & Walsh, 2024). Landfilling CRD waste can be problematic for a few reasons; while some construction materials pose little environmental threat due to their inert nature, others contain potentially harmful chemicals whose effects can be compounded by disposal in landfills (Wimalasena et al., 2010). For example, when gypsum is landfilled, anaerobic microorganisms can degrade the sulfate within gypsum to produce hydrogen sulfide, a flammable and hazardous gas that, if ignited, becomes sulfur dioxide, a known contributor to acid rain (Earle et al., 2014; Ndukwe & Yuan, 2016). Many construction waste materials, like concrete and masonry, are bulky in nature, taking up more space in landfills despite having potential recycling or reuse applications (Ajayi et al., 2015; Wimalasena et al., 2010).

Recycling and material reuse in the construction industry are receiving more attention. These terms are sometimes used synonymously as they both involve diverting waste that has already been generated; however, they typically have different implications for how the material is treated, although there can be overlap, as there are not yet widely accepted definitions of these terms. Recycling involves collecting, sorting, and processing materials for new applications (Ajayi et al., 2015). Recycling is sometimes separated into the categories of downcycling and upcycling. Downcycling refers to recycling materials into products of lower functional quality or economic value than their original purpose, while upcycling is the reverse (Goodland & Walsh, 2024). Transforming reclaimed wood into furniture would be an example of upcycling, whereas turning scrap wood into wood chips and combining it with an adhesive to make particleboards is considered downcycling (Dahche & Kowaluk, 2023; Kromoser et al., 2022). Recycling alone is not sufficient to address waste in the industry (Gorgolewski, 2018), especially when materials are often downcycled if recycled at all (Earle et al., 2014). Alternatively, reuse refers to using materials as is (Goodland & Walsh, 2024) or to using materials with little physical and no chemical transformation (Ajayi et al., 2015). For example, reuse could refer to removing a window component from a decommissioned building and using it in a new building, or dismantling wood pallets, cutting them to size, and using them for interior cladding (Gorgolewski, 2018). Material reuse is typically favourable to recycling because it involves less reprocessing and thus requires less additional time, labour, and expense as a result (Gorgolewski, 2018).

Modular, prefabricated construction is another waste prevention strategy. Using standardized elements makes the construction process faster and more resource-efficient (Kamali et al., 2019). In Canada, this method is used most commonly for residential construction. In 2025, the governments of Canada and Québec announced a joint initiative to use prefabricated housing “to create 8,000 social and affordable housing units in Québec” (CMHC, 2025), demonstrating its increasing popularity.

The strategy of design for deconstruction has similar aims to modular construction, but the concept places a stronger focus on reducing resource consumption and waste. This practice consists of designing a building so that it can be taken apart and its components reused at the end of its life (Gorgolewski, 2018). This strategy is not yet widely practiced, but its principles have been applied to projects in recent years, such as the Circle House development in Denmark by GXN and collaborators, constructed in 2020 (GXN Innovation, 2019). While no practical examples similar to Circle House exist in the Canadian context, there are research-based examples; for example, in 2025, UBC School of Architecture and Landscape Architecture PhD student Kaia Nielsen-Roine and Associate Professor Annalisa Meyboom published a design for deconstruction guide and built a partial wall mock-up applying the principles (Nielsen-Roine & Meyboom, 2025).

While deconstruction remains underutilized in the Canadian context (Roxas et al., 2023), a market for material reuse is beginning to develop. Specialized deconstruction firms Ouroboros Deconstruction and Vema Deconstruction have completed residential and commercial deconstruction projects in Ontario and British Columbia, respectively (Ouroboros Deconstruction, n.d.; Vema Deconstruction, 2025). In the local context, RÉCO is an initiative in partnership with Architecture sans frontières Québec, specializing in the sale of reused construction materials recovered via donation from renovation and demolition projects (RÉCO, 2023).

Despite these strategies, the construction industry still relies on new materials, and access to raw materials is becoming more constrained (Gorgolewski, 2018) as disposal of CRD waste increases (RECYC-QUÉBEC, 2021). While 75% of construction waste has the potential for reuse (Yeheyis et al., 2013), the industry lacks the systematic approach that would allow it to maximize material efficiency (Gorgolewski, 2018).

3.1.2 Future strategies

One prominent approach that would address waste generation and management in the industry, while also providing other socio-economic and environmental benefits, is the development of a circular built environment (CBE). In a CBE, buildings would be “designed, planned, built, operated, maintained and deconstructed in a manner in which waste is a resource that is not discarded to landfills.” (Goodland & Walsh, 2024, p. 9). The CBE approach encompasses a variety of waste reduction and sustainability strategies: material optimization, design for deconstruction, reuse and recycling, increased use of local, renewable and ethically produced materials, and favouring building repair/refurbishment over new building (UNEP, 2023). In a CBE, all material resources are part of a cycle, going back into the material economy at the building’s end-of-life or end-of-use. This perspective reinforces the idea that all materials have ongoing value and should be managed accordingly (Gorgolewski, 2018).

Adopting this approach would require government support, policy changes, a drastic change in the industry's perspective towards design, materials, and waste, and for the broader public to adjust cultural consumption patterns and negative perceptions around reused materials (Gorgolewski, 2018; UNEP, 2023). This approach would also require comprehensive collaboration from all stakeholders involved in the built environment and at all stages across building lifecycles, from government bodies to designers and developers, contractors, manufacturers, waste managers, and consumers, and as such, a true CBE has not been achieved anywhere nationally or globally.

The Canadian Standards Association has been researching the CBE and recently released a report detailing a strategic framework that could be followed to enable and adopt a CBE in Canada (Bansal et al., 2024). TRACE Lab at McGill University is also researching how a CBE could be implemented in Canada and the circular practices already at play in the industry (TRACE Lab, n.d.). École de technologie supérieure (ÉTS) has also established Institut AdapT to support research into climate-resilient and circular infrastructure across Québec (Institut AdapT, 2025). There are also built examples that apply circular strategies, for example, Alliander's office redevelopment in the Netherlands, designed by RAU Architects and completed in 2015. The project involved deconstructing the building interiors, reusing 90% of the existing buildings, reusing materials both from the on-site deconstruction and elsewhere, adapting the design to material availability, creating a material passport that provides information about material lifespans and opportunities for reuse, and employing energy-efficient systems (Gorgolewski, 2018).

Despite these examples and growing awareness and interest in the CBE and circular economy more broadly, most material flows still tend to be linear (UNEP, 2023), and systemic changes being made toward a CBE are incremental (Goodland & Walsh, 2024).

3.1.3 Barriers to increased material reuse and circular material practices

Many barriers to waste reduction and reuse stem from the lack of a holistic approach throughout the industry. Material supply chains and stakeholder interests are intertwined, but there is a lack of transparency in how actors interact with each other and how materials move through the industry (Keena et al., 2022). As outlined in section 2.2, construction waste management regulations are geographically disjointed (Goodland & Walsh, 2024), and better systems to manage residual materials need to be developed (UNEP, 2023).

Economic and time considerations related to construction waste management are also major barriers to increased reuse and circularity. The most common practice of building deconstruction is demolition. To reuse or recycle demolition materials, the materials must be sorted and separated, which is more time-consuming and therefore more expensive than it is to landfill them (Wimalasena et al., 2010). Additionally, reprocessing these materials for recycling incurs further

costs and time (Keena et al., 2022; Wimalasena et al., 2010). With concrete and masonry, for example, the recycled product is often of a lower quality compared to that made from new materials, meaning it is not cost-effective to spend the extra time and money to reprocess it (Earle et al., 2014). Recycling can also be made more time/cost-intensive by a lack of available facilities that can reprocess certain materials, as is the case with gypsum products in Canada (Earle et al., 2014).

Deconstruction through disassembly is favourable for reuse and extends the lifespan of building elements (UNEP, 2023) but can be an even longer and more expensive process, particularly for concrete, because it is often cast in place (Earle et al., 2014; Gorgolewski, 2018). There are also perceived economic constraints to designing for deconstruction because it requires additional time in the design and planning phases. The long-term benefits of increasing CRD waste recycling and reuse would outweigh the increased upfront costs associated with deconstruction, but are difficult to justify in the current system focused on profits and efficiency (Wimalasena et al., 2010).

Currently, reused/recycled materials have a lower market value (Keena et al., 2022). Despite being cheaper, since most material streams are still linear, recycled and reused materials are not available in sufficient quantities and qualities to meet demand, which hampers efforts to use them (UNEP, 2023). Ultimately, a supply chain of recycled/repurposed materials needs to be established (Gorgolewski, 2018). Designing for deconstruction from the outset and considering the cost of a material's full life cycle would support the development of a market for reused materials, make CBE practices more cost-effective, and help the industry reduce waste generation (Earle et al., 2014; Goodland & Walsh, 2024; Gorgolewski, 2018).

Other barriers to material reuse result from a lack of standards, policy, and information availability. Building materials must meet quality standards, and these either do not exist or are complicated to meet for many recycled/reused materials, which prevents their use and the development of a market for these materials (Goodland & Walsh, 2024). The entanglement of actors and policies involved in waste management, as discussed in Chapter 2, makes it difficult to create guidelines around material reuse. Consistent data also needs to be available and accessible about the environmental impacts, availability, and quality of materials (Goodland & Walsh, 2024; UNEP, 2023). There is also a lack of guidance in design standards and building codes regarding how to use reclaimed materials and incorporate circular building practices, such as design for deconstruction (Goodland & Walsh, 2024).

Alternative waste management strategies in the built environment, such as upcycling, material reuse, adaptive reuse, and design for deconstruction, are becoming more popular as collective environmental concerns grow, and the current predominant strategies of landfilling and recycling become increasingly inadequate (Gorgolewski, 2018). Alternative strategies are still primarily found in individual instances, however, and strategies for waste reduction are disjointed across

geography and industry sectors, which inhibits their uptake (Goodland & Walsh, 2024). Our economic reliance on linear models of production and disposability extends to the construction industry as well, meaning more sustainable strategies are also more expensive, and it is difficult to employ them without sacrificing profit (Keena et al., 2022; Wimalasena et al., 2010).

The strategies discussed above have the potential to effect significant change, but to do so, a systemic approach is needed involving the alignment of priorities and collaboration across the industry (Goodland & Walsh, 2024). Harmonizing the construction industry's approach to circularity with those of other fields in the built environment, while further complicating the range of stakeholders involved, would also provide additional opportunities to create change. Waste reduction and reuse techniques must be applied on an industry-wide basis in combination with the development of a market and standards for reused materials. Legislation and policy encouraging and even mandating waste prevention and reduction would also need to be introduced, as well as an overall circular approach towards the design, construction, and operation of the built environment. This reflection demonstrates that a shift toward circular thinking must position waste as a resource that is not currently maximized by current waste management systems.

3.2 Overview of Existing Examples

The current state of research on material reuse, recycling, and development in the construction industry and various design fields greatly informed how I approached material exploration.

The different states of CRD waste contribute to the applications for which it can be reused. When CRD waste is generated, it may be in the form of whole components resulting from disassembly/deconstruction, or in the form of crushed mixed debris resulting from demolition. Whole components, such as pieces of wood, drywall, or bricks, can be reused as is. However, reusing crushed concrete and masonry is challenging because it is much more difficult to verify their structural integrity and service life (Safiuddin et al., 2013). While there is research being done in that direction, it remains a challenge and impacts reuse applications (Safiuddin et al., 2013; Suchorzewski et al., 2023).

Below is an overview illustrating how CRD waste and waste generated from other sources are reused within the built environment. The first section focuses on applications within architecture, interior design, and infrastructure. The second section focuses on applications within industrial design, furniture design, and object design, identifying a gap in CRD waste reuse in these fields.

3.2.1 Architecture, interior design, and infrastructure

Firms across architecture and interior design that focus on designing with the reuse of CRD waste in mind support the development of a market for reused materials and contribute to establishing best practices in the industry. Five Mile Radius, for example, is an Australian design studio that

specializes in adaptive reuse and material reuse. They consult on architectural projects, advising on the development of circular material strategies (Five Mile Radius, n.d.-a). They also undertake architecture and interior design projects; for Matso's Sunshine Coast Brewery in Australia, they restored a heritage structure dating back to the 19th Century, designing an addition prioritizing the use of salvaged materials in the restoration, particularly from on-site deconstruction, in collaboration with architecture firm Knight Wilson (Five Mile Radius, 2024).

