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Willingness to Pay for Recycled Aggregates in Concrete among German Construction Clients

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Abstract

The construction industry claims a vast quantity of natural resources and is responsible for more than half of the waste generated in Germany. R-concrete contains recycled aggregates and is a resource efficient alternative to primary concrete. A central stakeholder whose preferences may significantly influence the use of R-concrete is the construction client. Despite their central role in this respect, little is known about clients. This study contributes to the understanding of the clients' demand decision. It determines the willingness to pay (WTP) for recycled aggregates and it examines which factors influence clients' propensity to choose R-concrete. Additionally, the study identifies barriers and drivers for the demand for R-concrete. Throughout these questions, differences between client groups are considered. In addition to item-based questions on potential barriers and drivers, a discrete choice experiment is applied to estimate the clients' WTP for a certain share of recycled aggregates in concrete. Positive and significant WTP estimates were found for all client groups. Overall, clients are willing to pay 0.26 € for every percentage point increase of added recycled aggregates. Private individuals' WTP is lowest, while organizations are willing to pay most. However, even organizations' WTP does not equal the price premium currently seen. The main barriers for demanding R-concrete are based on a lack of information. Therefore, in order to foster the use of R-concrete, instruments that rely on information provision are recommended. Moreover, the significant differences in client groups should be considered in designing these instruments.

Table of Figures

Table of Tables

1. Introduction

The construction industry is one of the most problematic sectors in terms of its environmental impact. Firstly, it is highly energy-intensive: in the EU, buildings are responsible for 40 % of energy consumption and 36 % of greenhouse gas emissions (European Commission, 2020). Secondly, it also claims a vast quantity of natural resources (Jacob et al., 2021; Knappe et al., 2017): EU-wide, 50 % of resources extracted are processed in the construction industry (*Ein Neuer Aktionsplan Für Die Kreislaufwirtschaft*, 2020). This share is even more striking in Germany. Of the 733 million tons of non-renewable resources extracted in Germany in 2019, 594 million tons (81 %) are non-metallic minerals of which 550 million tons (93 %) are used in the construction industry (Destatis, 2021). In 2021, more than 150.000 building permits were awarded in Germany, of which more than 80 % relate to residential buildings (Destatis, 2022). This number and its associated environmental impact are unlikely to decrease anytime soon. Population growth and urbanization come with the need to build living space (Ellen MacArthur Foundation, 2020). In Germany specifically, the federal government has set the goal to build 400.000 new residential apartments per year (*Koalitionsvertrag 2021 – 2025*, 2021), which would imply an increase of more than 20 % in the number of buildings yearly constructed of this type (Destatis, 2022).

At the other end of the life cycle, the construction industry is responsible for more than half of all the waste generated in Germany (Destatis, n.d.). Of the 413.994.000 tons of waste produced in 2020, more than 55 % (229.349.000 tons) were ascribable to construction and demolition. The recovery rate at 88 % is comparably high in Germany (Destatis, n.d.), but only 12.5 % of the demand for aggregates were covered by recycled aggregates in 2018. Of these recycled aggregates, only slightly more than a fifth was used in the production of asphalt and concrete (Kreislaufwirtschaft Bau, 2021). The majority of it is used for road filling, which is commonly labelled “downcycling” (Di Maria et al., 2018; Knappe et al., 2012; Kreislaufwirtschaft Bau, 2021). Downcycling is defined as “the practice of using unwanted material for an application of less value than its original purpose” (Allwood, 2014, p. 465). In contrast, recycling in the stricter sense refers to processing waste to material of at least equal quality. This implies keeping materials “in the loop” and thus closing material cycles, which is a political goal on a national and international level (Waste Framework Directive, 2008; *Koalitionsvertrag 2021 – 2025*, 2021). Using mineral construction waste for road filling is, strictly speaking, not in line with this goal since concrete, once part of the base layer of a road, cannot be turned into concrete again. Actually closing the material cycle and thereby retaining its value would mean using concrete rubble to produce new concrete (Di Maria et al., 2018). In so called resource-saving concrete (“R-concrete” from here on), the aggregates, usually primary gravel and sand, are partly replaced by recycled aggregates from construction and demolition waste. This building material is already admissible for many applications in building construction in Germany and has the same characteristics as concrete with primary aggregates (Knappe et al., 2013). Some of its advantages are closing cycles, resource efficiency, potentially shorter transport routes, and sparing landfill capacities (Knappe et al., 2012, 2017; Wizgall & Knappe, 2011). Despite these advantages, R-concrete is hardly used in Germany (Jacob et al., 2021; Wizgall & Knappe, 2011). While 192 million tons of gravel, sand, and natural stones were used in the production of concrete and mortar in Germany in 2020, the volume of recycled aggregates employed to this end was only 0.9 million tons (Verein Deutscher Zementwerke, 2022). At the same time, the case of Switzerland demonstrates that the widespread use of R-concrete is feasible. 90 % of the concrete required in building construction there can be supplied with R-concrete (Knappe et al., 2017; Stürmer & Kulle, 2017). The following sections will tackle the questions of why R-concrete is hardly used in Germany and what role the construction client holds therein.

The construction industry is characterized by a multitude of different stakeholders that come together in a project. Building a simple detached house, for example, already involves the client, an architect, engineers, suppliers, the municipality, and several contractors. In projects for which another building is demolished or dismantled first, even more parties add to the process. The client has a special standing among these stakeholders and is arguably the most important one (Diyana et al., 2013; Knappe & Theis, 2016; Scheibengraf & Reisinger, 2005). Construction clients are the ones "who initiate, commission, and pay for a construction project" and "formulate and communicate the requirements of a construction project to be accomplished for the intended usage of the facility" (Hartmann et al., 2008, p. 5). The entire construction project starts with the client's demand for a building and is then shaped by his or her expectations (Qi et al., 2010). Starting with the selection of the other stakeholders (Volk et al., 2019), clients are in charge (Knappe & Theis, 2016) and ultimately the decision makers in any construction project (Abidin & Pasquire, 2007). They are, therefore, often seen as the "predominant player in the construction process" (Oyedele et al., 2013, p. 140) and "the most influential stakeholder on construction projects" (Onubi et al., 2020, p. 1).

Given that clients have a decisive role to play in construction projects, they are also highly influential when it comes to adopting sustainable building practices. Several authors argue that change and innovation need to be driven by the client (Brandon, 2006; Brandon & Lu, 2008; Briscoe et al., 2004). Being the end-users (or representing them), clients shape demand and thereby have a significant role in driving sustainability (Mao et al., 2015; Ozorhon, 2013; Pitt et al., 2009) and in particular the use of recycled construction material (Shooshtarian et al., 2020). According to the Umweltbundesamt, the most efficient driver for high-quality recycling of resources is the demand for recycled material for the application in high-quality products (Janz, 2022). With this role, clients bear a great responsibility. As described above, buildings are not only a substantial investment in an economic, but also in an ecological sense. Accordingly, clients can be seen as ecological investors (Knappe & Theis, 2016).

This study investigates construction clients' consumption decisions regarding R-concrete. Specifically, it looks at the barriers and drivers for demand and clients' WTP for recycled aggregates in concrete. An experimental survey among three groups of construction clients (private individuals, organizations, and developers) is conducted. The main part of the survey is a discrete choice experiment, which is employed to determine clients' WTP and which is analyzed using a mixed logit model. The main results are the following: information-based barriers are most prominent in all client groups, such as a lack of knowledge and uncertainty regarding the norms and regulations pertaining to R-concrete. In contrast, clients are driven to use the material by their environmental awareness. The results show that the construction clients in our sample are overall more likely to choose R-concrete than conventional concrete, all else being equal. We find positive and significant WTP estimates in all groups, of which organizations are found to have the highest and private individuals to have the lowest WTP. Individual characteristics that influence clients' propensity to choose and to pay for R-concrete are discussed. The paper is organized as follows: chapter 2 gives an overview of the literature on the role of construction clients and their demand, potential barriers and drivers, and WTP for green building and its features. It finishes with the hypotheses that we derive from the literature and that guide this study. Chapter 3 illustrates the method used and chapter 4 shows the corresponding results. These are discussed and put into context in chapter 5. Chapter 6 concludes this paper.

2. Literature Review & Hypotheses

Research has confirmed the crucial role clients play in driving sustainable construction. Naturally, the supply of sustainable construction materials and processes is required to that end, but it “needs to be complemented with, driven by, and shaped around a willing and committed demand site” (Khan et al., 2020, p. 1). There seems to be a consensus in the literature that clients’ demand and commitment is essential to drive the implementation of sustainable building practices (Bornais, 2012; Darko et al., 2017; Diyana et al., 2013; Gou et al., 2013; Häkkinen & Belloni, 2011; Mandell & Wilhelmsson, 2011; Pitt et al., 2009). A worldwide survey conducted by Dodge Data Analytics found that client demand is the top trigger for green buildings (Dodge Data Analytics, 2016). Bornais analyzed three case studies of newly constructed green buildings in Canada and found that “one consistent measure for success was the owners’ commitment to the green building process”[1] (Bornais, 2012, p. 63). A similar conclusion is drawn by Rodriguez-Nikl and his colleagues. They asked structural engineers about the factors that increase the likelihood of them incorporating sustainable features in their designs as well as the actors that influence this decision. On the first place, respectively, are client requirements and the group of developers and owners (Rodriguez-Nikl et al., 2015). Based on these findings they conclude that “the client is the single most important influence on what a structural engineer can accomplish” (p. 8) in terms of implementing sustainable design strategies. This role clients hold does not only apply to sustainable construction practices in general, but also to the use of recycled building material in particular. The demand for recycled building material is crucial for an increase in the recycling rate of construction and demolition waste (Schmidmeyer, 2014). According to the ministry of the environment, climate protection and the energy sector of Baden-Württemberg, a German federal state in which R-concrete is more prominent, closed loops in terms of a circular economy can only be achieved if recycled products are demanded by the client (*Der Einsatz von Recyclingbaustoffen*, 2013). As such, clients are substantive in the adoption of a circular economy (Charef & Lu, 2021). In creating the demand and making the decisions, clients are viewed as one of the key players involved in the stages of a buildings’ life cycle that must take their responsibility in order to achieve a waste free construction industry (Scheibengraf & Reisinger, 2005).