Another example is Danish-Icelandic architecture firm Lendager, which is well known for its work specializing in material reuse and circularity. Their project, Resource Rows, a residential development in Denmark, used demolition waste for its façade, roof gardens, and floors. Another project, Upcycle House, a single-family home in Denmark, utilized primarily upcycled materials in both its structure and interior finishings, including shipping containers, wood, paper, soda cans, and cork (Lendager, 2025a, b, c).

CRD waste, industrial byproducts, and plastic waste are also used to make construction materials. Masonry waste is used to make bricks (FRONT, 2022; Local Works Studio, 2024). Crushed concrete and masonry are reused for land reclamation, road surfacing, and aggregate production (Ajayi et al., 2015). Concrete and masonry can also be recycled into new concrete; this is discussed in more detail in section 4.2.4. Industrial byproducts from metal production, cement production, mining and forestry processes, and coal-burning power plants are used as cement replacements in concrete and to develop aggregate replacements (Alghamdi, 2022; *OSTO*, 2024; Siddique, 2014). Gypsum products are recycled for reuse as a partial cement replacement (Takhiri & Sadeghian, 2024) and can be used to replace raw gypsum (Jia et al., 2021). Plastic waste is used to make modular building blocks (ByBlock, 2022; *PLAEX-Crete*, n.d.)

Construction waste can also be used to make architectural materials; glass and ceramic waste are used to make composite materials that have applications such as wall and floor tiles and solid surfaces (Alusid, n.d.; IceStone, 2020). Similarly, plastic waste is also used to make wall and floor coverings, countertops (*Sustorable*, 2020), and facade claddings (FRONT, 2024).

There is also a growing interest in the use and development of bio-based materials in the building industry as it seeks more regenerative and circular practices (ARUP, 2017; Chen et al., 2024). Biomaterials can be made from organic materials, organic waste, agricultural byproducts, or grown from living organisms like fungi, algae, and bacteria, and are sometimes combined with inorganic materials to make biocomposites (Camere & Karana, 2017; Manu et al., 2022). Some more widely researched applications in the building industry include wallboards, floor and ceiling coverings, and insulation made from cellulosic and fibrous organic materials and agricultural waste (ARUP, 2017; Chen et al., 2024), shells used as an additive for cement, concrete, and gypsum products (Fernandez et al., 2024; Local Works Studio, 2021; Martínez-García et al., 2017), and insulative and cladding materials grown from mycelium (Attias et al., 2020; Chayaamor-Heil et al., 2024).

3.2.2 Industrial, furniture, and object design

CRD waste is reused mainly for downcycling applications in architecture and infrastructure (Wimalasena et al., 2010) and is much less commonly reused at the furniture or object scale, but there is precedent. Five Mile Radius, mentioned above, explores CRD waste reuse in their waste terrazzo tables, for example. These tables are made using excess wet concrete salvaged from construction sites, which they process in their workshop, mixing it with ceramic demolition waste and casting it in reusable molds (Five Mile Radius, n.d.-b). Spain-based company Escofet uses recycled concrete, integrating locally sourced crushed CRD waste or steel slag as aggregate to make urban furniture and architectural concrete (Escofet, 2019).

Plastic waste from post-consumer, post-industrial, and marine sources is widely used across design fields (Karras, 2023). It is used in lighting design (space_available, n.d.; Spark & Bell, 2025) and furniture design (FUTURE re MADE, 2025; Space, n.d.). Plastic waste is also used to make textiles (Peek Neek, n.d.) and a variety of homeware items, such as tableware (Re-Play, n.d.), kitchen and bathroom accessories (ReBorn, n.d.), planters (Bloem, 2025), trays, and coasters (space_available, n.d.).

While not yet widely available on the consumer market, biobased materials, such as bioplastics, biocomposites, and grown materials, are also explored in furniture, homeware, and object design (Bos et al., 2022; Manu et al., 2022; Roussel et al., 2024; Sydor et al., 2021). Biomaterial applications in these fields may be derived from waste, like in the case of French company GWILEN, which uses dredged port sediment to create tiles, furniture, and custom objects (GWILEN, n.d.), or Dutch designer and researcher Tamara Orjola, who created a series of furniture pieces made only of pine needles, a byproduct of the forestry industry (Orjola, n.d.). Biocomposites combining multiple natural materials or a natural material with a synthetic material may also incorporate natural waste sources; Danish brand Mater, for example, makes furniture using a composite material comprised of fibre waste, typically coffee bean shells and sawdust, and post-consumer/post-industrial plastic (Mater, n.d.). Similarly, Studio newtab-22, based in London and Seoul, has developed a biocomposite using shell waste and natural binders, which they use to make decorative tiles, tabletops, plinths and vases (newtab-22, n.d.). Bioplastics also find applications in product design, including light fixtures and tableware (BE O, 2025; Snøhetta, n.d.). Grown materials, particularly mycelium and bacterial cellulose, are also emerging as sustainable textiles that can be used for a variety of design applications, including furniture, lighting, clothing and accessories (MycoWorks, 2025; Roussel et al., 2024).

A specific project that inspired this research, due to its exploration of biocomposite materials, was done at the Hub for Biotechnology in the Built Environment, a research collaboration between Northumbria University and Newcastle University, in which they grew exterior cladding tiles from

bacterial cellulose. The project also introduced sand and other fine aggregate into the material during growth to make it more like concrete (Morrow et al., 2023).

While the reuse of CRD waste in architecture and construction is exemplary of circular approaches and necessary for a CBE, incorporating CRD waste into industrial, furniture, and object design remains an underexplored area. As specialized design services³ contribute to the built environment and represent a \$4.5 billion annual industry in Canada (Statistics Canada, 2025b), this is an area that could benefit from further research, particularly because the structural integrity of the waste would not be as considerable a concern as it is in construction applications.

3.3 Chapter summary

This chapter provided an overview of the range of waste management techniques employed by the construction industry, detailing the shift towards more sustainable strategies focusing on waste prevention and reuse in recent years. Although progress is being made provincially and nationally to implement circular and sustainable strategies, many barriers remain, and residual materials continue to accumulate in landfills.

Based on the CMM's CRD waste statistics outlined in the Introduction, three preliminary waste sources were identified for potential exploration: wood, aggregates, and gypsum. The review of industry waste management practices in section 3.1.1 eliminated wood from contention as a potential waste source for exploration, because it is more readily reusable and can have an improved environmental impact through deconstruction and recycling (Zhu & Feng, 2024). Noted during this review were the challenges associated with recycling and reusing gypsum and concrete/aggregate (Earle et al., 2014; Keena et al., 2022; Wimalasena et al., 2010), confirming these materials as requiring more research to enable reuse.

This chapter also provided an overview of the range of material reuse in the built environment, including object design, establishing the context within which this research is situated. The narrow scope of existing reuse applications for CRD waste, limited primarily to downcycling within the construction industry (Wimalasena et al., 2010), indicated a gap in both research and practice. As the aim of this research is to explore materials that are underused and potentially undervalued, this gap further supported the selection of aggregate and gypsum as waste sources for design exploration. This review also established the research context within which this work is situated, highlighting approaches from CRD waste reuse in architecture and biomaterial use in product and object design that inspire the material exploration in this research.

³ Specialized design services refer to the North American Industry Classification System category, which includes interior design, industrial design, graphic design and other specialized design services (Statistics Canada, 2025a)

Chapter 4: Developing Contextually Informed Material Composites from CRD Waste

Having formalized gypsum and aggregate as residual materials selected for experimentation and reuse, this chapter elaborates on the material prototyping process.

The first section describes the material collection process. Next, the discussion details material reviews of gypsum and construction residue (a term used to refer to a crushed mixture of concrete, asphalt, and aggregate), examining their history, properties, current applications, and recyclability. This comprehensive overview provides a thorough understanding of the chosen materials and establishes the foundation for the subsequent prototyping process.

Finally, the discussion details the prototyping processes for recycled gypsum and two biobased composites integrating construction residue and investigates optimal methods for processing and reusing the collected waste materials. By exploring various formulations, binders, molding techniques, and surface treatments, the research focuses on evaluating material properties and determining how these properties can be most effectively utilized or enhanced.

4.1 Construction site visits and material collection

As access to local waste management facilities was difficult, materials were obtained through scavenging guided by the City of Montréal's *Map of Obstructions and Works in the City*, which identifies public worksites (Ville de Montréal, n.d.). This resource enabled the identification of potential collection points for residual materials (fig. 4.1; fig. 4.2). Over two months, ten collection trips were conducted across multiple sites. Conditions varied: some sites lacked ongoing activity, others were fenced or inaccessible, and certain projects extended beyond listed hours.



Figure 4.1 Construction residue collection site at Boulevard Saint-Michel and 10th Avenue.
Image by Elizabeth Vince.



Figure 4.2 Concrete chunks collected from Rue Saint-Denis and Rue Cherrier.
Image by Elizabeth Vince.

Aggregate presented difficulties in the collection process. The most accessible sources were excavation and roadwork demolition sites, where excavated materials were deposited in mixed piles of concrete, asphalt, aggregate, and soil. Its mixed nature raised the question of whether to attempt to focus collection on one constituent material or collect some mixture of each; either strategy would require extensive sorting and identification, making recovery inefficient and potentially unsafe.

Excavation activities also generated a fine residue composed of crushed concrete, asphalt, and aggregate, which accumulated around sites. This construction residue (CR) remained after work completion and was likely removed later by contractors or municipal cleaning services. Its fine, dust-like texture made it a suitable candidate for material recomposition, as well as collection using simple tools.

Gypsum-based materials were identified later in the process. While most roadwork sites lacked such materials, a nearby renovation site contained mixed waste piles that included drywall fragments (fig. 4.3). Partially crushed pieces were collected, while intact ones were left for potential reuse. Additional drywall was sourced from another site (fig. 4.4), as well as the Concordia University Center for Creative Reuse (CUCCR).

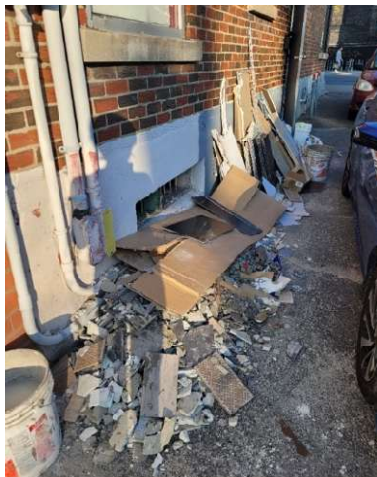


Figure 4.3 A drywall collection site.
Image by Elizabeth Vince.



Figure 4.4 Recovered drywall.
Image by Elizabeth Vince.

The collection process required adaptation and revision of initial plans, underscoring the exploratory and experimental approach of the research.

4.2 Material reviews: gypsum and construction residue

Two pieces of Sheetrock® Brand UltraLight drywall panel, as well as two other unmarked pieces of drywall, were salvaged. The composition of drywall is relatively standard across products.

Sheetrock® Brand UltraLight panels are composed of 87 – 95% gypsum (HPDC, 2024). Their remaining composition is microcrystalline cellulose and various additives. Gypsum is a naturally occurring mineral, comprised of calcium, sulfur, oxygen, and water (Deer et al., 1989). It has a capacity for hydration that can be reversed through calcination, where heating the gypsum to specific temperatures drives off its water molecules.

Referred to as construction residue (CR), the second major waste source comprised a mixture of concrete, asphalt pavement, aggregate, and likely some residual soil. The majority of Montréal's road infrastructure is composed of asphalt pavement, while concrete pavement is typically used for highways, curbs, and sidewalks (Applied Research Associates, 2015; FCM & NRC, 2004; Transports Québec, 2002). Both pavement types share a similar layered structure composed of a soil subgrade topped with various grades of aggregate, differing primarily in the surfacing material (Applied Research Associates, 2015).

4.2.1 Gypsum applications

Gypsum has been used in construction as a structural material, plaster, and mortar since the Neolithic era (Wright, 2005). Its primary global use today remains in the construction industry, for cement and drywall production (Crangle, 2018; Fentiman, 2014). In drywall production, raw gypsum is dehydrated, mixed with water and additives, spread as a slurry between two paper layers, and dried.