Since the demand for sustainable practices and recycled material is of such significance, the lack of it explains why these practices have not yet been established. Hwang and Tan, for example, surveyed professionals and managers of green building projects in Singapore and found a main barrier to be “the lack of expressed interest from clients or market demand” (Hwang & Tan, 2012, p. 324). Similarly, in a questionnaire study of building surveyors, Pitt et al. (2009) found the lack of client demand to be one of the top barriers to sustainable construction. The same barrier seems to apply to the case of R-concrete. Researchers point to the lack of demand in Germany for recycled material and R-concrete in particular as a reason for its very limited use (Hinzmann et al., 2019; Nobis & Vollpracht, 2015; Scheibengraf & Reisinger, 2005). Katerusha (2021) conducted a questionnaire study among executing companies in the German and Swiss construction industries with a particular focus on concrete production. He finds that a lack of demand is a main barrier for the use of R-concrete in Germany, only second to a lack of governmental support. In Switzerland, where the use of R-concrete is already common, this was not found to be a major barrier. The case of Switzerland shows that R-concrete can be introduced to the market successfully through a corresponding demand (Knappe et al., 2012; Wizgall & Knappe, 2011). In summary, a main barrier for incorporating sustainable practices is a lack of desire on the part of clients (Rodriguez-Nikl et

[1] Bornais uses the terms ‘client’ and ‘owner’ synonymously, see p. 50.

al., 2015) and in order to foster the use of these practices and R-concrete in particular, demand for it must be stimulated (Potrykus et al., 2021).

As described above, R-concrete is considered to have the same characteristics as conventional concrete and can be used in almost all applications (Knappe et al., 2013). At the same time, public environmental awareness has increased (European Environment Agency, 2019; Rubik et al., 2020). Thus, the question arises as to why there is a lack of demand from clients for recycled building material in general and for R-concrete in particular.

A main barrier for the demand of sustainable building is simply the **lack of awareness and knowledge** of sustainable alternatives in construction (e.g., Adams et al., 2017; Gan et al., 2015; Shooshtarian et al., 2020). 35 of the 36 articles that Darko and Chan reviewed on the barriers for green building adoption point to a "lack of Information, Education and Research, Knowledge, Awareness, and Expertise " (Darko & Chan, 2017, p. 4). This barrier can be divided into a lack of awareness (simply being unaware of the existence) and a lack of information, knowledge, and experience on green building practices or materials. Unsurprisingly, not knowing of a material precludes demanding it. As such, Pitt et al. (2009) find that a lack of client awareness is among the main barriers for sustainable construction. This is reinforced by the finding that clients are among the least informed groups regarding circular economy in construction (Adams et al., 2017). A lack of awareness also seems to be a problem with respect to R-concrete specifically. One of the main barriers Stürmer and Kulle (2017) address in their report on using R-concrete is the insufficient familiarity of planners and clients with the material. Clients that are unaware of a product automatically lack information and knowledge on it. However, even clients who know that a product exists can still feel like they lack information, knowledge, and experience with it. For example, Rodriguez-Nikl et al. (2015) find that the lack of information and of knowledge, not only of clients but also of contractors and structural engineers, is a main barrier for incorporating sustainable design features. This in combination with clients' risk adversity hampers the demand to implement these materials and features in their construction projects (Häkkinen & Belloni, 2011; UKGBC, 2019; Yusof et al., 2021; Zahirah et al., 2013). These barriers create a vicious circle: a lack of awareness, knowledge, and experience leads to a lack of demand, which entails a lack of supply, which then again precludes gaining experience (Wizgall & Knappe, 2011).

Related to this lack of awareness and experience is a **lack of acceptance** among clients, which additionally hinders their demand for recycled material (Scheibengraf & Reisinger, 2005; Shooshtarian et al., 2020). A lack of acceptance in this case means an unwillingness to use secondary material in construction because of the perception that it is inferior. Knappe et al. (2012) devote an entire paper to boosting the acceptance and use of secondary raw materials in construction. Reasons they name for the low acceptance levels are the disadvantageous market situation for recycled materials and the fact that public authorities do not set an example by incorporating these materials in their tenders. Many of these authorities, who act as clients for public building projects, are not willing to use recycled material due to scepsis towards these materials. This scepsis is likely to be even higher for commercial or private clients (Dechantsreiter et al., 2015). According to Darko and Chan (2017), a lack of information, as described above, can also lead to low acceptance of green building. Besides, it can result from bad experiences. Knappe et al. (2012) describe that recycled materials have not always undergone adequate quality controls in the past. The result is a bad image that sticks, even though the processing of mineral construction and demolition waste as well as the quality control has improved in many ways. Oyedele et al. (2014) conducted a study among construction stakeholders in the UK and find that a main barrier to the use or recycled construction products is the lack of a positive perception by clients, based on the idea that secondary material is inferior. Since clients alongside the designers determine the material that is used in their construction project, this perception inhibits demand for recycled material.

The **costs** of building sustainably also hamper the demand for the corresponding practices and materials. Costs were found to be the number one barrier for clients in demanding sustainability in their construction projects in numerous studies (e.g., Gan et al., 2015; Lam et al., 2009; Pitt et al., 2009; Shooshtarian et al., 2020). An issue at the core of this barrier is that while the client is the one paying for any sustainable investments, he or she is not necessarily the beneficiary. Instead, the environment and future generations are the ones reaping the rewards (Scheibengraf & Reisinger, 2005). Especially in the case of developers, these so-called split incentives[2] can hinder investments in sustainable construction, since they act as clients but not users. When considering these investments, developers weigh the costs against the premium that the end users are willing to pay. If the market doesn't value these features, developers are unlikely to invest the costs (Choi, 2009). Similarly, additional costs for R-concrete compared to conventional concrete hinders many stakeholders from using it. Stürmer and Kulle (2017) asked architects, structural engineers, and producers of prefabricated concrete parts about reasons against using R-concrete. Unsurprisingly, a majority mentioned that they were not willing to cover the extra expenses. These extra costs are a product of the costly selective demolition and elaborate processing of waste material to building products (Knappe et al., 2012; Nobis & Vollpracht, 2015). Additionally, the prices for primary material are beat down due to revenues generated through backfilling of mines (Knappe et al., 2012) and the external costs that primary material entails not being incorporated (Silva et al., 2017). The price for R-concrete compared to conventional concrete shows a wide range. Some concrete manufacturers calculate a premium of 10 to 15 % (interviewee 10, personal communication, August 3, 2021) or even 25 € per m³ additionally (interviewee 9, personal communication, August 2, 2021), which translates to around 17 %. These are a result of higher prices for recycled aggregates compared to primary aggregates. In some regions however, R-concrete is not more expensive than its primary counterpart. Especially in the German province Baden-Württemberg, the supply of recycled aggregates is such that concrete manufacturers can offer R-concrete for the same price as the conventional product (interviewee 2, personal communication, July 1, 2021). In Switzerland, where the material is established, R-concrete can even be offered at a lower price (interviewee 4, personal communication, July 6, 2021; Eberhard Bau AG, 2021).

Another potential barrier is the (perceived) **lack of supply**. The "circle of blame" explains why this can lead to a lack of demand. This concept describes the observation that suppliers would principally build sustainably, but bewail that there is no demand, while the demand side would principally buy or lease sustainable buildings, but bewail that there is no supply (Andelin et al., 2015; Keeping, 2000). Gou et al. (2013) for example, found that the lack of green materials suppliers is viewed by developers as one of the main issues hindering green construction in Hong Kong. Similarly, Lam et al. (2009) surveyed construction stakeholders about barriers to green specifications in construction, of which the limited availability of suppliers turned out to be significant. The executing companies surveyed by Katerusha (2021) also rated the lack of supply as problematic in the use of R-concrete in Germany. A big concrete producer warns in its product overview that R-concrete is not yet comprehensively available due to its regionally limited availability (Holcim Beton und Betonwaren GmbH, 2021).

A final barrier for demand that is prominent in the green building literature is the **lack of incentives**. The use of primary aggregates produces externalities that are not incorporated into the price for conventional concrete. This contributes to R-concrete being more expensive, which

[2] Split incentives can be defined as the "separation of investor costs from user benefits" (Choi, 2009, p. 128).

incentives could compensate for (Silva et al., 2017). Zhang et al. (2012), for example, studied the implementation of green roof systems in Hong Kong and found a lack of incentives from the government towards developers, but even more prominently those directed at clients, to be crucial impediments. The literature review by Darko and Chan (2017) similarly showed the lack of incentives to be one of the most reported barriers for green building. In contrast, when these incentives are in place, they have been found to drive sustainable construction as, for example, Pitt et al. (2009), Olanipekun et al. (2017), and Adams et al. (2017) show. A lack of incentives also seems to work as a barrier in the specific case of R-concrete. Katerusha (2021) asked executing companies to rank potential barriers on a scale from 1 to 100. The lack of tax incentives reached a score of 76.5.

The literature on drivers for the demand of sustainable construction is much scarcer than it is for barriers. Still, some drivers that have been mentioned recurrently in the literature will be discussed. Going beyond stimulating the voluntary adoption of sustainable construction practices through incentives, researchers point to **policies and regulations**. Gan et al. (2015) found policies and regulations to be positively correlated with Chinese construction clients implementing sustainable features. For the case of recycled construction material, Shooshtarian et al. highlight the enabling factor of "develop(ing) supportive regulations, policies, and specifications" (2020, p. 11). In fact, public institutions in Germany are required by law to give preference to construction products that have been recycled or prepared for reuse (Kreislaufwirtschaftsgesetz, n.d.). Similarly, the Construction Products Regulation (CPR) by the EU stipulates secondary material to be used in construction projects (EU Construction Products Regulation, n.d.). It seems reasonable that being obliged to fulfil certain requirements naturally creates demand. However, having these regulations in place is not sufficient. Often, the problem is a lack of enforcement and monitoring (interviewee 1, personal communication, June 29, 2021; interviewee 3, personal communication, July 5, 2021). For example, while recycled material may legally not be excluded in tenders (Kreislaufwirtschaftsgesetz, n.d.), it still regularly is. But because third parties have no legal claim, this behavior is not changed (interviewee 2, personal communication, July 1, 2021). In addition, many of the relevant policies fall under the responsibility of the federal regions in Germany, which makes it difficult for actors to keep an overview (interviewee 1, personal communication, June 29, 2021). In the case of R-concrete, additional regulations hinder its demand: the requirements are higher compared to those for conventional concrete and construction waste has to be tested extensively for it to be introduced back into the market as a product (interviewee 5, personal communication, July 8, 2021).

Especially for construction clients that are organizations or companies rather than private individuals, the **image or reputation** plays another important role in wanting to build sustainably. Diyana et al. (2013) identify four main groups of drivers for green construction from the perspective of developers, of which one pertains to their image. Developers gain a competitive advantage through certifications and awards that improve their reputation. Similarly, Zhang et al. (2011) investigated several case studies of green building in China and found that the responsible developers believed in a reputational advantage of implementing sustainable features. The Australian project owners surveyed by Olanipekun et al. (2017) confirmed that reputation played an influential role in their motivation for green building.

A further driver for demanding sustainable construction is of moral nature: **environmentally-friendly attitudes**. Olanipekun et al. (2017) studied project owners' motivation for delivering green building projects and found the internal factors, among which pro-environmental attitudes were most prominent, to be critical. Darko et al. (2017) distinguish between five different categories of drivers for green building, one of which are individual-level drivers.

These include moral imperative or social conscience, personal commitment, attitudes and traditions, and self-identity. The researchers point out that these drivers can be effective, but only little research has focused on them. A similar category of drivers for green construction is highlighted by Diyana et al. (2013). The category ‘ethical’ includes social and environmental responsibilities.

Sustainable alternatives to conventional products often come with a price premium. Consumers’ willingness to pay (WTP) for these alternatives have been investigated for many products and sectors, such as investments, electricity, food, vehicles, and recycled or remanufactured products in general (e.g., Gutsche & Ziegler, 2016; Hamzaoui Essoussi & Linton, 2010; Hansla et al., 2008; Longo et al., 2008). Several researchers have investigated stakeholders’ acceptance of these premiums in sustainable construction and found that there generally is a positive WTP for environmentally friendly attributes (Mandell & Wilhelmsson, 2011) in buildings. Potential homebuyers in Pakistan, for example, were found to be willing to pay an extra 11 % for sustainable housing (Khan et al., 2020). Portnov et al. (2018) used a nationwide survey in Israel and discovered that a price premium between 7 and 10 % for green building was found acceptable. Wiencke (2013) surveyed private as well as public corporations in Switzerland to investigate their WTP of for green buildings. Compared to conventional buildings, the firms’ accepted price premium ranged between 1.3 and 7.9 %.

On a smaller scale level, researchers have studied to what extent construction clients, homebuyers, and tenants appear to be willing to pay for specific green attributes. Robbins & Perez-Garcia (2005) used a choice-based survey to investigate the WTP for features that improve the environmental performance of construction in the general population as well as among real estate agents. The former group was found to be most responsive to reductions in greenhouse gas emissions, being willing to pay for the reduction of around half of what building a house emits. Smaller, but still positive, was their WTP for reductions in air pollution and solid waste. Compared to the general public, real estate agents were found to be much more sensitive to reductions in solid waste and much less willing to pay for reducing greenhouse gas emissions.

The willingness to pay for R-concrete specifically has not yet been investigated. However, as described above, the price seems to be a barrier for its demand. One reason might be that using R-concrete, as opposed to installing measures of energy efficiency for example, do not directly translate into economic benefits (Zalejska-Jonsson, 2014). Katerusha (2022) surveyed architects and engineers in Germany and used the Price Sensitivity Meter to determine the optimal price for R-concrete. He found the optimal pricing point, the price at which an equal share of respondents judges the product to be too expensive and too cheap, to be around 14 % cheaper than conventional concrete. The range of acceptable prices for R-concrete appears to lie between 83.3 and 100 % of the price of conventional concrete.

Several factors influence clients’ WTP, such as income, age, gender, and education (e.g., Chau et al., 2010; Khan et al., 2020; Park et al., 2013; Yau, 2012). Especially the positive effect of environmental awareness on the willingness to pay for environmentally friendly products is uncontroversial. It has been found for various products, such as renewable energy sources (Zografakis et al., 2010) and electric vehicles (Ziegler, 2012), but also in the building sector. Yau (2012) found that residents with higher environmental attitudes had a higher WTP for green housing attributes. Similarly, the respondents surveyed by Mandell and Wilhelmsson (2011) who viewed themselves as environmentally aware were willing to pay more for environmental housing attributes compared to their counterparts. Familiarity in the sense of experience with and knowledge of the environmentally friendly product has also consistently found to be advantageable for consumers’ WTP (e.g., Shen, 2012; Zografakis et al., 2010). Zalejska-

Jonsson (2014), in her study on WTP for green apartments in Sweden, observes that customers are only willing to pay for those attributes that they understand. Similarly, Portnov et al. (2018) found that potential homebuyers who are familiar with the concept of green building are willing to pay more than those who are not. Finally, as described above, construction stakeholders often repudiate their own responsibility for employing sustainable practices and materials and hold each other responsible instead (Andelin et al., 2015; Keeping, 2000). This (lack of) feeling of responsibility also influences consumers' WTP. Wang (2022) found that individuals who feel an environmental responsibility have a higher WTP for improvements to the environment.

The above overview of the current state of scientific literature on clients, their demand and WTP for sustainable building materials, and the barriers (and drivers) that impede (foster) this demand leads to the contribution of this study. The research on socioeconomic aspects of the demand for recycled material and R-concrete specifically is not sufficient to draw informed conclusions. The material is a specific case of sustainable construction since, for example, it does not have an apparent financial long-term benefit, such as energy efficiency measures do. Thus, the existing research cannot necessarily be applied to R-concrete. This study combines the above research fields for the specific case of R-concrete to understand clients' consumption behavior of the material.

Summing up the literature on barriers, construction clients' demand for R-concrete is likely to be hampered by them not knowing of the material or having too little information or experience with it, by a lack of supply in their region, by a lack of financial incentives to use R-concrete, and by higher prices compared to conventional concrete. From the literature on drivers, we deduce that demand for R-concrete is likely to be driven by policies and regulations that prescribe its use, a positive image effect, and environmentally-friendly attitudes. One of the contributions of this study is to identify the barriers and drivers construction clients face for demanding R-concrete by surveying them directly, which has not been done so far. This part of the study is guided by the following hypotheses:

H1.1 Important barriers for clients to demand R-concrete are a lack of awareness and knowledge, of acceptance, of supply, and of incentives as well as a higher price.

H1.2 Important drivers for clients to demand R-concrete are policies and regulations, image/reputation considerations, and environmental awareness.

These are hypothesized to be the most important barriers and drivers since they are prominent in the literature on green building. However, additional ones are conceivable and were discussed during expert interviews. Note that some aspects can be perceived as barriers as well as drivers, depending on their value. For example, the price can hinder as well as drive demand for R-concrete, depending on whether it is higher or lower than that of conventional concrete. Another example is the familiarity with the material: a lack of it is likely to inhibit clients' demand, but having experience with R-concrete, for example, can be a driving force.

So far, it is unclear whether construction clients are willing to pay more for R-concrete compared to its conventional alternative. On the one hand, they have repeatedly been found to be willing to pay for green buildings and certain specific environmentally-friendly features. On the other hand, the higher price for R-concrete seems to be a barrier and the optimal price for R-concrete has been suggested to lie below or at most at the same level as that of conventional concrete. Thus, the existing research is not conclusive in this regard. The reasons named above suggest that clients' WTP for R-concrete differs from that of conventional concrete, but it is unclear whether it is higher or lower. This study aims to resolve this issue by studying clients' WTP for recycled aggregates in concrete directly.

H2 Clients' WTP for recycled aggregates in concrete differs from their WTP for primary aggregates.

This study further aims to identify factors that influence clients' propensity to choose and pay for R-concrete. To do so, we check whether those factors that have been found to play a role in sustainable construction in general also apply to the specific case of R-concrete.

H3.1 Clients who value sustainability as a criterion in construction higher are more inclined to choose R-concrete and are willing to pay more for recycled aggregates in concrete compared to clients who value this criterion less.

H3.2 Clients who are familiar with R-concrete are more inclined to choose R-concrete and are willing to pay more for recycled aggregates in concrete compared to clients who are not familiar with the material.

H3.3 Clients who feel responsible for considering sustainability in construction are more inclined to choose R-concrete and are willing to pay more for recycled aggregates in concrete compared to clients who do not feel responsible.

So far, construction clients have been treated as one group. While all construction clients share the defining characteristic of initiating and financing a project, there are crucial differences between them that might affect their demand for R-concrete. This study distinguishes private individuals, organizations, and developers and asks whether these different types of clients differ in terms of their barriers and drivers and/or their propensity to choose and pay for R-concrete. Since developers act as clients on a professional basis, it can be assumed that they are better informed about different construction materials and thus also about R-concrete. Organizations, while not themselves active in the construction industry like developers, are likely to have commissioned more than one building and therefore are likely to have more experience and information than private individuals, who usually only build one house in their lifetime. Further, while all three groups might be intrinsically motivated to use resource efficient materials, developers and organizations are additionally motivated by external factors such as their image and reputation (Diyana et al., 2013; Zhang et al., 2011). The resulting hypotheses are the following:

H4.1 Developers have the highest WTP for recycled aggregates in concrete, followed by organizations and then private individuals.

H4.2 For private individuals, informational barriers are more relevant than for developers and organizations.

H4.3 For developers and organizations, reputational aspects are more relevant drivers than for private individuals.

3. Methodology

2.1 Research Strategy & Data Collection

To achieve the research objectives named above, a two-part online survey among construction clients was conducted. The multitude of stakeholders involved in construction projects adds to the ambiguity around the definition of the client (Gan et al., 2015; Olanipekun, Chan, et al., 2017; Rodriguez-Nikl et al., 2015). This study, following Hartmann et al. (2008), defines the client as the one who initiates and finances the construction project. In practice, the client can take several forms. Here we distinguish between three groups that make up our sample: private individuals, organizations, and developers. Private individuals were part of our target group if they have built a home in the previous five years, are currently in the process of building, or are planning to build in the near future. Organizations were represented by the employees responsible for the construction of new buildings for private as well as non-profit organizations. Public authorities as well as organizations that are themselves active in the construction sector were excluded from the sample. Finally, the group of developers includes property developers, investors who initiate construction projects, and housing associations.

Before the start of the survey, several interviews were conducted with industry experts in order to validate the information that the survey questions are based upon. Among the experts were concrete producers, a recycler, a researcher in the field of construction material, and representatives of German associations for green building, the concrete industry, and secondary resources. An anonymous list of interviewed experts can be found in Table A1 in the appendix.

The first part of the survey consisted of item-based questions while the second part was of experimental nature. After having confirmed that they belong to the target group, respondents were asked to give some demographic information. Next, a short description of R-concrete was given, and respondents were asked about their familiarity with the material. In the next block, a list of ten potential barriers was presented, each of which the respondents were asked to rate according to the extent to which they experience this factor as a barrier for using R-concrete. The scale ranged from ‘not at all’ (0 %) to ‘totally’ (100 %). Next, the same procedure followed for a list of ten potential drivers. The list of barriers and drivers was created based on a thorough literature review and then checked with the industry experts. For both barriers and drivers, the respondents had the chance to additionally mention further aspects. The experimental part of the survey followed, which will be described below. Finally, the survey finished with some item-based questions on the role of sustainability generally and in the construction project(s). Only the questions concerning demographic information differed considerably between the three groups. The remaining questions were only adapted in wording to suit the type of respondent. The full survey transcript can be found in Table A2 in the appendix.