Gypsum has also had applications in art and architectural ornamentation dating back to the third century BCE, being used as a binder, sculpting/molding material, and pigment (Lepinski, 2012; Mishmastnehi et al., 2023). Today, gypsum remains widely used in the arts, commonly known as plaster of Paris (McCormick, 2024). Typical methods for working with gypsum include casting, relief molding, or modelling by hand (Lepinski, 2012; McCormick, 2024).

Beyond its established uses in construction, architecture, and art, gypsum has applications as a soil amendment (Ndukwe & Yuan, 2016), in dentistry and medicine (Ma et al., 2021; Scheinberg et al., 2024), and as a food additive (Health Canada, 2024).

4.2.2 Recycling gypsum

Ideally, many applications of gypsum could be reused if deconstruction practices were widely adopted, which is not currently the case (See Chapter 3, section 3.1).

Due to its capacity for repeated hydration and dehydration, gypsum can be recycled and reused as a substitute for raw gypsum (Geraldo et al., 2017; Jia et al., 2021). In Canada, recent research has focused on incorporating recycled gypsum waste as a partial cement replacement (Takhiri & Sadeghian, 2024) or on its agricultural applications (Ndukwe & Yuan, 2016).

Reusing drywall from the CRD waste stream could decrease the demand for virgin gypsum and the associated land degradation from mining (Ndukwe & Yuan, 2016; Weimann et al., 2021). It could also mitigate the environmental impacts linked to gypsum disposal (see section 3.1.1).

Several factors limit the feasibility of gypsum recycling in Canada, affecting economic and environmental outcomes. Recycling gypsum-based waste requires more sorting and separation stages in comparison to landfilling, making the process more complex and costly (Ndukwe & Yuan, 2016; Weimann et al., 2021). Access to recycling facilities also remains a major barrier (Earle et al., 2014; Weimann et al., 2021). Québec has no operational gypsum recycling facilities. The nearest facility, New West Gypsum Recycling, is located roughly 600 km from Montréal in Oakville, Ontario (New West Gypsum, n.d.-b). When recovery facilities are accessible, emissions and energy use associated with the process are reduced, and gypsum recycling can be sustainable (Pedreño-Rojas et al., 2020; Weimann et al., 2021).

A further limitation is the lack of a stable market for recycled gypsum (Ndukwe & Yuan, 2016). Current regulations permitting gypsum disposal, combined with low landfill tipping fees relative to recycling costs, reinforce the preference for virgin gypsum. In British Columbia, several municipalities have banned gypsum disposal in landfills, helping establish a market for recycled material (Earle et al., 2014). However, such measures remain localized.

Ultimately, these barriers reflect the construction industry's prioritization of economic feasibility. Without regulations that discourage disposal and incentives that support more sustainable practices, minimizing immediate costs continues to take precedence.

4.2.3 Concrete and asphalt overview and applications

Concrete and its material predecessors have been used as building materials since ancient times (Gromicko & Shepard, n.d.). Modern concrete is composed of cement, water, and aggregates, along with various additives (Neville, 2011). Portland cement is the most common cement and acts as a binder when mixed with aggregate and water (Gromicko & Shepard, n.d.; University of Illinois, 2019). As the mixture cures, it hardens into a strong and durable material.

Today, concrete is extensively used as a structural material in infrastructure and buildings (Gromicko & Shepard, n.d.; Neville, 2011). It is also valued for its aesthetic qualities in architecture, as well as in the arts, particularly sculpture (Forty, 2012). Beyond these applications, concrete also has uses in industrial and interior design (Ching & Binggeli, 2012).

The road surfacing asphalt pavement is a composite material made from asphalt, which acts as a binder, and aggregate (Baker, 2018). Asphalt can occur naturally, but the majority of asphalt used in construction today is produced through the distillation of petroleum (Speight, 2016). Asphalt is primarily used for road surfacing or for waterproofing products like roof shingles.

4.2.4 Recycling of concrete and asphalt

Concrete is most often recycled by being crushed and transformed into aggregate (Earle et al., 2014). Although interest in the use of recycled concrete aggregate is increasing (Safiuddin et al., 2013), several barriers limit its widespread adoption. Recycled concrete aggregate is typically lower in quality, but its cost often does not reflect this due to the additional steps required for recycling (Earle et al., 2014). Recycled concrete aggregate is used mainly in road bases, general fill, asphalt pavement, and occasionally in the production of structural concrete (Bastidas-Martínez et al., 2022; Tam et al., 2018). However, further research is needed before it can be widely applied in high-performance structural concrete (Safiuddin et al., 2013).

Concrete structures can also be deconstructed and their elements reused in their original form (Küpfer et al., 2023). Nonetheless, this practice remains rare due to challenges related to determining the service life of used concrete and economic constraints associated with deconstruction (Al-Faesly & Noël, 2023; Suchorzewski et al., 2023).

Asphalt pavement is recycled for new pavement construction, although it is always used in combination with new materials (Speight, 2016). The process involves crushing or heating the old pavement and then recombining it. However, asphalt binder deteriorates over time, which limits the effectiveness of recycled asphalt pavement (Muñoz Perez & Onofre Maicelo, 2021).

The economic and technical constraints that impede recycling and reuse of gypsum, concrete, and asphalt, and their limited applications for reuse, reinforce that these materials are underutilized and demand further exploration.

4.3 Material prototyping: exploring properties and characteristics

The prototyping process involved developing recycled gypsum, a potato starch-based CR biocomposite, and a SCOBY-based CR composite. Important information was tracked for each prototype, such as the date the composite was made, the date it was dried, the full recipe, a description of the mold used, and any notes or observations about the material properties⁴ and behaviour. This detailed record proved useful in refining the prototyping process as it progressed.

⁴ Crystalline silica is a mineral that can be found in many earthen construction materials, including concrete, brick, gravel, sand, and gypsum (CGC 2017; McLean et al., 2017). When these construction materials are mechanically broken down, either crushed, cut, ground, etc., a respirable crystalline silica dust is created. Exposure to this dust has long been known as a hazard in the construction industry that can lead to serious health issues (Linch, 2002; McLean et al., 2017). As this hazard could be present in both gypsum and construction residue, I obtained a Safety Data Sheet for the drywall I collected, and followed the recommended precautions (gloves, protective eyewear, and a respirator) when working with both the drywall and the CR.

4.3.1 Gypsum processing and prototyping

The optimal method for reusing drywall employed gypsum's ability to undergo repeated dehydration and rehydration without significant deterioration in quality. By relying solely on the material's natural properties and the addition of water, the process avoided introducing external substances, facilitating potential future recycling. This approach also permits the application of conventional gypsum-based techniques, such as casting and sculpting.

The drywall recovery process used in this research is based on industrial methods utilized by New West Gypsum Recycling (McCamley, 2004; New West Gypsum, n.d.-a) and similar approaches reported in scholarly literature (Geraldo et al., 2017; Rosetto et al., 2015). Easily accessible equipment and manual techniques were adapted to replicate the essential functions of industrial processing (fig. 4.5).



Figure 4.5 Gypsum recovery process. From left to right: crushing, grinding, sieving/filtering, and calcining. Image by Elizabeth Vince.

Following the removal of the paper backing, the gypsum was cut into pieces approximately 3 cm by 3 cm or smaller and then crushed with a mallet to produce granular material with grains around 5 mm in diameter or smaller. Commercial gypsum typically exhibits grain sizes ranging from 0.15 to 0.6 mm (Fernandez et al., 2024). Although precise particle size measurements were not conducted, an early prototype that was only crushed by hand yielded a fragile and breakable prototype (fig. 4.6), indicating that further grinding was necessary. A burr grinder set to an espresso setting produced gypsum powder with particle sizes close to 0.3 mm (MasterClass, 2021), which was then sieved to remove residual paper pulp.

The final stage involved calcining the gypsum powder to dehydrate it. Heating gypsum to temperatures between 125 and 180 °C reduces its water content by approximately 75%, transforming it into bassanite (Geraldo et al., 2017). The resulting dehydrated powder can be mixed with water and set to form solid gypsum again. In this study, a toaster oven with an internal thermometer was used to maintain precise temperature control. The gypsum was calcined at 150 °C for three hours, a duration and temperature shown by Rosetto et al. (2015) to yield high compressive strength and surface hardness.

The primary objectives of recycled gypsum prototyping were to evaluate different water-to-gypsum ratios, investigate the incorporation of CR at varying proportions, and assess the performance of molds, surface finishes, and sealants.

The properties of rehydrated gypsum are influenced by powder fineness, calcination temperature, and the water-to-gypsum ratio (Geraldo et al., 2017). Studies on recycled gypsum indicate that a finer powder and a water-to-gypsum ratio of 0.7–0.8:1 by weight produce stronger prototypes (Geraldo et al., 2017; Li et al., 2021). This range is also typical in commercial gypsum preparation and recycling processes (Geraldo et al., 2017; Rosetto et al., 2015). Ratios above this range extend setting time but reduce strength, while lower ratios may impede proper hydration.

In practice, manual processing and the use of kitchen appliances introduce greater variability in particle size and, consequently, in the optimal water-to-gypsum ratio. Using too much or too little water resulted in fragile and friable prototypes (fig. 4.6). Incrementally increasing the water content led to a ratio closer to 1.2:1, yielding a smoother, more fluid consistency that allowed additional time for mixing and pouring before setting. Strength assessments, conducted by manual breakage, indicated that prototypes with this ratio resisted breakage by hand unless thinner than 1.5 cm.



Figure 4.6 Early recycled gypsum prototypes, using powder that is too coarse (left) or too much water (right). Image by Elizabeth Vince.

Small amounts of construction residue (CR) were added to introduce textural and visual variation. An optimal ratio of 1:4 CR-to-gypsum by weight was identified, providing aesthetic variation without compromising material strength (Fernandez et al., 2024).

Prototyping also involved traditional artistic techniques such as casting and molding (fig. 4.7). Molds made from flexible low-density polyethylene (LDPE) plastic, like that used for bread bags, proved most effective. This material combined sufficient flexibility for easy manipulation with adequate rigidity to maintain shape, allowed enough air permeability to support setting, produced

relatively smooth cast surfaces, and was simple to clean and reuse. Following standard procedures, gypsum samples were left to set within the molds and then removed to cure in open air at room temperature for various durations, in line with established methods (Geraldo et al., 2017; Rosetto et al., 2015).



Figure 4.7 Refined recycled gypsum prototypes. From left to right: sealed with drying oil, no sealant, testing various colourants in beeswax, and wax polish. Colourants were not pursued past the material prototyping stage. Image by Elizabeth Vince.

After casting, the prototypes were sanded to refine their shape and produce a smoother surface. While sanding could be omitted when using more precise molds, manual shaping of the prototypes was considered advantageous.

The final step involved sealing the gypsum to prevent the release of a powdery residue during handling. To achieve a natural, chemical-free finish, various drying oils and beeswax were tested. A wax polish formulated for woodworking, composed of a mixture of drying oil and beeswax (Orvar, 2022), yielded a smooth and soft surface. The wax polish layer was also removable, allowing the gypsum to be recycled and reused in subsequent cycles.

4.3.2 Construction residue (CR) processing and prototyping

The collection of construction residue focused on material already consistent with fine aggregate (particles between 0.075 mm and 5 mm) and dust (particles smaller than 0.075 mm, Neville, 2011; Speight, 2016). Larger chunks of concrete were also gathered to assess the effort required for manual crushing. These pieces were initially broken down with a mallet and chisel, then further reduced using a handheld rock crusher into medium aggregate (particles between 5 mm and 20 mm). The range of construction residue sizes is pictured in Figure 4.8.



Figure 4.8 Construction residue grades. From left to right: dust, fine aggregate, medium aggregate. Image by Elizabeth Vince.

Various biomaterial formulations were explored as potential binders. Biomaterials were selected for investigation due to their growing prominence in material research (see Chapter 3, section 3.2) and their potential contribution to sustainability. Derived from renewable resources, biomaterials are often biodegradable, can significantly reduce the energy emissions associated with material production, and are generally more recyclable than synthetic alternatives (Chen et al., 2024). Many also rely on readily available ingredients such as agar, a potato starch, and resin⁵ (fig. 4.9).



Figure 4.9 Early CR biocomposite tests. From left to right: agar-based bioplastic, potato starch-based composites, resin-based composite. Image by Elizabeth Vince.