The second part of the survey, placed in between the item-based questions, is the experimental part consisting of a discrete choice experiment. In discrete choice experiments, respondents are given a set of alternatives from which they are asked to choose their most desired one. These alternatives differ on a certain number of attributes, which enables the researcher to determine the influence of these attributes on the probability of choosing an alternative. Discrete choice experiments are based on Random Utility Theory and therefore the assumption that individuals derive utility not from whole goods but from the attributes of that good (McFadden, 1986). By including price as one of the attributes describing the alternatives, a willingness to pay (WTP) for the other attributes can be calculated. In that vein, the discrete choice experiment in this study has the purpose of answering the questions of whether construction clients are willing to pay for increasing the share of recycled aggregates in concrete (H2), whether this WTP is influenced by certain individual characteristics (H3), and whether it differs between different types of clients (H4). The alternatives in this study are different forms of R-concrete, which are characterized by four attributes. The first one is the price per m^3, which is likely to have an influence on the probability of choosing any product and in particular R-concrete, as higher prices seem to be a barrier (see section 1.3). In addition, this attribute is necessary to determine respondents' WTP for the other attributes. The price can take the values of 125 €, 150 €, and 175 €. These are based on the price lists of various German concrete producers. The second attribute is the share of recycled aggregates contained in the concrete. It can take the values of 10 %, 55 %, and 100 %. Currently, 45 % is the maximum share that can be substituted in Germany (DAfStb, 2010). However, discrete choice experiments offer the possibility of identifying preferences in hypothetical situations, which this range of values takes advantage of. Another attribute is the CO_2-footprint per m^3 of concrete, taking values of 170 kg, 200 kg, and 230 kg. These values are taken from the Sustainable Construction Information Portal Ökobaudat (Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen, 2021) and interviews with the experts. The CO_2-footprint is arguably the most salient environmental parameter of any product, activity, or sector, while R-concrete and its share of recycled aggregates might be unfamiliar to many construction clients. This attribute is included to compare clients' sensitivity to changes in these differently familiar parameters. The last attribute is the certification with a CSC-R label. The Concrete Sustainability Council (CSC) certifies companies and their supply chain in the concrete industry in the categories economic, ecological, and social sustainability as well as management and has an additional R-module for companies that produce R-concrete (Concrete Sustainability Council, 2020). This is a binary attribute such that it only takes the values of 'yes' or 'no'. Since labels are a means of information provision, this attribute is included to test whether it could help to increase the demand for R-concrete. These attributes were also checked with the interviewed experts. Table 1 gives an overview of all attributes and their possible values.

Table 1: Attributes and values of the discrete choice experiment

Attribute	**„Worst" value**	**Middle value**	**„Best" value**	**Primary concrete**
Price	175€	150€	125€	150€
Rec. Aggregates	10%	55%	100%	0%
CO_2-footprint	230kg	200kg	170kg	200kg
CSC-R Label	No	-	Yes	No

The experiment is unlabeled, indicating that the names describing the different alternatives do not have a meaning. Respondents were given eight decision situations (choice sets), each of which shows three forms of R-concrete (A, B, and C) and a status-quo alternative, which is primary concrete. The values of this primary concrete do not change and is always characterized by a price 150 € per m^3, 0 % share of recycled aggregates, 200 kg of CO_2-emissions per m^3, and no label (see Table 1). The values for the price and CO_2-emissions are chosen based on literature reviews, screening price lists, and the interviews with experts. This alternative can be considered an opt-out option, which was added to resemble a real-life choice situation, in which respondents are not forced to choose R-concrete, more closely. Since showing all possible choice sets to respondents – a so-called full factorial design – is not feasible (157.464 possible choice sets[3]), a fractional factorial design was generated using Lighthouse Studio (Sawtooth Software, 2021). The Balanced Overlap design option was chosen, which ensures statistical efficiency while allowing some overlap between alternatives, enabling the researcher to identify interaction effects. 12 different versions of the experiment were created, to which respondents were allocated along the principle of drawing from an urn without replacement, to ensure that each version is presented roughly an equal number of times. Respondents were asked to imagine that they are currently planning a building and must choose the type of concrete to be used. They were instructed to assume that all presented types, including the primary concrete, have the same characteristics beyond those explicitly mentioned. Respondents were given some facts about an exemplary building for orientation, including surface area, overall costs, amount of concrete necessary, costs for this volume of concrete in absolute terms and as a percentage of overall building costs. This exemplary building was either a typical family home in the case of private individuals or an office building in the case of organizations and developers. Additionally, a reference in car travel kilometers was given for the magnitude of a 30 kg difference in CO_2-emissions. An exemplary choice set is shown in Table 2. The survey finished with a factorial survey vignette, which is the focus of a follow-up paper in progress, to which interested readers are referred.

Table 2: Exemplary choice set

	R-concrete A	**R-concrete B**	**R-concrete C**	**Primary concrete**
Price per m³	175€	125€	150€	150€
Share of recycled aggregates	10%	100%	55%	0%
CO_2-footprint per m³	230kg	170kg	230kg	200kg
Environmental label (CSC-R)	No	Yes	Yes	No
Which concrete do you choose?	◯	◯	◯	◯

◯ I cannot answer this question.

The survey was designed using the online platform SoSci Survey (Leiner, 2021) and made available to participants via www.soscisurvey.de. A pilot study was conducted prior to running the actual survey. 24 private individuals in the target group, mainly social contacts of the researcher, completed the pilot study and a further ten individuals started it without finishing. Additionally, one representative of the group of organizations and developers each looked through the survey. Based on the respondents' feedback and metrics such as the completion time, some minor changes were made to the survey design. The actual survey was then available from December 2021 to mid-February 2022. Private individuals were mainly targeted via social media posts and distributors such as housing organizations or architects. Organizations and developers were invited to participate in the survey via e-mail. Contact details were assembled via publicly accessible websites and the firm database Amadeus (Bureau van Dijk, 2010).

2.4 Empirical Model

While the first research question on barriers and drivers will be answered using descriptive statistics, the second – clients' WTP – requires an empirical model. According to Louviere et al. (2010), the utility of a consumer in a choice situation can generally be formalized as follows:

[3] The set of all possible alternatives is formed by the Cartesian product of all attributes and levels (3 x 3 x 3 x 2 = 54). With three alternatives, there are 157.464 (54 x 54 x 54) possible choice sets.

$$U_{ia} = V_{ia} + \varepsilon_{ia}$$

where U_{ia} is the utility of the ath alternative for the ith individual, V_{ia} is the systematic or representative component and ε_{ia} is the random component. The former denotes the part of utility that the attributes of the alternatives contribute to and that can be observed, while the latter is the part of utility contributed by the attributes that cannot be observed. The main assumption here is that the individual i will choose an alternative a if and only if the utility he or she gets from that utility is bigger than the utility he or she would get from the other available alternatives:

$$U_{ia} > U_{ib} \qquad all\ b \neq a \in A$$

Since the random component of utility cannot be observed, one can only make statements about probabilities. The previous two equations lead to the following probability:

$$P(a|C_i) = P[(V_{ia} + \varepsilon_{ia}) > Max(V_{ib} + \varepsilon_{ib})], \text{ for all } b \text{ alternatives in choice set } C_i$$

where a is an alternative from a set of competing options in a choice set C. In words, the probability that individual i chooses the alternative a from the given options in a choice set C is equal to the probability that the systematic and random components of utility of that alternative are bigger than these components of all other options in that choice set. Depending on the assumption one makes about the probability distribution of the random components ε_{ai}, different choice models can be derived from this equation.

The basic choice model, the conditional logit choice or multinomial logit (MNL) model by McFadden (1974), assumes that the unobserved effects are independently and identically distributed (IID) among the alternatives in the choice set. Additionally, "the ratio of the probabilities of choosing one alternative over another (given that both alternatives have a non-zero probability of choice) is [assumed to be] unaffected by the presence or absence of any additional alternatives in the choice set" (Louviere et al., 2010, p. 44) – the so called Independence of Irrelevant Alternatives (IIA) assumption. In other words, introducing a further alternative should not change the relative probabilities of the alternatives already in the choice set. Technically, this means that the error terms may not be correlated. Introducing an opt-out option, as was done in this study, often violates this assumption (Dhar & Simonson, 2003). Diagnostic tests also show that the IIA assumption does not hold in our data (see section 3.3). Therefore, this study uses a mixed logit (ML) model (McFadden & Train, 2000). The ML model allows for the coefficients of one or more of the attributes describing alternatives to be random, thus able to vary across individuals in the sample and thereby taking into account preference heterogeneity. A certain distribution of these coefficients is assumed, and parameters of that distribution calculated. This allows for correlations among alternatives and thereby relaxes the IIA assumption (StataCorp, 2021). The ML model separates the unobserved error component into two parts: one that contains this correlation and can follow any distribution and one that is IID-distributed (Train, 2009). Since the subjects in this study made a choice in several choice sets, the data can be viewed as panel data. Therefore, a time component is added to the equation. The utility an individual i gets from an alternative a at time t in the ML model can be described by

$$U_{iat} = \beta_i\, x_{iat} + \alpha\, w_{iat} + \delta_a\, z_{it} + \varepsilon_{iat}$$

where x_{iat} and w_{iat} are vectors of attributes (variables) that describe the alternatives. β_i are the random coefficients that can vary over individuals in the sample, while α are fixed coefficients that do not vary over individuals. z_{it} is a vector of variables describing the individuals (the decision-makers) and δ_a are the corresponding fixed coefficients. The command "cmxtmixlogit" in the statistical software Stata estimates α, δ_a, and the parameters of the distribution of β_i using maximum simulated likelihood (StataCorp, 2021).

The WTP for a certain attribute can be calculated by dividing the coefficient of the attribute of interest k by the coefficient of the price variable c (Hole, 2007):

$$WTP_k = -\frac{\beta_k}{\beta_c}$$

It is likely that there is preference heterogeneity with respect to the price of concrete in the sample. However, modeling the price coefficient as random with the usually assumed normal distribution would mean that the WTP is the ratio of two normal distributions, which is statistically problematic (Carson & Czajkowski, 2019). A common way to deal with this issue and the one taken here is to fix the price parameter. The resulting WTP then follows the distribution of the attribute of interest (Sillano & de Dios Ortúzar, 2005; Train & Weeks, 2005). Because the WTP follows a distribution, we do not only report the estimated values for the WTP throughout the results, but also the corresponding confidence intervals[4]. These are calculated using the delta method implemented in the "wtp" command in Stata (Hole, 2007; StataCorp, 2021).

In order to pool the R-concrete alternatives and as a robustness check, the nested logit model is applied (Hensher & Greene, 2002). The nested logit model relaxes the assumptions made by the MNL model (IID & IIA) by grouping similar alternatives into nests, creating a hierarchical choice. In this example, the choice could be structured into a first choice between primary and R-concrete and a second choice between the different versions of R- concrete (see Figure 1).