4.3.2.1 Potato starch biocomposite prototypes

The potato starch composite recipe (Pavez, n.d.) was selected for further experimentation due to its suitability for broad formal exploration and its cost-effectiveness. The formulation consists of potato starch, glycerin, vinegar, and water, which together produce a thermoplastic starch, a viscous mixture that air dries into a solid. In this study, CR was added.

As multiple grades of CR were collected (dust, fine aggregate, and medium aggregate), different proportions were combined to assess their effect on the composite's strength, texture, and

⁵ All recipes were adapted from <https://www.materiom.org/>

consistency (fig. 4.10). As with the gypsum prototypes, manual breakage tests were conducted to evaluate material resistance. Prototypes composed solely of dust were the most fragile, whereas those incorporating multiple aggregate grades demonstrated significantly greater strength than both the gypsum prototypes and those made with a single aggregate size. This improvement is likely due to the varied particle sizes allowing denser packing, thereby increasing the overall solidity of the composite.



Figure 4.10 Testing different grades of construction residue in the biocomposite. From left to right: only fine aggregate, a mix of fine aggregate and dust, and only dust. Image by Elizabeth Vince.

The material requires direct air exposure to dry, so molds made from air-permeable materials or partial molds that left part or most of the prototype exposed to air were used. Hand-shaping was also explored and proved effective when working with small quantities. This method could be applied additively, allowing one layer to dry before additional material was added. Once air-dried, the material was dehydrated to eliminate residual moisture. This process facilitated the binding of starch to the construction residue, resulting in a relatively solid and durable composite (fig. 4.11).



Figure 4.11 Refined CR biocomposite prototypes with different finishes, from left to right: beeswax, no finish, drying oil. Image by Elizabeth Vince.

The same finishes as those used for the gypsum were tested, including drying oils, beeswax, and wax polish. All seal the material and can be used depending on the desired surface finish.

4.3.2.2 SCOPY and CR prototypes

Inspired by the bacterial cellulose shingle façade project at the Hub for Biotechnology in the Built Environment (Morrow et al., 2023), the research explored the potential of bacterial cellulose.

Bacterial cellulose is a form of pure cellulose (Navya et al., 2022) that can be produced by a wide range of non-pathogenic bacterial species through oxidative fermentation (Quijano et al., 2024; Navya et al., 2022).

Within sustainable design research, bacterial cellulose is valued for its biodegradability, biocompatibility, high tensile strength, and potential for low-impact manufacturing (Quijano et al., 2024). It has been investigated for diverse applications, including as a plastic alternative in food packaging, as a medium for tissue regeneration and drug delivery in medicine (Choi et al., 2022), and as a textile material (Domskiene et al., 2019). Bacterial cellulose can also substitute for plant cellulose in paper products, where it functions as a reinforcement agent (Choi et al., 2022; Skočaj, 2019) and has been studied as an additive to improve concrete performance (Gregory et al., 2021). This research investigated how bacterial cellulose, when combined with CR, can form a flexible and lightweight composite material that contrasts with CR's rigid structure.

Culture methods and media are selected based on the intended application (Ramírez Tapias et al., 2022). Among these, the kombucha method is widely adopted for its accessibility to non-specialists and its popularity among DIY practitioners (Morrow et al., 2023). In this method, bacterial cellulose is produced through interactions between bacteria and yeast, commonly referred to as a symbiotic culture of bacteria and yeast (SCOBY). The process begins by combining tea, sugar, and a starter liquid containing the necessary microbial cultures (May et al., 2019; Quijano et al., 2024). Sugar serves as the carbon source and is converted into glucose and fructose by invertase, an enzyme secreted by yeast. The bacteria subsequently metabolize these sugars to produce cellulose at the air-liquid interface (May et al., 2019). When left undisturbed, the cellulose forms a thick gelatinous pellicle that grows over time (Morrow et al., 2023; Ramírez Tapias et al., 2022). Once it reaches the desired thickness, the pellicle can be removed, drained, and air-dried. As it dries, it shrinks in size and thickness, remaining slightly flexible while retaining its shape.

The prototyping process began with the cultivation of small quantities of SCOBY (Braun, 2021). Black tea, water, sugar, and commercially available kombucha were used, the latter serving as the microbial starter. The culture was grown in a glass container for approximately one month, resulting in a SCOBY pellicle with a thickness ranging from 1 to 2 cm. After harvesting, part of the pellicle was retained to initiate new cultures, while the remainder was used for prototyping. An initial attempt involved blending the SCOBY and mixing it with CR to evaluate whether it would naturally bind during drying. This approach was unsuccessful, indicating that the pellicle must remain intact for further experimentation.

In a second prototype, CR was massaged into the SCOBY pellicle and left to dry. During the drying process, the pellicle shrank and absorbed the CR, resulting in a successful CR SCOBY composite (fig. 4.12). However, further exploration was undertaken to integrate CR during the growth phase rather than after drying.



Figure 4.12 A piece of SCOBY after being massaged with CR and drying.
Image by Elizabeth Vince.



Figure 4.13 The process of adding CR to an in-progress SCOBY, and the SCOBY after drying.
Image by Elizabeth Vince.

Incorporating CR during the growth process allowed for greater control over the degree of absorption and distribution within the material (fig. 4.13). Experiments were conducted by introducing CR at different stages of growth and in varying quantities to observe the resulting effects after drying. Increased amounts of CR produced a material that was less flexible and more opaque. This approach allowed for the testing of aesthetic and material properties of the composite, which informed subsequent experiments with larger batches intended for object-scale prototypes.

The final series of tests focused on determining how the material could be shaped after removal from the growth medium. Common shaping techniques in craft and design practices involve either draping the wet material over a form so that it adopts the desired shape as it dries or cutting dried SCOBY into patterns and joining the pieces with stitching or other fasteners (Roussel et al., 2024). The draping method was selected for experimentation due to its relative simplicity and the aesthetic qualities it produced (fig. 4.14; fig. 4.15).



Figure 4.14 Testing draping SCOBY over a balloon.
Image by Elizabeth Vince.



Figure 4.15 Dried, draped SCOBY.
Image by Elizabeth Vince.

It was observed that the supporting form needed to be sufficiently rigid to bear the weight of the wet SCOBY while remaining flexible enough to be removed without causing damage once the

material had dried and contracted around it. It was also necessary to use a non-absorbent surface to prevent the form from being damaged by the SCOBY's moisture. To achieve this, cardboard forms were constructed and covered with scrap plastic to protect them from water absorption. This approach proved effective for both small and large SCOBY samples.

A range of materials and processes was explored through this iterative and reflective prototyping process. Exploring with recycled gypsum, CR biocomposite, and CR SCOBY composite allowed for an in-depth understanding of how to work with the material composites and prepared me to think about how these composites could be used in the design and fabrication of objects.

4.4 Chapter summary

This chapter presented the process of residual material collection, reviews of gypsum, concrete, and asphalt, and material prototyping. Material collection was conducted by scavenging from municipal construction sites and waste left on street curbs. Through this process, drywall was gathered, and a mixture of concrete, asphalt, and aggregate, referred to as CR, was collected in dust and particulate form.

The material reviews provided an improved understanding of the materials' chemical and physical characteristics, applications, and recyclability. For gypsum, an understanding of its chemical characteristics and industrial recycling process was crucial to support prototyping. For CR, the research indicated that a reuse strategy distinct from those currently employed for its constituent materials would be required. The composite nature of CR and its constituent materials also informed the decision to explore its integration into a new biocomposite material for reuse.

The prototyping examined variables individually to determine their effects on material behaviour: composite formulations and component ratios, molding and sculpting techniques, and surface treatments and finishes. Hands-on experimentation deepened awareness of the materials' characteristics and informed potential applications. Repeated interaction with the residual materials also led to a gradual shift in the perception of waste, a process that will be further examined in the following chapter.

Chapter 5: Valorizing Waste Through Embodied Object Making

After finalizing the material prototypes, determining what kind of objects to make became the focus before exploring design and fabrication. Based on current downcycling applications (see section 3.2), the research aimed to explore new and more diverse applications for these material composites.

The first section of this chapter explores the factors that contribute to why and how we ascribe value—be it economic, sentimental or otherwise—to some things and not others, and how people form attachments to possessions. The investigation of value draws most notably from anthropologist Michael Thompson’s *Rubbish Theory: The Creation and Destruction of Value* (2017), as well as from the work of material culture and queer theorist David M. Halperin (2003). The work of Liboiron (2018) and Reno (2009) is also drawn on as they investigated different approaches people employ to determine the value of waste. In Chapter 2, waste was established as a contextually situated category of matter. By investigating the factors that inform how value is gained, this chapter builds on that idea to explore how something categorized as waste can be reclassified. This section also explores attachment formation to examine how this contributes to the creation of value, drawing on the work of consumer researcher Marsha L. Richins (1994), consumerism and business scholar Russell W. Belk (1988), and design researchers Mugge et al. (2005). These ideas inform specific design strategies to reinforce the valorization of residual materials.

The second part is concerned with how people interact and engage with materials and objects, both as makers and as users. To this end, new materialist perspectives on agency from philosopher Jane Bennett (2010) and approaches to hand-making described by anthropologist Tim Ingold (2013) are investigated. Embodied cognition perspectives compiled by artists, designers, and craft researchers Nithikul Nimkulrat and Camilla Groth in their 2024 book *Craft and Design Practice from an Embodied Perspective* are also examined. These approaches foreground sensory experiences as ways of thinking and learning. Emphasizing the connection between a maker and materials provides a position from which the material potential of waste can be reinterpreted.

The third section puts these theories into practice, detailing the object prototyping process for the recycled gypsum, CR biocomposite, and CR SCOBY composite material prototypes developed in Chapter 4.

Lastly, the discussion includes the results of a group interview that was conducted in June 2025 to explore user perceptions of the object prototypes. The results of the interview provide insight into how users’ perceptions and estimations of the value of the artifacts compare to their perceptions of waste.

5.1 Value and attachment

How we define waste is partially informed by what we perceive as being useful or valuable. Understandings of value, like those of waste, are subjective. Halperin argues that value is not an inherent quality of a thing, “but a residue deposited in them by our activity of valuing them” (2003, p. 5). For something to have value, there must be something without value to compare it against (Thompson, 2017). Notions of value can be informed by economic factors, cultural factors, and our ideas of what is morally right (Halperin, 2003; Hawkins and Muecke, 2003). Our valuation of certain things may come from seeking social differentiation, or may be informed by class distinctions, which dictate standards of living and define what is necessary to belong to certain social groups and what is not (Frow, 2003). Understanding how value is “deposited” into objects can be used to facilitate the valorization of residual materials.

This research is not focused on creating economic value from residual materials. Instead, the research focuses on how to manifest other types of value, either sentimental, aesthetic, or based on usefulness. While there is no direct equivalence between monetary and non-monetary value, Liboiron (2018) found that people equated high sentimental value with things they perceived as having high monetary value. This implies that there are links between different kinds of value as well as between public and individual understandings of value.

The value of an object is also shaped by the individual relationship a person has with it. The relationship between a person and their possessions can be linked to what the possession represents, and how it contributes to the creation of personal identity (Belk, 1988; Richins, 1994). Also explored are the factors that contribute to the development of an emotional bond with possessions, and how they can inform the choice of what artifacts to make and their designs.

5.1.1 The value of waste

Thompson (2017) proposes an explanation of how value is formed and lost, and the role of waste in this process. He describes two pre-existing types of value any material object may have: transient value, which decreases over time, and durable value, which increases over time (fig. 5.1). An example of the transient category would be disposable packaging, whereas fine art would be an example of the durable category. Thompson proposes rubbish as a third category, which has no value and no associated temporal element, arguing that this category mediates the transference of value from the transient to the durable category. Thomson addresses the transformation of both aesthetic and economic value, illustrating how things can move out of the waste category.

Drawing from Douglas (2003), the categorization of things within the transient, durable, and rubbish categories is a function of socio-cultural and economic rules, Thompson (2017) states. Most objects in the transient category will eventually end up in the rubbish category, as their value

depreciates to zero. This was the path taken by the drywall and construction residue used in this research. Although durable objects are less likely to lose value, they may still become rubbish through damage or degradation. Objects in the rubbish category may regain value passively over time as cultural attitudes change, or through a perspective shift Thompson calls a “creative leap” (2017, p. 42), and move into the durable category. Restoration and labour can also imbue an object with value and affect its shift out of the rubbish category. Laval-based non-profit Mine Urbaine, who refurbish and sell recovered bulky waste, demonstrate this strategy (Mine Urbaine, n.d.), which is also applied to valorize residual materials in this research.