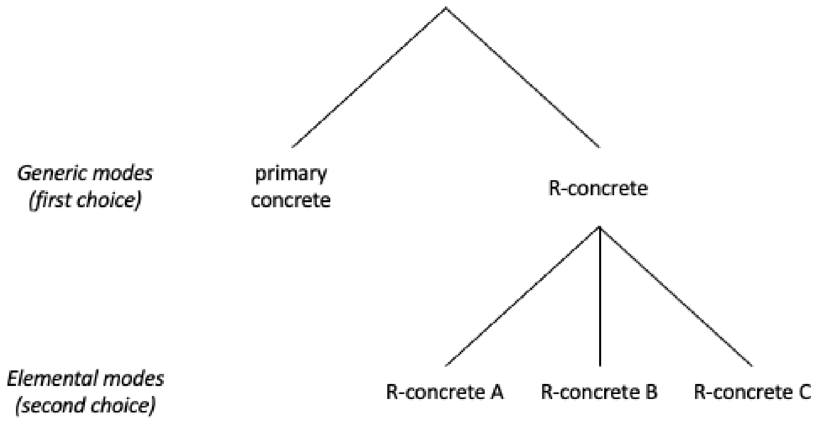

Figure 1: Hierarchical choice

The utility for a so-called elemental mode m that is contained within a generic mode g is given by

$$U_{gm} = U_g + U_{m|g}, m \in M_g, g \in G$$

or in terms of the systematic and unobserved components of utility:

$$U_{gm} = V_g + V_{m|g} + \mu_g + \varepsilon_{m|g}, m = 1, \ldots, M_g, g = 1, \ldots, G$$ (Louviere et al., 2010).

[4] The lower and upper limits are abbreviated with "ll" and "ul", respectively.

The nested logit model is fitted using the command „nlogit“ in Stata (StataCorp, 2021).

4. Results

3.1 Sample Descriptives

After excluding cases that quit without answering any of the substantial questions, that do not belong to the target group, or that did not give their consent, 834 private individuals, 624 organizational representatives, and 129 developers who started the survey remain (total: 1587). Of those, 305, 366, and 87 completed the survey, respectively (total: 758). Followingly, the attrition rate overall is rather high with 52 %. Reasons could be the rather long time necessary to complete the survey (13 minutes on average for completed surveys and after correcting for breaks) or the complexity of the questions, especially in the discrete choice experiment. Nevertheless, the discontinued surveys still contain valuable information that can be used in parts of the analysis. For example, more than half of those participants who did not finish the survey did answer the questions on barriers and drivers.

The distribution of the main demographic variables in the sample can be seen in Table B1, Table B2, and Table B3 in the appendix. The samples of developing companies and organizations seem to be representative of their respective population, except with respect to the organizations' turnover. This is much higher in our sample than the average among organizations in Germany. However, given that a prerequisite to participate in the study was that organizations act or have acted as construction clients, it is plausible that the sample is biased towards bigger, higher-turnover ones. A similar pattern can be seen in the sample of private individuals: our respondents are generally younger, more highly educated, have a higher average household income, are more likely to be employed, and are more likely to be married than the general population. These differences are plausible considering that all respondents in our sample are building, have built, or will be building a family house. Similar tendencies have been found in an analysis of real estate financing by private clients in Germany (Europace, 2023).

The descriptive results regarding the role of sustainability, the familiarity with R-concrete and consideration of using it, as well as the driving forces and responsible stakeholders for considering sustainability in construction can be found in appendix B.

3.2 Barriers & Drivers

The ratings of possible barriers for the use of R-concrete by respondents can be found in Figure 2. The number of observations per barrier differs, since items could be left unrated if the respondent was unable to judge it. Taking the entire sample together, the number one barrier is the lack of knowledge and/or experience with R-concrete on the side of the clients themselves or their building partners. The second most important reason for not using R-concrete is the uncertainty surrounding norms and regulations of the material. Ranked third is the notion that it is easier or more convenient to use primary concrete. Organizations and developers each viewed separately show the same pattern as the overall sample. For private individuals, the top three barriers are the lack of knowledge and/or experience, not knowing of R-concrete until now, and the uncertainty about norms and regulations.

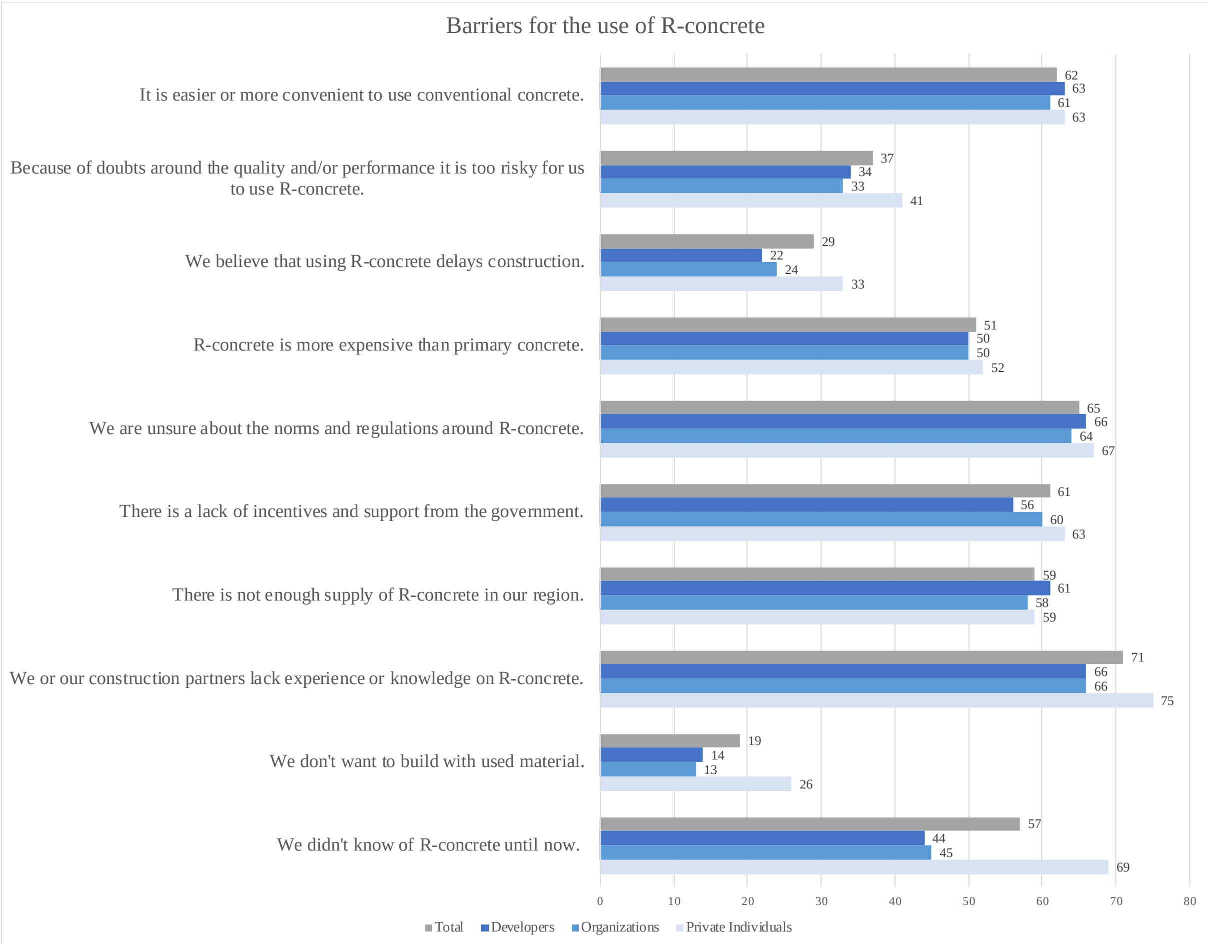

Figure 2: Barriers for the use of R-concrete (N = 1011 – 1276). Answers were given on a scale from 0 to 100.

Compared to our hypothesis (H1.1), most barriers are confirmed to be important for clients. Firstly, the lack of knowledge and experience is the most prominent barrier in all groups. Additionally in the group of private individuals, a complete lack of awareness (not knowing of R-concrete) is the second most important barrier. As expected, developers and organizations are affected by this ignorance to a much lesser extent than private individuals (rank 7). Our hypothesis that informational barriers are more relevant for private individuals than for the other two groups (H4.2), is thus partly confirmed: while a lack of fundamental awareness of the existence of the material is indeed much more prominent among private individuals, all groups are primarily held back by a lack of a deeper understanding. Given their rating (see Figure 2), the lack of incentives, of supply, and the higher price of R-concrete can also be considered important, but they only rank 4th, 5th, and 7th, respectively. Finally, the results do not confirm that a lack of acceptance is an issue among construction clients. This barrier was not rated to be important by the respondents and even ranked last.

The ratings of possible drivers for the use of R-concrete by respondents can be found in Figure 3. Overall, the number one driver is wanting to put a strain on the environment as little as possible. The second highest rated driver is related to this environmental consciousness: the notion that R-concrete is part of a sustainable way of construction. The driver that ranks third is a quality label certifying that R-concrete is equivalent to primary concrete. This pattern is also evident when viewing private individuals separately. However, organizations and developers rank the idea that using R-concrete is advantageous for their image third.