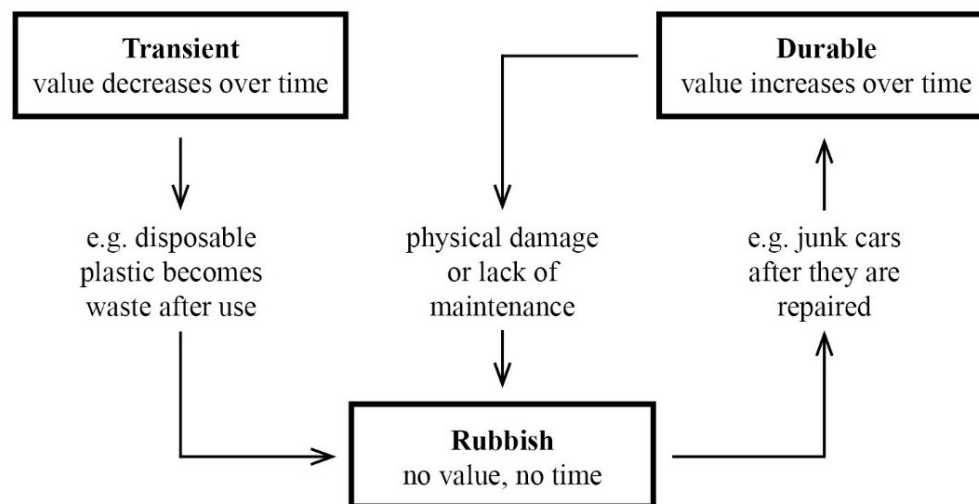


Figure 5.1 Diagram of the circulation of value. Drawn by author, adapted from Thompson (2017, p. 4).

Echoing Thompson, Reno (2009) exemplifies how objects move out of the rubbish category by examining how landfill employees value scavenged trash. Sometimes an item is deemed momentarily interesting and assigned only temporary value. In other instances, the scavenger may identify a unique quality about something that could be realized through reuse or transformation, like a mechanic who repairs junk cars. Liboiron (2018) similarly argues that physical characteristics play an important role in how waste is revalued, as these qualities inform how it could be reused.

As exemplified in Figure 5.1, Thompson’s and Reno’s descriptions of how objects can move through the value categories demonstrate that physical characteristics alone do not determine these shifts; they are also mediated by perspective and social acceptance.

How we value our possessions individually differs from broad, socially and economically accepted regimes of value. Richins (1994) described two approaches people may take to define the value of personal possessions: they may represent the self or be used to create identity, or possessions may represent a particular meaning.

5.1.2 Possessions and their meanings

How people cultivate personal attachments to objects also contributes to how they are valued on an individual basis. Richins (1994) contends that one way we form attachments to possessions is based on their meaning. Possessions can have public and private meanings, both of which are informed by socio-cultural and economic factors and affective interactions, but private meanings contribute more strongly to attachment. Private meanings can be impacted by the owner's personal history with the possession, including its usefulness, the enjoyment it provides, how they interpret its financial, aesthetic, or sensory aspects, the representation of cultural ties, and identity confirmation (Belk, 1988; Richins, 1994). Repeated interactions with an object can also cultivate sentimentality over time, as it becomes connected to experiences and memories. Contributing factors to possession meaning are outlined in Figure 5.2.

possession meaning	
public meaning	private meaning
> culture > class > aesthetics > economics > media > marketing/advertising	> public meaning > usefulness > personal enjoyment > financial aspects > aesthetics > sensory aspects > contribution to identity creation • affirmation of personal values • memories/past experience • cultural ties

Figure 5.2 Breakdown of factors contributing to a possession's meaning.
Diagram by Elizabeth Vince.

Design researchers Mugge et al. (2005) contend that when consumers have a stronger emotional bond to products, they are less likely to throw them out, and designing for emotional attachment can be an eco-design strategy to reduce consumption. To design for emotional attachment, the authors suggest making products unique, as this can appeal to an individual's desires for identity construction. Embodying a product's meaning within its design also assists the product in being perceived as irreplicable, due to what it represents, and cultivating user attachment.

Value appears as a fluctuating attribute. Based on the investigation into value and attachment formation, functional décor was chosen for object prototyping because these types of objects can be interacted with regularly, and these interactions could facilitate the object being seen as valuable. Factors contributing to value and attachment also shaped design choices, with the intention that

the artifacts embody the sustainable ethos of the research, allowing those who identify with it to see their values reflected and form personal connections to the objects.

5.2 Materiality, agency, and embodied making

To further stimulate the valorization of residual materials, the physical properties and creative capacity, or agency, of the materials were foregrounded in the design and fabrication process. Drawing on Bennett's vital materialist philosophy (2010), embodied cognition as it applies to design and craft practices (Nimkulrat & Groth, 2024) and diverting but similarly aligned perspectives offered by Ingold (2013), the approach to the design and making process intended to let the materials take the lead.

5.2.1 Working *with*: Adopting a materialist perspective

Experimentation foregrounded the potential creative power of matter. Bennett (2010) attends to the capacity of things, materials, and objects to cause effects. She argues that things have "trajectories, propensities, or tendencies of their own" (2010, p. viii) and uses the terms "vibrant matter" and "thing-power" to refer to matter's activity or agency.

Drawing from Latour's actor-network theory (1996) and Deleuze and Guattari's process philosophy (1987), Bennett (2010) insists on the distributed nature of agency. Matter doesn't act alone, but rather in cooperation with humans, non-humans, technology, environments, and other matter. She refers to these ad hoc groupings as assemblages and insists on their collective agency and the relationality of their elements.

This materialist standpoint questions the root of agency and notions of human intentionality. To attune to the agential and affective nature of non-human matter, Bennett (2010) stresses the importance of being open-minded, to suspend disbelief and resist the tendency to attribute one's actions to human agency alone. How well we can perceive thing-power, Bennett argues, depends on our embodied experiences and recognition of the non-human forces operating outside and inside the body. Bennett (2004; 2010) also draws attention to the agentic capacity of waste, as she questions how patterns of consumption might change if we acknowledged the liveliness of trash and its constituent parts.

Bennett's materialism collapses the hierarchy that would position humans as masters of the natural world and waste as a residual material to be managed, instead creating a more horizontal juxtaposition. This suggests that by acknowledging the shared material basis of all things, a maker can work *with* their materials instead of simply using them.

In the object prototyping process, working *with* materials was manifested by using methods and exploring forms that best suited the materials' physical properties and their behaviour. It also

meant being receptive to sensory feedback and adapting processes throughout. Each material produced affects or altered situations in different ways. Making *with* recycled gypsum meant using a specific molding material that allowed it to take on expressive forms, and responding to the sensory feedback when carving it to emphasize these forms. The CR biocomposite demonstrated its agency by refusing to conform to the molds or shapes it was sculpted into (fig. 5.3). Its refusal to be controlled inspired the making process and the final forms.



Figure 5.3 CR biocomposite deforming after being molded. Image by Elizabeth Vince.



Figure 5.4 Air bubbles under the surface of the SCOBY pellicle. Image by Elizabeth Vince.

Because the SCOBY material is alive, it requires attention and cultivation during its growth, and for the maker to be responsive to certain changes. One of the SCOBYs grew mold early in the process. Sometimes large air bubbles would develop between the SCOBY and the growth medium, which needed to be popped to allow for growth to continue (fig. 5.4). Additionally, while the ingredients of the recipe can be adjusted, the outcome cannot be totally controlled. The thickness, surface texture, and colour of the SCOBY may all vary, subject to distributed factors.

Attending to the material's agency, and making *with* its emergent, relational properties facilitated a shift from an anthropocentric view of materials that centers on human needs to a non-anthropocentric viewpoint that centers on the relationship between humans and material. Instead of looking at waste as something that has fulfilled its purpose, engaging directly with it allows it to become something new: a material opportunity to be enhanced through the making process. Centering agency allowed it to be recognized as a valuable property of the material, facilitating unique interactions. Additionally, sharing these experiences with the material facilitated a connection between material and maker.

5.2.2 Making by hand and embodied material knowledge

Nimkulrat and Groth (2024) suggest that many practitioners who write about their embodied experience in craft and design draw on the concepts of material dialogues, material engagement, and affordances.

Material dialogues are described by Malafouris and Koukouti (2022) as arising from a skilled practitioner's situational awareness in which they use tactile perception to respond to the affordances of a material, and the material in turn is responsive to the maker. This process involves multimodal sensory engagement and mindful presence. Similarly, interdisciplinary scholar Ingar Brinck (2024) describes skilled hand-making as fundamentally collaborative. A maker can get to know their material by learning the material's history or its use in other contexts (Ingold, 2013; Lange-Berndt, 2015). Touch can be a tool to discover material properties, to learn how much force to exert and in what direction, or to determine the correct rhythm of movement to bring about the desired manipulation. The materials, Ingold argues, "carry a memory of [the hands'] manipulation" (2013, p. 118).

The repetitive, hands-on process of carving recycled gypsum contributed to the development of embodied knowledge of the material. This time-intensive process necessitated learning how much pressure to exert while carving or sanding to create the desired shape. Specific qualities that needed to be maintained so that the recycled gypsum would retain its structural integrity were also determined through this hands-on engagement, such as how thick the material needed to be to prevent it from breaking under the pressure of my hands or when dropped (fig. 5.5). This demonstrated that the recycled gypsum is better suited to rounded, softly curved shapes, as edges and corners break more easily when handled. Material engagement with the CR biocomposite was also built through interactions with the hands, which facilitated an awareness of how it would respond to certain manipulations. Paying attention to certain material characteristics, such as its tendency for deformation and shrinkage, and its drying time, facilitated a better understanding of how to work with the material. Other environmental factors, such as the material of the work surface I used, also impacted the process. These effects, in addition to sensory stimuli and material properties, contributed to the development of a situated material engagement.



Figure 5.5 Failure and broken prototypes facilitate a better understanding of material properties and deepened material engagement.
Image by Elizabeth Vince.



Figure 5.6 CR biocomposite pawns, the shape becomes more refined with practice, progressing from left to right.
Image by Elizabeth Vince.

With time and repetition, embodied experiential knowledge is constructed, which can then be drawn on in times of difficulty when making or interacting with new materials (Groth, 2016). Repetition is necessary not only to build skill with the material, tools, or processes one is working with, but also to “understand the creative potential inherent in the materials and processes involved” (Niedderer & Townsend, 2024, p. 68). Employing repetitive, time-consuming, and effort-intensive processes also furthered the cultivation of an attachment to the materials. These transformations also worked to imbue the materials with value, as described by Thompson (2017).

Sixteen pawns were made for the chess set, eight from recycled gypsum and eight from CR biocomposite (fig. 5.6). The first pawn made from each material required more attention to detail to create the mold correctly and form the material into the desired shape. For the recycled gypsum, more dedicated sanding was also required to create a smooth surface. Over time, a flow of movement, feedback, and adjusted movement emerged: I knew when to adjust the CR biocomposite to counteract material deformation, and how much to sand the recycled gypsum pawns.

Making by hand, Ingold (2013) argues, also facilitates communication with those not involved in the making process. Through the manipulation of tools and materials, a maker can convey meaning to a viewer or user, but the feelings of the maker can also be conveyed. Nimkulrat (2024) contends that the viewer or user is sometimes able to grasp part of a maker’s thought process or experiential knowledge when physical traces of the making process are left behind on a finished artifact, particularly when engaging with the artifact haptically. The communicative nature of hands-on making and materials is explored in more detail in section 5.4, where user feedback is discussed.

Accounting for the agency of matter guided the creation process and cultivated a more caring and open relationship with it. Design was used as a prediction tool to be amended throughout the process, reflecting the link between thinking and making. Engaging with sensory stimuli, responding to material affordances, and using the hands as tools for making facilitated the development of embodied knowledge.

The handmade nature of the objects also facilitated communication between maker and user, hopefully conveying an effort toward waste valorization through their formal and aesthetic qualities as objects.

5.3 Object prototyping process

The iterative object prototyping process (resulting in a series of trays, coasters, candle holders, vases, a bowl, a chess set, and a lamp) used the three materials described in Chapter 4: recycled gypsum, CR biocomposite, and CR SCOBY composite. The process for the first object, a recycled gypsum coaster (fig. 5.7), involved developing a rough concept, only enough to develop the idea

and make a mold. Working *with* the material's unpredictability allowed the forms to emerge from the process and the materials themselves.

As a commitment to sustainability and to facilitate recycling, only the prototyped composites were used initially. This strategy was also a way to explore how the materials could stand on their own aesthetically. Various metals were introduced in a second iteration (fig. 5.7) to create contrast between textures and forms, as well as visual interest in the works. For example, the shiny surface of metal contrasts well against the matte, textured composite materials.



Figure 5.7 Various metal elements compared to CR biocomposite (top right) and recycled gypsum (bottom right) coasters.

Image by Elizabeth Vince.

These additional materials were sourced from CUCCR. I selected antique window latches, hooks, and sheet metal in a variety of metal finishes. These materials and objects would also be used in the built environment and aligned appropriately with the use of residual CRD materials. Including other reused elements would make the recycled nature of the artifacts more obvious and would help make each artifact individually distinct, thus contributing to their potential for facilitating greater product attachment (Mugge et al., 2005). These strategies encouraged an exploration of how the form and function of the composite materials and metal elements could complement each other.

5.3.1 Recycled gypsum object prototyping: Reflecting hands-on interactions

Prototyping techniques using recycled gypsum were informed by casting and carving methods used for artistic and architectural applications of gypsum. I focused first on molding and how the material could be shaped when wet. For the coaster prototype (fig. 5.7), a recycled piece of plastic sheeting was used as a mold, onto which gypsum was cast, then manipulated by the hands to shape the plaster into an oval disc and create indentations with my fingers. After the recycled gypsum had set, I demolded it and sanded it, primarily focused on creating a smooth surface. The same process was observed for subsequent prototypes, as exemplified by *Candle holder #1* (fig. 5.8; fig. 5.9).



Figure 5.8 From left to right: *Candle holder #1* before and after sanding, and after sealing and addition of the copper inlay. This candle holder was sanded to refine its shape and create a smooth surface. Image by Elizabeth Vince.



Figure 5.9 *Candle holder #1*: Recycled gypsum base, copper inlay. Image by Elizabeth Vince.

However, recycled gypsum sets very quickly, and there is a limited amount of time and limited room for error when manipulating the wet material. As an alternative, I explored carving the material after it had set (fig. 5.10). This allowed for the gypsum to be cast into a rough idea of the intended outcome and the continued development of the shape as I carved it. The design and making process were directly linked: as I developed an understanding of the material, I worked on prototypes without knowing what the final artifact would look like, but knowing it would emerge from the process.



Figure 5.10 From left to right: Recycled gypsum *Tray #2* in the mold, after carving and sanding, and after sealing. This is an example of the carving required for most prototypes. Image by Elizabeth Vince.

The artifacts (fig. 5.9 to fig. 5.14) are designed to reflect their handmade nature, their material sustainability, and to evoke natural forms. Creating organic, imperfect shapes reminiscent of naturally occurring forms reflects the material's natural origin. Their shapes also reflect how I interacted *with* them in the making process and how they might be interacted with by a user.



Figure 5.11 *Candle holder #2*: Recycled gypsum base, aluminum inlay. Image by Elizabeth Vince.



Figure 5.12 *Candle holder #3*: Recycled gypsum base, brass window latch handle. Image by Elizabeth Vince.



Figure 5.13 *Vase #2*: Recycled gypsum around a steel pipe. Image by Elizabeth Vince.



Figure 5.14 *Bowl*: Recycled gypsum, metal window latch handles. Image by Elizabeth Vince.

Brass and copper complement the warm tone of the recycled gypsum while contrasting against its texture. The inclusion of the metal elements also became a way to further emphasize the interaction between the hands and the material; *Candle holder #1* (fig. 5.8; fig. 5.9), for example, has copper embedded to emphasize the divots for fingerprints; *Vase #2* (fig. 5.13) is formed around a steel pipe and similarly has divots for fingerprints carved out, and *Candle holder #3* (fig. 5.12) and the *Bowl* (fig. 5.14) have latches embedded in them that can be used as handles. The metal in *Candle holder #2* (fig. 5.11) is introduced solely as a point of aesthetic contrast, whereas the copper on *Tray #2* (fig. 5.10) is functional, adding a protective layer to the bottom of the tray.

5.3.2 Construction residue biocomposite: An unruly material

Unlike the recycled gypsum object prototyping, the object prototyping process for the CR biocomposite was not heavily informed by any manufacturing methods for its waste source materials. The unique nature of the CR biocomposite made for much more exploratory object prototyping. The CR biocomposite needs more exposure to air in drying, dries much harder than recycled gypsum, is less easily sanded, and has a more differentiated surface texture (fig. 5.7). This observation was made possible through engaging with the agency of the materials, rather than forcing it to do something it was not well-suited for.

The first CR biocomposite object prototype was a coaster shaped by hand (fig. 5.7). As it started to dry, the shape began to deform and curl. Embracing the material's tendency for shrinkage or deformation, I continued to sculpt the CR biocomposite, without molds (see Chapter 4).

The CR biocomposite could not capture fine details or edges well because of its textured aggregate and tended to deform toward amorphous, blob-like shapes. These more amorphous shapes, however, contrast against the rough surface texture created by the aggregate. In response to this tendency, I explored simple shapes that could highlight the material surface texture and reduce deformation during drying (fig. 5.15). I also explored different combinations of aggregate grades to create various textures. Silver metal pieces complemented the grey and black tones of the construction residue while contrasting in texture.



Figure 5.15 *Tray #1*: CR biocomposite base, aluminum inlay.
Image by Elizabeth Vince.



Figure 5.16 *Coaster #2*: CR biocomposite base, aluminum inlay & ornaments.
Image by Elizabeth Vince.

As I had already been exploring making candle holders before introducing the metal, it seemed fitting to use a steel pipe that was nearly the perfect size for a candle holder (fig. 5.17). *Vase #1* (fig. 5.18) is made with the same steel pipe. The bases for *Candle holder #4* and *Vase #1* take a simple rounded shape, partly as a reflection of the CR biocomposite's material properties, also to align with the rounded smoothness of the steel pipe, allowing the CR biocomposite's varied texture to stand out. For the other two CR biocomposite artifacts, *Tray #1* (fig. 5.15) and *Coaster #2* (fig. 5.16), sheet metal is used to provide a flat base, in addition to acting as a textural point of contrast with the CR biocomposite.



Figure 5.17 *Candle holder #4*: CR biocomposite base, steel pipe. Image by Elizabeth Vince.



Figure 5.18 *Vase #1*: CR biocomposite base, steel pipe. Image by Elizabeth Vince.



Figure 5.19 *Chess set*: Recycled gypsum and CR biocomposite pieces and board. Reclaimed wood and fabric were used for the base and inlay. Chess pieces: Recycled gypsum (top) and CR biocomposite (bottom). Reclaimed metal fasteners for king and queen pieces.

Image by Elizabeth Vince.

The recycled gypsum and CR biocomposite were brought together in the creation of a chess set (fig. 5.19). Their contrasting colours were well suited to this application. Chess pieces also provide an interesting avenue for tactile interaction with the materials, with each piece designed to invite a different grip. Metal fasteners (brass for recycled gypsum, steel for CR biocomposite) add a point of contrast to the king and queen. The base of the board is made from reclaimed wood and features a recessed compartment in which to store the pieces.

5.3.3 Construction residue SCOBY composite: Contrasting solid synthetic and flexible organic

The object prototyping process for the CR SCOBY composite was considerably different from the other two materials. The SCOBY's growth was time-consuming and led to fewer hands-on experimentations. Lampshades were explored to experiment with the flexible, lightweight, and transparent nature of the CR SCOBY composite. While this application does not necessarily maximize the amount of CR that could be incorporated into the SCOBY, the compelling way the

CR is incorporated supports the residual material's valorization because the application is so different from its origin.

I prepared large batches of growth medium for these prototypes. Multiple factors affect SCOBY growth, including ambient air temperature and pH⁶ (Quijano et al., 2024). I added CR to one of the batches as the SCOBY grew, sprinkling it onto the SCOBY after it had grown a base layer, waiting for the SCOBY to grow over the CR, and adding more.

After two months, the SCOBYs had grown to a thickness of ~1 cm. They were removed from the growth medium, rinsed, and drained. Using the SCOBY to which no CR had been added during the growth process, I massaged it with CR and draped it over a dome-shaped form, trimmed it to shape, and left it to dry (fig. 5.20). After two months, the CR SCOBY composite was dry to the touch and had shrunk to a thickness of ~1mm. It was then removed from the form. It remained soft and flexible, and over time, it became harder, slightly more brittle, and continued to deform as more of its moisture evaporated.

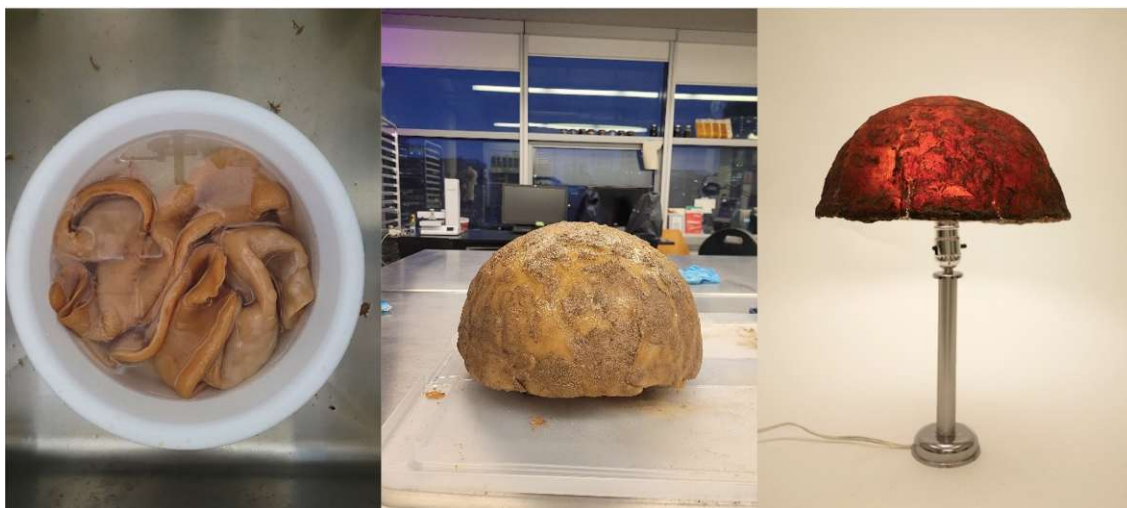


Figure 5.20 SCOBY lampshade process. From left to right: the pellicle soaking after removing from the growth medium; after adding the construction residue and draped over the domed form, and assembled with the lamp. The lamp base, apart from the socket, is made from metal recovered from CUCCR. Image by Elizabeth Vince.

In the other SCOBY, the layers of CR were visible throughout it (fig. 5.21). After rinsing and draining the CR SCOBY composite, it was laid flat to dry. It was then soaked in water to restore some of its flexibility, and draped over a smaller domed form, letting the bottom hang freely to create a draped shape, and allowed to dry. With this approach, the CR SCOBY composite maintained its draped, fluid shape after drying and did not stick to itself.

⁶ With a temperature typically between 22-24°C during the time my CR SCOBY composite was growing, a pH of 3-3.5 was optimal to support its growth and prevent mold.



Figure 5.21 From left to right: The layers of construction residue in the SCOBY, the SCOBY drying flat, and the SCOBY draped over a form. Image by Elizabeth Vince.

Despite the lack of hands-on contact with the CR SCOBY composite during the majority of the object prototyping process, I still felt the development of a strong, caring engagement with the material. This feeling of care is likely bolstered by the fact that SCOBY is alive and requires attention during cultivation, whereas the other materials were inanimate. This connection reflects the ease with which the agency of a living organism can be recognized compared to an inanimate object.

By engaging with three different composites (recycled gypsum, CR biocomposite, and CR SCOBY composite), the iterative and intuitive object prototyping process relied on an embodied understanding of the materials. It was informed by sensory feedback provided by the materials as well as their properties, histories, and past uses. Working by hand served to strengthen this relationship with materials while facilitating emotional and haptic engagement. Hands-on processes also invested the materials with value and informed design decision-making. Developing a stronger connection to the materials, where their agency is respected, made it easier to make *with* them throughout the design and making process.