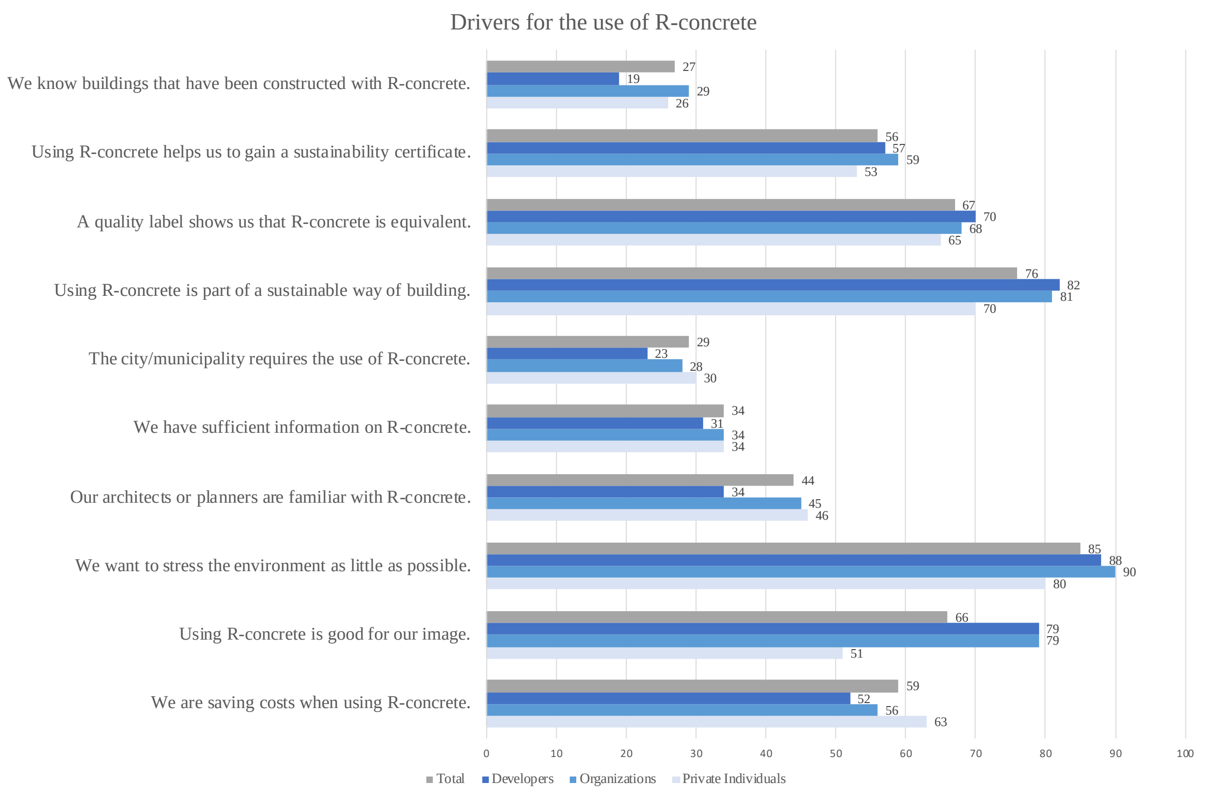

Figure 3: Drivers for the use of R-concrete (N = 890 – 1060). Answers were given on a scale from 0 to 100.

These results partly confirm our hypothesis on the main drivers for the use of R-concrete (H1.2). Environmental awareness is indeed the most important driving force for construction clients. Image and reputation considerations are also found to be highly influential, but only for developers and organizations. This is in line with the hypothesis that reputational aspects are more relevant for these two groups than for private individuals (H4.3). Against expectations, the other driver that was hypothesized to be important, policies and regulations, only ranks 9th. That the driver of saving costs achieved a similar rating to the respective barrier suggests that the price can be perceived as a driver and a barrier, depending on how it compares to that of conventional concrete. This is in line with the notion that there are regional differences in the price for R-concrete, which is why this factor requires a differentiated view.

3.3 Willingness to Pay

The coefficients of the alternative-specific attributes in the mixed logit model are all highly significant and have the expected sign. While individuals are less likely to choose alternatives with a higher price and higher CO_2-values, they are more likely to choose alternatives with higher contents of recycled aggregates and those that have a label (see Table 3). The alternative-specific constant (ASC) is a dummy variable that takes the value 1 for all R-concrete alternatives and the value 0 for the alternative of primary concrete. The results indicate that, holding the attributes constant, respondents were overall more likely to choose R-concrete compared to primary concrete. On average, respondents are willing to pay 0.26 € for every percentage point increase of added recycled aggregates. This value lies in a range of possible values between 0.18 € and 0.33 €. This finding confirms our hypothesis that clients' willingness to pay for recycled aggregates differs from that for primary aggregates (H2) such that they are willing to pay more for recycled aggregates in concrete.

Table 3: Regression results (cmxtmixlogit)

	Baseline
Price	– 0.0551***
	(0.00231)
Rec. aggregates	0.0141***
	(0.000907)
CO_2-footprint	– 0.0405***
	(0.00192)
Label	0.937***
	(0.0607)
ASC	1.632***
	(0.232)
/Normal	
sd(Rec. aggregates)	0.0167***
	(0.00127)
sd(CO_2-footprint)	0.0350***
	(0.0019)
sd(Label)	1.129***
	(0.0833)
sd(ASC)	2.784***
	(0.261)
N	24896

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The second half of the table gives the standard deviations of the attributes. All values are highly significant, indicating preference heterogeneity across the sample. Moreover, this indicates that the assumption of IIA is indeed violated in our sample, and it is therefore appropriate to use a mixed logit model.

The regression results for the separate groups, the corresponding marginal effects as well as WTP estimates can be found in Table 4, Table 5, and Table 6. Among the three groups, private individuals are most affected by the price of concrete. An increase of 15 % in the price for R-concrete decreases the probability of private individuals choosing it by 11.4 percentage points. However, the differences between the groups are only moderate in this respect. In contrast, the share of recycled aggregates most strongly affects the group of organizations. Increasing the share of recycled aggregates in R-concrete by 20 percentage points translates to an increase in the probability of organizations choosing it by 3.3 percentage points, while the increase is only by 2.4 percentage points for private individuals[5]. In the same line, organizations are the group

[5] This difference in the effect of the share of recycled aggregates on organizations vs. private individuals is statistically significant.

most willing to pay for increasing the share of recycled aggregates in concrete, while private individuals' WTP is lowest. Developers, organizations, and private individuals are willing to pay 0.27 €, 0.30 €, and 0.21 € for a percentage point increase of the share of recycled aggregates, respectively. This order differs from the one we hypothesized to find (H4.1). As expected, private individuals have the lowest WTP, but we find organizations instead of developers to have the highest WTP. The difference between the WTP of organizations and private individuals is significant, since the respective values do not fall in the other groups' estimated range of possible values.

Table 4: Regression results for developers, organizations, and private individuals separately (cmxtmixlogit)[6]

	(1) Developers	(2) Organizations	(3) Private Individuals
Price	– 0.0528***	– 0.0536***	– 0.0569***
	(0.00679)	(0.00331)	(0.00369)
Rec. aggregates	0.0140***	0.0162***	0.0118***
	(0.00227)	(0.00138)	(0.00138)
ASC	3.042**	1.584***	1.369***
	(0.948)	(0.370)	(0.314)
/Normal			
sd(Rec. aggregates)	0.0112**	0.0162***	0.0184***
	(0.00348)	(0.00190)	(0.00223)
sd(ASC)	4.254***	2.630***	2.697***
	(0.820)	(0.396)	(0.365)
N	2744	11188	10964

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Marginal effects of changes in the price and the share of recycled aggregates in percentage points

	Overall	**Developers**	**Organizations**	**Private Individuals**
Price (+ 15 % on R-concrete)	– 11.1	– 10.8	– 10.7	– 11.4
Rec. agg. (+ 20 p.p. on R-concrete)	+ 2.9	+ 3.0	+ 3.3	+ 2.4

[6] Because the focus here is on the share of recycled aggregates and the WTP for it, the results for the variables *CO_2-footprint* and *Label* are omitted from the regression tables from here on. The complete results for Table 4 and Table 7 can be found in Table C1Table C2 in the appendix, respectively.

Table 6: WTP estimates for a percentage point increase in the share of recycled aggregates for the different client groups

	Developers	**Organizations**	**Private Individuals**
WTP Rec. aggregates (1%)	**0.27**	**0.30**	**0.21**
Lower limit	0.16	0.25	0.16
Upper limit	0.37	0.36	0.26

In order to estimate the effect of individual characteristics on the choice between primary and R-concrete, a nested logit model is applied. Simply adding individual characteristics to the mixed logit model is meaningless in case of unlabeled experiments. Unlabeled experiments are those in which the names of the alternatives in a choice set do not carry any meaning (e.g., R-concrete A, B, and C). In contrast, labeled experiments include meaningful names of the alternatives. The most common example is the choice between means of public transport, in which the alternatives are labeled e.g., "bus", "train", and "subway" (Ben-Akiva & Bierlaire, 1999). Since there is no meaningful difference between the alternatives above and beyond the varying attributes, it is also meaningless to estimate the effect of individual characteristics on the probability of choosing R-concrete A over R-concrete B. It is however valuable to estimate the effects of individual characteristics on the probability of choosing R-concrete or primary concrete, the nests in our nested logit model. To identify the effect that these individual characteristics have specifically on the effect of the share of recycled material on the choice probability of that type of concrete, interaction terms are added to the cmxtmixlogit model. Thus, we use the nested logit model to identify the effect of individual characteristics on the choice of R-concrete generally and the cmxtmixlogit model to identify the effect of individual characteristics on the impact of the share of recycled aggregates.

For the sample overall, individual characteristics that are of interest on the choice between primary and R-concrete are to what extent sustainability is/was a criterion in construction for respondents (*Sustainability*), whether they had heard of R-concrete before (*Familiarity*), and whether they think that the responsibility of considering sustainability in construction lies with themselves (*Responsibility*). Table 7 shows the results of both a nested (nlogit) and a mixed logit (cmxtmixlogit) model that includes interaction terms between these individual characteristics and the share of recycled aggregates. The results show that the effects are as expected in most instances. A higher valuation of sustainability as a criterion in construction, being familiar with R-concrete, and a higher sense of responsibility for sustainable construction all significantly increase the probability of construction clients choosing R-concrete and, except for the feeling of responsibility, the responsiveness to the share of recycled aggregates. Thereby, our hypotheses on the value of sustainability in construction (H3.1) and on familiarity (H3.2) are confirmed. The hypothesis on a feeling of responsibility (H3.3) is only partly confirmed, since it does increase the probability of choosing R-concrete, but not the responsiveness to the share of recycled aggregates. Interestingly, controlling for these individual characteristics turns the sign of the alternative-specific constant in the nested logit model. This suggests that the earlier finding of clients generally being disposed to choose R-concrete over conventional concrete was largely due to them valuing sustainability, feeling responsible for considering it, and being familiar with the material. Holding these characteristics constant, respondents seem to be more likely to choose conventional concrete. Note that the ASC does not change its sign in the mixed logit model. Thus, it seems like the observation that the individual characteristics are responsible for clients choosing R-concrete over its conventional alternative cannot fully be explained by the influence of these characteristics on the effect of the share of recycled aggregates. Adding to the importance of these characteristics is the finding that the main effect of the share of recycled aggregates in the mixed logit model turns insignificant when the interaction terms are added. This shows that the utility of (hypothetical) individuals who do not value sustainability at all, who are unfamiliar with R-concrete, and who do not hold themselves responsible for considering sustainability in their construction projects, does not respond to variation in the share of recycled aggregates.