The recycled gypsum objects were carved into forms that reflect the maker's interactions with physical and temporal processes. The CR biocomposite objects were sculpted to foreground the material's texture, rather than into any specific forms. The CR SCOBY composite lampshades highlighted the qualities of the SCOBY and its ability to transform the construction residue into an application with such converse properties to its original purpose. Reclaimed metal elements were introduced to contrast and emphasize the material properties as well as draw attention to their recycled nature. Amplifying the materials' inherent qualities is intended to create new and interesting sensory experiences for users, in order to facilitate the reinterpretation of the residual materials' purpose or value, separate from that of their origin.

5.4 User feedback

A group interview with two participants allowed for the gathering of feedback on object prototypes (Barbour, 2018). The purpose of the activity was to investigate the perceptions of others when they engage with the materials and objects, to examine how people's perceptions of waste could change, and to evaluate how successfully the waste material was valorized. The small sample size imposed limitations on the diversity of feedback that was received, and this must be acknowledged.

Interview questions were informed by the concept of materials experience, described by design and materials researchers Karana et al. (2014) as the experiences both consumers and designers “have with, and through the materials of a product” (p. xxv). Pedgley et al. (2021) assert that materials experience consists of three levels: sensorial experience, experience of meaning, and emotional experience. Materials can create a lasting positive or negative experience with an object, drawing us in or deterring us. Sensory experiences with materials are inherently subjective (Karana et al., 2014); however, designers can manipulate material properties to communicate certain ideas and to help facilitate the development of emotional bonds between a person and product (Pedgley et al., 2021). Giaccardi & Karana (2015) assert that materials are experienced subjectively “on the basis of the characteristics of a situational whole” (p. 3), informed by the product's form and function, the user's values, and the meaning they attach to a product, so a material alone may not facilitate attachment, but it is a contributing factor.

Framing the interview questions through the levels of materials experience helped to explore how participants interpreted the objects and what kinds of sensations and associations the materials elicited. This framing was also used to explore how the formal and material qualities and use context contributed to participants' evaluation of the objects and their estimation of whether they could become attached to the objects.

The activity was divided into three stages: the first involved gathering contextual information relating to participants' sustainable behaviour and typical interactions with waste; the second focused on perceptions of construction waste; in the third phase, participants were asked to interact with and discuss the object prototypes.

Both participants described themselves as environmentally conscious, with an average understanding of waste management systems, but expressed feeling like they could do and know more. They also noted the difficulty in making changes because unsustainable behaviour and disposal practices are ingrained in both their personal lives and society. The participants both came from a design background and had either academic or professional experience with sustainable design and recycled materials but felt a wariness toward greenwashing in the marketing of recycled materials and products. Outside of professional and academic contexts, they did not pay much attention to CRD waste unless directly presented with it. One participant, who self-described as

having eco-anxiety, was more inclined to think about the energy usage and deforestation associated with new construction rather than the waste generated by the process. This information provided the context that both participants were receptive to and felt favourably towards the idea of waste reuse in design.

The participants were asked to handle, describe, and suggest past and future uses for a range of construction waste, including a stone block, drywall, a brick, a chunk of concrete, and a piece of planed stone (fig 5.22; fig. 5.23). They described the brick, concrete, and stone block as heavy and austere, and imagined they were used for structural purposes and could have landscaping, sculptural, or industrial furniture applications. The drywall was described as lightweight, dusty, and synthetic. The participants correctly identified it as drywall, so the suggested uses were limited to drywall applications. The perceived fragility of the drywall made it difficult for them to imagine its reuse, whereas they found it easier to predict future reuse applications for the more durable elements. They gave more detailed descriptions for the planed stone than any other materials, calling it solid, smooth, pretty, having an interesting, organic, and minerally texture, and reminiscent of crystals, and suggesting it could be used as an interior cladding or used in a mosaic. It can be inferred that the extra attention given to this piece of stone was a result of it being the most traditionally aesthetically interesting of the options presented. The participants were also asked to observe a nearby active construction site that featured piles and dumpsters full of CRD waste. In comparison, seeing the CRD materials removed from the context of the construction site allowed the participants to notice the materials' unique textures and composition, and said there was "something more intimate and kind of like, artistic about that." This response links to the idea of defamiliarizing waste (Liboiron & Lepawsky, 2022) as discussed in Chapter 2. By interrupting the typical way CRD waste is perceived and presenting it in a new setting, the participants were able to engage with these materials and think about them in a way they usually would not.



Figure 5.22 Construction waste presented to participants. Clockwise from top left: stone block, drywall, brick, concrete, planed stone. Image by Elizabeth Vince.



Figure 5.23 Participants handling construction waste. Image by Elizabeth Vince.

Lastly, they were asked to handle, describe, and discuss the object prototypes (fig. 5.24). The recycled gypsum objects were described as “very sculptural and organic”, lightweight yet sturdy, and as visually resembling cork, ceramics, cement, or even driftwood because of their textural quality. The CR biocomposite objects were described as industrial, and the participants correctly identified their material, saying, “This to me feels like asphalt or something of that nature. It's like small stone aggregates, like crushed up.” The recycled gypsum objects received more attention and more detailed descriptions than the CR biocomposite objects. This could be because the CR biocomposite objects’ material source was clear, whereas the source material of the recycled gypsum objects was less clear and thus warranted more investigation: “I'm wondering if it's in the process of how you made them. You can kind of see, like, the streaks and the scratches, and that kind of reminds me of driftwood and more organic, natural elements.” The extra attention paid to the recycled gypsum objects could also be because they found them more visually interesting. The descriptors used for the recycled gypsum had a less industrial quality than those used for the CRD waste in the second stage. Few of the descriptors used overlap with how the drywall or any other CRD waste was described. This discrepancy in descriptions validated the idea that transforming the residual materials into new applications could help establish new perspectives on their use and value.

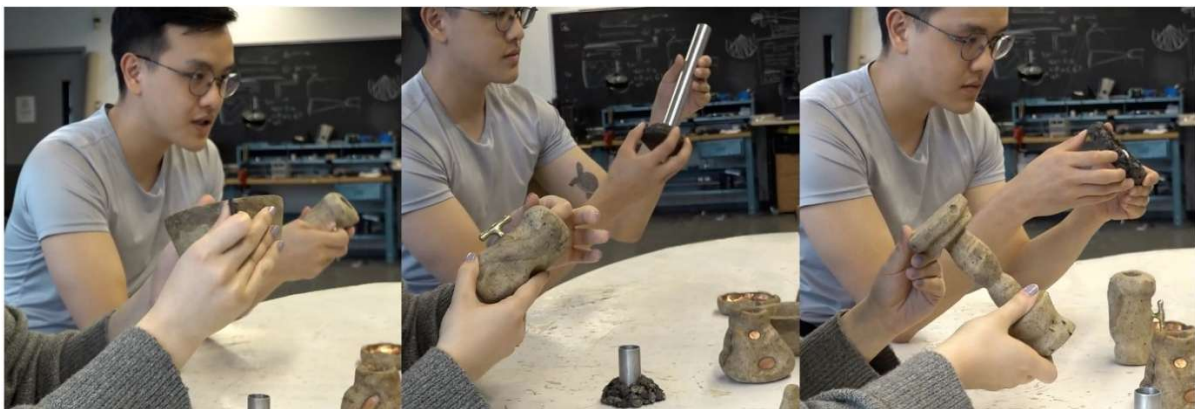


Figure 5.24 Participants handling various object prototypes. Image by Elizabeth Vince.

The participants were already aware that the artifacts were made from residual materials, as this information was included in the recruitment materials. The precise material, however, was not disclosed. One participant wondered if the recycled gypsum artifacts were made of sand. In response to learning what the recycled gypsum objects were made of, they said:

I was quite surprised to hear that it's made from, like, the drywall gypsum. Like, especially our conversation earlier about, like, how I thought it was very fragile, but these were a lot more solid than I would have expected coming from that material. So, it's really cool. And with that [earlier discussion of CRD waste], we were talking about, like, the different textures of the more solid pieces, and we kind of, like, overlooked the gypsum. But, like, this has that kind of, like, natural look to it, too. So, like, you kind of brought that back, which is really, really nice.

The other participant added, “You turn something so synthetic-y into something that looks, like, cute and organic-looking. I think it's cool. I feel like it's upcycling, which I'm, again, I'm very for. So, I really like it, actually. I have a better appreciation for it.”

The participants described the series of object prototypes as “read[ing] organic” in their shape and surface texture, adding that these qualities “adds to, like, the texture and aesthetic of it. It's like the handcrafted quality, which is nice.” The handmade nature of the objects, the use of recycled materials, and the uniqueness provided by the metal elements added to both participants’ appreciation of the objects. They could also imagine the artifacts fitting into a domestic context. As the objects were designed to reflect their handmade nature as a way of personalizing the objects and embodying their meaning to facilitate emotional attachment (Mugge et al., 2005), these comments were partial confirmation that these intentions were communicated to participants, and along with the metal elements, contributed to the artifacts being perceived as unique.

One participant felt an attachment to the chess set in particular, having made one herself in the past and commenting on the difficulty of “reinventing” something that has been made and redesigned so many times throughout history. The influence of the participant’s experience on her attachment to the chess set demonstrates how personal contextual factors influence the development of private meanings and the cultivation of attachment (Richins, 1994).

Watching the participants handle the artifacts offered additional insight into their experience and perspective beyond their verbal responses. While they did not directly comment on the objects being shaped to fit the hands, when they handled the objects they interacted with them as intended and held them in the same way I did while making them. This emphasized the potential of the artifacts to communicate haptic experience from maker to user (Ingold, 2013).

The group interview offered an outside perspective on the object prototypes. As the participants were already interested in and had knowledge of sustainable design, it is acknowledged that they were likely more inclined to have a favourable reaction to the artifacts than someone who did not have the same preexisting knowledge. The small number of participants also limits the variety of responses received. Still, discussing a range of construction materials prompted their reflection on how construction materials and waste often get overlooked in everyday life. Particularly with the recycled gypsum objects, the participants had a different perspective of the source material after seeing the object it had been transformed into, so in that way, it can be argued that the object prototypes succeeded in valorizing the waste drywall and facilitating a perspective shift.

5.5 Chapter summary

This chapter first explored the creation and loss of value to understand how materials become waste and how they can be valorized. Value is not inherent but socially constructed and fluid (Halperin, 2003; Thompson, 2017). Objects may regain value through restoration, changing contexts, or natural changes in societal perception of value. These strategies were applied in the object prototyping process.

How attachment is formed with possessions was investigated to inform the decision of what objects to make. Functional décor objects were explored because these types of objects could be used in the home and interacted with regularly, resulting in a higher likelihood that a user could develop an attachment to the object and consider it more valuable (Richins, 1994). These ideas also informed design decision-making.

Materialist and embodied cognition perspectives shaped the making process, fostering a relationship with the materials. Being receptive to sensory stimuli, understanding agency as contextually distributed, and accepting humans as part of an assemblage allows one to recognize matter's agentic capacity as proposed by Bennett (2010). Similarly, the embodied cognition perspective stresses the connection and conflation of thinking and making. Haptic experience, in this case, is a tool for learning about and forming an emotional engagement with materials (Brinck, 2024; Groth, 2016). Through this approach, the significance of the materials as well as the effort invested in their valorization was translated into the object prototypes and could be perceived by viewers and users.

Embodied knowledge of each material was continually developed throughout the prototyping process, built by haptic, sensory, and emotional feedback. A range of coasters, trays, vases, bowls, and candle holders, as well as a lamp and a chess set, explored various material properties and aesthetic qualities. Unique reclaimed metal elements created a point of contrast and visual interest.

Lastly, a group interview provided feedback on the object prototypes and explored perceptions of CRD waste. The discussion allowed participants to imagine more creative or artistic applications for CRD waste reuse and to have a stronger appreciation for its sensory qualities. Through sensory engagement, the participants were able to recognize the care and effort that was put into making the object prototypes. This increased their appreciation of the objects, while also broadening their understanding of the potential of CRD waste.