Table 7: Regression results with individual characteristics in the whole sample

	Baseline	
	nlogit	cmxtmixlogit[7]
Price	-0.0398^{***}	-0.0557^{***}
	(0.00343)	(0.00243)
Rec. aggregates	0.0106^{***}	-0.000907
	(0.000968)	(0.00273)
ASC	-1.514^{***}	1.460^{***}
	(0.233)	(0.232)
	R-concrete (nest)	Interaction terms with rec. aggregates
Sustainability	0.0158^{***}	0.000146^{***}
	(0.00181)	(0.0000333)
Familiarity	0.354^{***}	0.00444^{*}
	(0.103)	(0.00174)
Responsibility	0.516^{***}	0.00312
	(0.108)	(0.00199)
N	22896	22896

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The marginal effects (the differences in probability) from the cmxtmixlogit model can be calculated using the formula

$$probability = \frac{\exp(Xb)}{(1+\exp(Xb))}$$

where Xb is the linear predictor. For a share of 10 % of recycled aggregates and the case of the dummy variable *Familiarity*, for example, the difference in probability is given by

$$\frac{\exp\,(10\cdot(-\,0.000907)+10*0.00444)}{(1+\exp(10\cdot(-\,0.000907)+10*0.00444))}-\frac{\exp\big(10\cdot(-\,0.000907)\big)}{\big(1+\exp\big(10\cdot(-\,0.000907)\big)\big)}$$

[7] In these comparative tables of the nlogit and cmxtmixlogit models, the results for the SD in the cmxtxmixlogit model are omitted. All coefficients are significant.

The results for the variables *Sustainability* and *Familiarity* for three different levels of the share of recycled aggregates can be found in Table 8. Since the interaction term with *Responsibility* is not significant, marginal effects are not calculated. The results illustrate that the positive effects of valuing sustainability and being familiar with R-concrete increase with an increasing share of recycled aggregates. For example, at a moderate share of 55 % recycled aggregates, being familiar with R-concrete means an increased probability of choosing this concrete by 8.5 percentage points, while the probability increases by 15.1 percentage points for a R-concrete with recycled aggregates only (100 %). Note that these values should be treated with care, since the main effect of *Rec. aggregates* is insignificant in the regression.

Table 8: Marginal effects of changes in individual characteristics for different shares of recycled aggregates in percentage points

	10 % rec. agg.	**55 % reg. agg.**	**100 % reg. agg.**
Sustainability ($\bar{x} \pm s$)[8]	+ 1.9	+ 9.5	+ 14.7
Familiarity (no/yes)	+ 1.6	+ 8.5	+ 15.1

These individual characteristics also affect clients' WTP for increasing the share of recycled aggregates in concrete (see Table 9). Especially the importance clients place on sustainability as a criterion in construction and whether they are familiar with R-concrete or not significantly influence their WTP. Clients who gave a rating to the importance of sustainability that is lower than the median[9] are willing to pay 0.16 € on average, while those who gave a rating above the median are willing to pay 0.38 € per percentage point of recycled aggregates. Similarly, clients who had never heard of R-concrete before are willing to pay 0.19 € and those who were familiar with the material in the sense that they had at least heard of it before were willing to pay 0.33 € for a percentage point increase of the share of recycled aggregates. Feeling responsible for considering sustainability has a smaller, but still considerable, effect: those clients who do not feel responsible have a WTP estimate of 0.21 €, while those who do are estimated to be willing to pay 0.27 €. The respective regression results can be found in Table D1, Table D2, and Table D3 in the appendix.

Table 9: WTP estimates of various subgroups of clients (based on cmxtmixlogit)

	WTP Rec. Aggregates (1%)	Lower limit	Upper limit
Sustainability			
Less important (< $\tilde{x}$)	0.16	0.14	0.18
More important (> $\tilde{x}$)	0.38	0.28	0.48
Familiarity			
Not familiar	0.19	0.14	0.25
Familiar	0.33	0.28	0.38
Responsibility			
No	0.21	0.18	0.25
Yes	0.27	0.19	0.35

[8] $\bar{x} = 73.83$, s = 25.58
[9] $\tilde{x} = 79$

Looking at the client groups separately, additional individual characteristics seem to influence the propensity to choose R-concrete, the responsiveness to the share of recycled aggregates, and the WTP for it. We will only discuss one aspect here that stands out in all three client groups. (Regarding the other influences, the interested reader is referred to Appendix E.) Organizations with a higher yearly turnover are more likely to choose R-concrete compared to ones with a lower turnover[10]. In contrast, turnover does not seem to influence their responsiveness to the share of recycled aggregates (see Table E3 in the appendix for both results). Interestingly, if we compare the WTP of organizations by turnover, we find that organizations with a lower turnover are willing to pay a significantly higher amount per percentage point increase in the share of recycled aggregates (0.37 €; ll 0.26 €, ul 0.48 €) than those with a higher turnover (0.23 €; ll 0.16 €, ul 0.29 €; the respective regression results can be found in Table E4 in the appendix). This is the opposite of what we would expect given the finding that higher-turnover organizations are more likely to choose R-concrete than their lower-turnover counterparts. A close look at the regression results suggests that this difference does not necessarily come from a difference in valuation of recycled aggregates (which the insignificant result in Table E3 show, too), but from a difference in price sensitivity. Lower-turnover organizations appear to be much less price sensitive than higher-turnover ones. The exact same pattern is also observed for the group of developers (see Table E1Table E2 in the appendix). In that case however, the difference in WTP cannot be said to be significant, which could be ascribable to the sample size.

For private individuals, the equivalent to turnover, the household income, is also of interest. The overall picture here is more consequent, but not less surprising. Respondents with a lower household income were found to be more likely to choose R-concrete over primary concrete compared to ones with a higher household income[11] and they were more responsive to an increase in the share of recycled aggregates (see Table E6 in the appendix). Following this line, they are significantly more willing to pay for a percentage point increase in the share of recycled aggregates (0.34 €; ll 0.22 €, ul 0.45 €) than their counterparts (0.17 €; ll 0.11 €, ul 0.22; the respective regression results can be found in Table E7 in the appendix).

3.4 Robustness Checks

To validate the overall results received using a mixed logit model, a nested logit model is applied. Table F1 in the appendix shows the regression results. According to these results, on average, respondents are willing to pay 0.27 € for every percentage point increase of recycled aggregates. The corresponding possible values range from 0.24 € to 0.29 €. The value estimated with the mixed logit model (0.26 €) falls well within this range. Thus, our original estimates are supported by this alternative specification.

This section further summarizes the results of a series of robustness checks that use sub-samples based on different criteria (see Table F2 in the appendix). First of all, two quality indicators are used that the software SoSci Survey (Leiner, 2021) provides to identify extremely fast respondents. A value of more than 100 on the first indicator (DEG Time) indicates data of low quality. Threshold values of 75 or even 50 are recommended for stricter filtering. Samples with values below 100 and below 50 are used in models (2) and (3) in Table F2. 52 and 151

[10] Organizations were characterized as lower- or higher-turnover ones using a threshold of 5 million €. This threshold was chosen based on the distribution in the sample. It roughly divides the sample in half.
[11] Private individuals were characterized as lower- and higher-income ones using a threshold of 4000 €. This threshold was chosen based on the average household income in Germany in 2018, which was 3661 € (Bundeszentrale für politische Bildung, 2020).

participants (translating into 1328 and 3704 observations) are excluded, respectively. The other indicator, a relative speed index (Time RSI), is a more elaborate measure and denotes all observations with a value of 2 or more as critical. Model (4) applies this criterion by excluding these extremely fast respondents. 39 respondents and therefore 1016 observations are excluded. Another robustness check uses only the data from respondents that finished the complete survey. This results in a sample of 720 participants (22.388 observations; see model (5)). Finally, model (6) only uses the data from respondents who answered all choice sets of the discrete choice experiment without choosing the opt-out option "I cannot answer this question" (711 participants, 22.752 observations). Overall, Table F2 shows no meaningful differences between the baseline model and the robustness checks such that the results reported above can be considered robust. Table F3 in the appendix shows the respective WTP estimates from these robustness checks. All models' estimates are within the limits of the other models' estimates. In fact, the estimated mean WTP for a percentage point increase in the share of recycled aggregates is 0.26 € in all models except the ones that exclude unusually fast respondents (DEG Time 50) and those that haven't answered all choice sets (DCE Complete). The estimate in both cases is 0.25 €, thus differing only inconsiderably.

5. Discussion

4.1 Barriers & Drivers

The barriers and drivers for the use of R-concrete experienced by construction clients are partly in line with previous research. The main barrier found in this study, the lack of knowledge and experience among clients and their construction partners, has been identified as prominent in sustainable construction generally by Adams et al. (2017), Darko and Chan (2017), Gan et al. (2015), and Shooshtarian et al. (2020), for example. As Stürmer and Kulle (2017) point out, the lack of familiarity with R-concrete specifically among clients hinders demand for the product, which the current findings confirm. Especially private individuals are unfamiliar with R-concrete. The respective barrier, not knowing of R-concrete, ranked 2nd in this group and more than 75 % indicated that they had never heard of R-concrete before. The second most prominent barrier in this study also relates to the lack of awareness: the uncertainty regarding norms and regulations. Awareness and knowledge among clients should be increased in order to alter their behavior and attitude toward recycled products like R-concrete (Hossain et al., 2020). The most forward way to achieve this is through the provision of information. In this vein, Banfi and her colleagues (2008) argue that barriers for investing in sustainable attributes in residential buildings can be overcome by providing information to stakeholders, such as consumers and investors. Construction clients should be sufficiently informed about the existence of recycled alternatives, their applicability, and the regulations that surround its use. Only then can the vicious circle be interrupted such that demand increases, suppliers follow, and experience with the material can be gained, which will in its turn increase demand.

The idea of information provision also relates to two important drivers found in this study among all three groups: not wanting to harm the environment and the notion that using R-concrete is part of a sustainable way of construction. Few researchers have focused on this type of internal driver (Darko et al., 2017; Diyana et al., 2013; Olanipekun, Xia, et al., 2017), though they ranked highest in this study. Information asymmetry could hamper the positive influence of environmental awareness on the demand for R-concrete. The stakeholders in construction projects as well as the recycling industry have access to relevant information to different degrees (Forsythe et al., 2015; Li et al., 2020). In the case of R-concrete, information on how beneficial the material really is in terms of its environmental impact is also not readily accessible by clients. To avoid this sort of information asymmetry and reap the advantages of the driving force of environmental awareness, a label certifying the quality and/or sustainability related aspects of R-concrete could be useful. The inclusion of a label as an attribute in the discrete choice experiment (see section 2.1) allows us to check this idea. We find that respondents were significantly more likely to choose a type of concrete if it had a label than if it didn't (see Table 3). Developers, organizations, and private individuals have an additional estimated WTP of 19.83 € (ll 11.33 €, ul 28.33 €), 17.54 € (ll 13.97 €, ul 21.22 €) and 15.70 € (ll 12.21 €, ul 19.20 €), respectively, for a m^3 of concrete with compared to one without a label (see Table G1 in the appendix). Translated to an average-priced type of concrete (150 € per m^3), this is equivalent to 13 %, 12 %, and 10 % of the price. This is in line with previous research that found consumers to be willing to pay more for products, among which building materials, with eco-labels (e.g., Shen, 2012; Ward et al., 2011). The finding that a label providing proof that R-concrete is equal to conventional concrete in quality is a top driver (ranked 3rd) for the clients in our sample supports the idea that labels would be advantageous for demand.