Chapter 6: Conclusion

This research addressed how underutilized construction, renovation, and demolition waste might be reused in new ways, with the goal of demonstrating the potential of residual materials and contributing to an understanding of waste as a resource. As Hird (2021) argues, to address our waste problem and the upstream issues that contribute to it, we need to look at waste as something to be used and managed ethically. Reimagining CRD waste as a resource could work to interrupt the built environment's linear material flows that inundate landfills and compound environmental issues, particularly resource scarcity and GHG emissions. In pursuit of this goal, material composites were developed from CRD waste, and objects were designed and fabricated using these materials. Creating with residual materials was employed to draw attention to wasting systems and encourage others to reconsider their perceptions of waste. This research can be useful for students and other practitioners working in the field of material reuse by identifying specific materials in the waste stream that are underutilized. The material prototyping process also contributes to open-source recipes and methods of reuse. The discussion of material engagement through prototyping also demonstrates the importance of hands-on embodied knowledge from a design perspective, as it offered insights that could only emerge through direct interaction with materials.

The discussion first addressed the contextual, shifting status of waste. The influence of socio-cultural, economic, and political systems on understandings of waste in the Canadian context showed that these systems work together to position disposability as convenience and waste as a technoscientific issue, emphasizing individual responsibility for its management. As a result, the waste management industry remains profitable, and cycles of production and consumption remain intact. Unpacking the influences of these systems creates room to establish an alternative perspective on the value of waste. An investigation of waste governance and management in Montréal also demonstrated that, while the city has begun shifting its waste management strategy towards circular approaches, these plans are still in the early stages, and Montréal's waste management still resembles a profit-driven model reliant on waste. The complex range of stakeholders involved in local waste governance and management makes it difficult to navigate or introduce changes. This was further emphasized by interviewees who underscored the waste management system's impermeability to outsiders, while also providing examples of how regular interactions with residual materials shifted their perception of its value.

An overview of the current state of waste management in the construction industry demonstrated its present focus on economic feasibility and efficiency. This discussion also illustrated the slow speed of progress towards circularity, emphasizing the need for new approaches to better facilitate CRD waste reduction and reuse. A review of waste reuse examples in design and architecture highlighted the limited examples of CRD waste reuse in industrial and object design, revealing a gap that was addressed. This investigation also helped to confirm gypsum and aggregate as the materials to be explored for reuse.

Initially, material collection was intended to be conducted in conjunction with observation at waste management facilities in Montréal; however, I was unable to secure permission to visit any facilities, demonstrating the lack of citizen access to the waste management system. While this barrier requires more attention in the future, it could not be fully addressed in this research. Considering that our waste management systems are constructed and operated with the intention of keeping waste and the negative effects associated with its management hidden (Hird, 2021), it was understandable that local facilities may not be receptive to a visitor interested in observing and analyzing their operations. Through scavenging, gypsum and construction residue (a crushed mixture of aggregate, asphalt, and concrete) were collected from construction sites.

Drawing from background research into gypsum and the constituent materials of construction residue, three material prototypes were iteratively developed: recycled gypsum, a potato starch-based CR biocomposite, and a SCOBY-based CR composite.

Value was then established as a fluctuating attribute, which can be gained through a repositioning of perspective or the investment of time and labour and lost due to damage or natural depreciation over time (Thompson, 2017). It was also determined that personal attachment to possessions can imbue them with value (Richins, 1994). These ideas informed the choice to make functional décor objects designed for regular interaction at the scale of the body, as this would make them more accessible to interaction than CRD waste typically is. This investigation also resulted in making design choices to reflect the objects' sustainable nature, as this could make them more desirable to those who value that quality.

The object prototyping process was directly informed by theories of material agency and embodied cognition. Through this framing, every interaction with the recycled gypsum, CR biocomposite, and CR SCOBY composite, through haptic, sensory, or emotional feedback, offered something to learn from and guided the making process. As a result of repeated hands-on engagement, embodied knowledge of each material was developed, influencing prototype designs in the direction that felt most apt to follow the material's liveliness. A series of coasters, trays, vases, bowls, candle holders, a lampshade, and a chess set using recycled gypsum, CR biocomposite, and CR SCOBY composite were created, designed to reflect the hands-on iterative making process and in response to feedback and inherent material properties, but also in response to my intuition. Handmaking also reflected the time and energy invested into the objects, demonstrating how the residual materials could be imbued with value (Thompson, 2017) and gave them individuality, reflecting Mugge et al.'s (2005) suggestions for increasing product attachment and longevity.

Transforming the residual materials into objects allowed them to become detached from the meanings associated with their residual material sources and reinterpreted anew, effectively defamiliarizing waste. This was confirmed through the group interview: when presented as waste, CRD materials were seen as austere and structural with limited reuse applications, but when presented with CRD waste in the form of object prototypes, it was described as sculptural and organic. The use of handmaking as a communication tool was proven effective by participants

whose haptic interaction with the objects reflected my own during the making process. Learning that the objects were made of CRD waste bolstered both their appreciation of the objects and their opinion of CRD waste. This feedback reinforced that the creative works reflected a theoretical analysis of how waste can be valorized. The feedback also illustrated how design can be used to draw attention to larger systemic issues and demonstrated the effectiveness of using waste to exemplify waste issues. CRD waste was used to expose issues in the construction industry, and it is plausible to imagine that other types of waste could be used to highlight industry-specific issues.

The research was limited in investigating the social acceptability of CRD waste reuse. As there are fewer practical examples of CRD waste reuse, it remains difficult for people to reimagine it creatively. The group interview sought to achieve this, but the small sample size must be acknowledged, as the results cannot be interpreted as indicative of a larger group opinion. Exploring ways to better engage the public and create exposure for material reuse prototypes, through the introduction of products into the market, design exhibitions, or education, is an area that could benefit from additional attention.

The impact of CRD waste at large was investigated, but the specific environmental footprint of the waste that was reused could not be addressed. To do this, a life cycle analysis or similar assessment would have been necessary, which would have required precise details relating to the impacts of extraction, processing, distribution, use, and disposal of each material. This type of assessment, as well as a similar assessment of the processes used in recovery and reuse, would be necessary to determine if these strategies could be beneficial on a larger scale. Scaling up would introduce other challenges, as well. As exemplified in sections 2.1.3 and 3.1, an economy focused on profit maximization requires waste management to balance environmental and economic concerns, imposing challenges to scale up an upcycling process focused on environmental benefit. Additionally, while there may be an abundance of waste that could be reused, gaining access to it can be a challenge, as demonstrated in this research. Collaboration with other industry actors would likely need to be established to ensure a constant source of materials, introducing additional economic barriers. However, as the objects created are not meant to be a product yet, but rather to serve as an exploratory example, determining the feasibility of scaling up their fabrication was beyond the scope of this research.

The small-scale, DIY nature of the material and object prototyping allowed for broad experimentation both in methods and output. These experiments represent how responsible design can be expanded through waste reuse and how discarded materials can be valorized. This research also benefits my development as a practitioner. Ideally, I would continue to explore waste reuse in design and fabrication as a profession, either using the materials developed in this thesis or exploring other waste sources. I would also like to share the work and its findings through exhibitions or shows such as the DesignTO Festival or Material Matters Fair. Lastly, the need for more exploration into how the implementation of material reuse can be scaled up was elucidated, which I aim to explore from a policy or planning perspective.

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Appendix 1: Object Prototype Images



Figure A.1 *Candle holder #1*. Recycled gypsum base, copper inlay. Image by Elizabeth Vince.



Figure A.2 *Tray #2*. Recycled gypsum, copper inlay. Image by Elizabeth Vince.



Figure A.3 *Candle holder #2*. Recycled gypsum base, aluminum inlay. Image by Elizabeth Vince.



Figure A.4 *Candle holder #3*. Recycled gypsum base, brass window latch handle. Image by Elizabeth Vince.



Figure A.5 *Vase #2*. Recycled gypsum around steel pipe. Image by Elizabeth Vince.



Figure A.6 *Bowl*. Recycled gypsum, metal window latch handles. Image by Elizabeth Vince.



Figure A.7 *Tray #1*. Construction residue biocomposite base, aluminum inlay. Image by Elizabeth Vince.

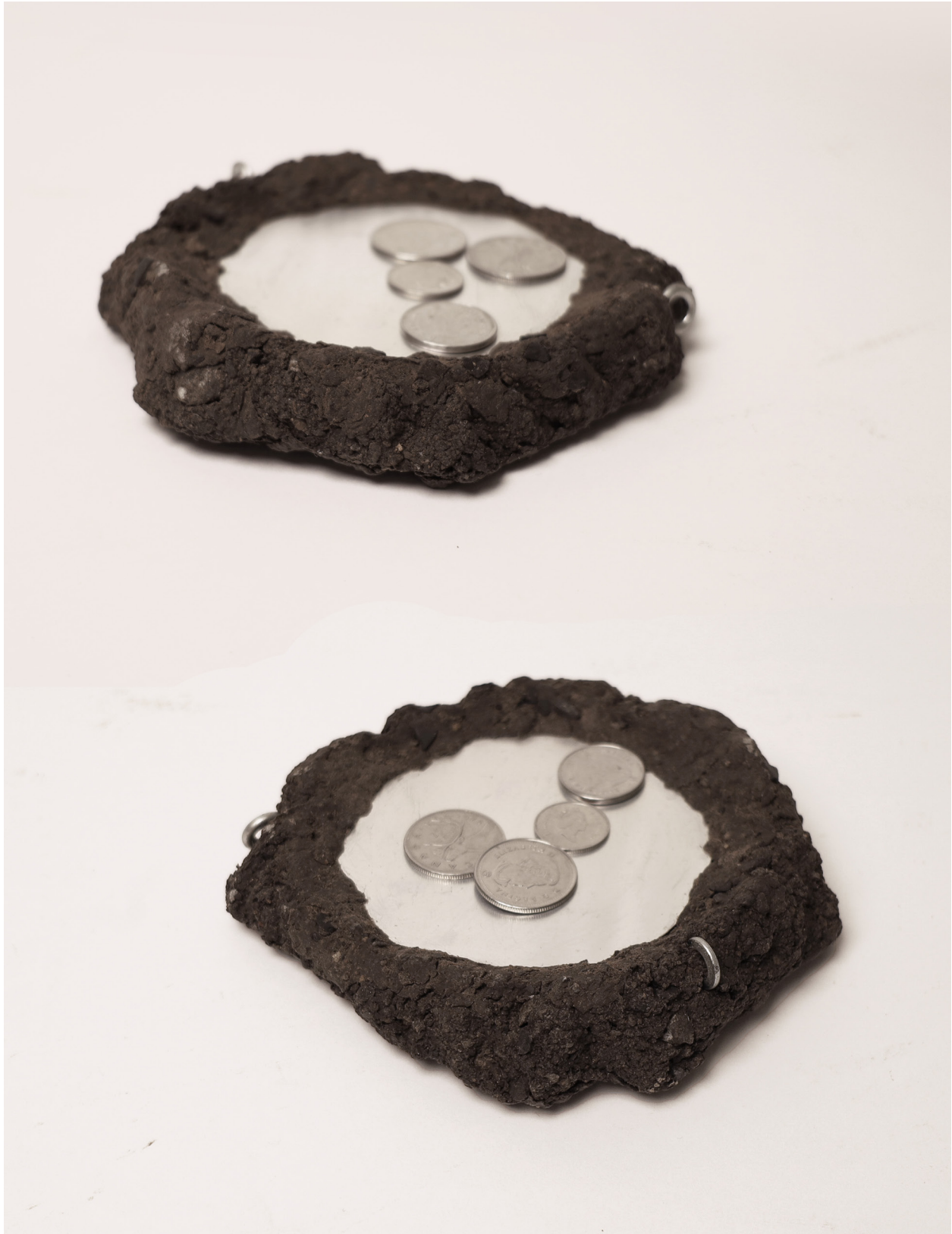


Figure A.8 *Coaster #2*. Construction residue biocomposite base, aluminum inlay & ornaments.
Image by Elizabeth Vince.



Figure A.9 *Candle holder #4*. Construction residue biocomposite base, steel pipe. Image by Elizabeth Vince.



Figure A.10 *Vase #1*. Construction residue biocomposite base, steel pipe. Image by Elizabeth Vince.



Figure A.11 *Chess set*. Recycled gypsum and construction residue biocomposite pieces and board. Reclaimed wood and fabric were used for the base and inlay. Reclaimed metal fasteners for king and queen pieces. Image by Elizabeth Vince.



Figure A.12 *Lamp*. Construction residue SCOB shade, recovered metal base. Image by Elizabeth Vince.