The lack of acceptance for recycled material that has been found repeatedly in the literature (Knappe et al., 2012; Scheibengraf & Reisinger, 2005; Shooshtarian et al., 2020) did not emerge from this study as much as expected. The barrier of uncertainty and doubts regarding the material's quality and performance only ranked 8th (with a score of 38 on a scale from 0 to 100). Not wanting to build with recycled material even ranked last (10th, with a score of 20). Another barrier that appears to be less of a problem than previously expected is the higher price of R-concrete. This barrier is not unimportant and should be tackled, since it did reach a score of 52, but it only ranked 7th (out of 10). Thus, it seems like a range of other aspects hinder the creation of demand for R-concrete more than its higher price does. The positive WTP found confirms this and will be discussed in the next section. The lack of supply of R-concrete (Katerusha, 2021) also plays a role in impeding its demand, but is among the top four barriers only for developers. It is conceivable that the developing companies have dealt with the supply of R-concrete in their region more than the other two groups and especially the private individuals have, since they build more by definition. The finding that around 40 % of developers have considered using R-concrete while not even 20 % of private individuals have, supports this idea. A lack of incentives and support from the government (e.g., Darko et al., 2017) appeared to be among the main barriers specifically for organizations. However, this barrier was not found to be as prominent as in the study of executing companies by Katerusha, 2021. If executing companies were supported in their production of R-concrete, the conditions for the client might be favorable enough for them not to need any more incentives.

The third most prominent barrier in this study was the ease and convenience of building conventionally, which has not received much interest in the literature (an exception is Joachim et al. (2015)). The experts interviewed however all agreed that the construction industry is a conservative one that doesn't adopt changes or innovation easily. The current findings seem to support this idea. Tackling this barrier could imply information provision or incentives such that clients are willing to invest some effort. At the same time, choosing R-concrete will be just as convenient once the demand and supply for it have reached a certain level such that it has become a standard praxis.

While policies and regulations were found to be a driver for sustainable construction, not many are in place (yet) for R-concrete. Municipalities can however prescribe certain construction approaches, as is done for example in the so called Faktor X residential areas (Faktor X Agentur & der Entwicklungsgesellschaft indeland GmbH, n.d.). A certain factor of resource efficiency is determined there, meaning that all houses must be built with only a share (e.g., half for factor 2) of the conventionally required resources. The driving force that the city or municipality prescribes the use of R-concrete has not been ranked very high by the respondents. Since this is a prescription and not a voluntary agreement, it would most probably be considered a driver if it was in place. The low rank therefore points toward these policies still being seldom.

That acting environmentally friendly is advantageous for a company's image is not new – it is why greenwashing has become an issue (Delmas & Burbano, 2011). It is not surprising then that the positive effect of using R-concrete on their image is a main driver for organizations and developers like previously established in the literature (Diyana et al., 2013; Zhang et al., 2011). In both groups, the driver ranked 3rd (with a score of 79 points on a scale from 0 to 100). In contrast, image considerations seem to be much less important to private individuals. In this group, this driver only ranked 6th (with a score of 51). This discrepancy is unsurprising since private individuals are not dependent on their image or reputation like companies are. A related driver is the advantage of using R-concrete for gaining a sustainability certificate. Since these certificates are a way of demonstrating one's environmentally friendly behavior and thereby boosting one's image (Diyana et al., 2013), they too are ranked higher by organizations and developers than by private individuals.

Finally, a group of drivers have reached surprisingly low scores. Apart from the already mentioned aspect of municipalities prescribing its use, these are the knowledge or experience among architects and construction partners, having sufficient information on R-concrete, and being aware of buildings that have been constructed with R-concrete. It is likely that these aspects simply aren't given (yet) and therefore cannot drive clients in demanding R-concrete.

4.2 Willingness to Pay

Our results show that respondents on average tend to choose R-concrete over concrete with primary aggregates when these do not differ in the attributes we modeled. This suggests that when confronted with two types of concrete, of which one is R-concrete and the other is not, and which have the same price, share of recycled aggregates (although per definition not possible), CO_2-footprint, and environmental label, construction clients would choose the R-concrete. Further, all estimates for clients' WTP for an increase in the share of recycled aggregates found in this study were positive and significant. An estimate of 0.26 € for every percentage point more per m^3 of concrete was calculated, but rather big differences were found here between the groups. Private individuals are estimated to be willing to pay 0.21 € on average. Assuming a one-family dwelling that needs 100 m^3 of concrete and an average price of 150 € per m^3, these clients would be willing to pay 945 € more for building their house with R-concrete that has a share of 45 %[12] of recycled aggregates compared to one that has only primary aggregates, which translates to 6 % of the price for concrete. Organizations and developers have an estimated WTP of 0.30 € and 0.27 €, respectively, for every percentage point increase. Assuming a large office building that requires 15.000 m^3 of concrete, these client groups would be willing to pay an extra 9 % (202.500 €) and 8 % (182.250 €). These values are in the same range as findings of WTP for green building overall found by other researchers (Khan et al., 2020; Portnov et al., 2018; Wiencke, 2013). The price premium for R-concrete in most parts of Germany currently lies between 10 and 17 %[13] (interviewee 9, personal communication, August 2, 2021; interviewee 10, personal communication, August 3, 2021). This difference suggests that R-concrete is currently only consumed by construction clients with an above-average WTP for recycled aggregates. The respondents with the highest WTP for the share of recycled aggregates in our sample are presumably organizations that value

[12] 45 % is the maximum share currently admitted in Germany (DAfStb, 2010).
[13] The share of recycled aggregates contained varies. However, since 45 % is the maximum share currently admitted, the comparison is rather conservative.

sustainability in construction, who feel responsible for considering it, and who are familiar with R-concrete. The estimated WTP for this group is 0.50 € (ll 0.32 €, ul 0.68 €; respective regression results in Table E14 in the appendix). This translates into a price premium of 15 %. Thus, while there are clients who are willing to pay the current price premium, a lot of them are not. Given that stimulating recycling is a political goal in Germany (*Koalitionsvertrag 2021 – 2025*, 2021), the EU (Waste Framework Directive, 2008), and worldwide (United Nations, 2015), increasing the use of R-concrete is desirable. This can be achieved by stimulating demand among the whole range of construction clients. One idea would be to subsidize the use of R-concrete. Our results show that demand is price sensitive (see e.g., Table 3) and the current market price is hindering for a majority of construction clients, which speaks for the effectiveness of financial incentives. These incentives might only be necessary temporarily, since with increasing resource scarcity the market itself will presumably produce price competitiveness in the future, which would render incentives unnecessary.

We find that clients who value sustainability in construction, who feel responsible for considering it, and who are familiar with R-concrete are all more likely to choose R-concrete. In fact, our results suggest that these characteristics are what makes clients choose R-concrete over its conventional alternative when these do not differ in the attributes we modelled. In contrast, individuals who do not value sustainability, feel responsible, or are familiar with the material do not respond to a change in the share of recycled aggregates. Particularly environmental awareness or valuing sustainability highly has been shown to have a strong effect. Clients with these characteristics are much more likely to choose R-concrete and more willing to pay for the share in recycled aggregates contained. This is in line with previous research on the influence of environmental attitudes (Mandell & Wilhelmsson, 2011; Yau, 2012). Further, our results support the finding that the familiarity with the concept positively influences WTP for green building. Portnov et al. (2018) found that when potential homebuyers are familiar with the concept of green building, they are willing to pay a price premium of 1.5 percentage points more than those who are not. In our sample, the difference between the WTP for R-concrete of respondents who are and who are not familiar with the material expressed as a price premium is even higher with 4.2 percentage points (see Table 9). This finding shows that awareness of the existence of the material is already very beneficial, which could easily be achieved on a large scale through a simple information campaign. The feeling of responsibility for considering sustainability is not a prominent determinant of WTP in previous studies, but our results confirm the findings by Wang (2022) that a feeling of responsibility positively influences WTP. This also relates to the idea of a "circle of blame" described above (see section 1.3). The demand and supply side both point to each other as the ones responsible for the sparse use of, in this case, R-concrete (Andelin et al., 2015; Keeping, 2000). Our results indicate that this vicious circle can be broken when stakeholders, in our case clients, take responsibility. These results can be used to design potential incentives to increase demand for R-concrete efficiently.

Regarding demographic determinants of WTP, we will only briefly discuss the effect of turnover (for developers and organizations) and income (for private individuals). Interestingly, we find a higher WTP for organizations with a lower turnover. A similar pattern was observed for private individuals: those with a lower household income were willing to pay more for increasing the share of recycled aggregates. Previous research has more often found a positive correlation between income and WTP for sustainable housing or green building attributes (e.g., Chau et al., 2010; Mandell & Wilhelmsson, 2011; Yau, 2012). However, there have been contrary findings, too. Khan et al. (2020) found a negative correlation between income and WTP for sustainable housing attributes such as wall insulation or air quality in his sample of Pakistani homebuyers. The negative influence of income on WTP might suggest that the share of recycled aggregates is considered an inferior good (Ebert, 2003). Although the environment is most often seen as a normal good (WTP increases with income), there are studies that find environmental goods to be inferior. For example, Huhtala (2010) finds a negative income effect on the WTP for recycling in Finland. Similarly, Vo and Huynh (2017) estimate WTP for groundwater conservation and also finds that respondents with a higher income are less willing to pay for clean groundwater. Some explanations in the direction of context-dependency and substitutability are offered (Dupoux & Martinet, 2022), but should be studied further.

As a comparison to the WTP for increasing the share of recycled aggregates, the WTP for saving a kg of CO_2-emissions is calculated. Averaged over all three client groups, an estimated 0.74 € (ll 0.54 €, ul 0.93 €; see Table 3 for the regression results) would be accepted for a kg more CO_2-emissions per m^3 of concrete[14]. For the three groups separately, values of 0.62 € (private individuals; ll 0.53 €, ul 0.71 €), 0.68 € (developers; ll 0.48 €, ul 0.87 €) and 0.87 € (organizations; ll 0.75 €, ul 0.98 €) were calculated (see Table G2 in the appendix; respective regression results in Table C1). Projected to a ton of CO_2, private individuals, developers, and organizations would be willing to pay 620, 680 and 870 € to avoid its emission, respectively. With that, the respondents' WTP exceeds the current price for a ton of CO_2-equivalents by far (Ember, n.d.; The World Bank, 2022).

Previous estimates of WTP for saving CO_2-emissions cover a very wide range (Alberini et al., 2018), the higher end of which our estimates are located at. These high estimates could be explained by a heightened media attention for issues of global warming and climate change at present (Achtnicht, 2012). Additionally, respondents could have seen the reduction in CO_2-emissions as being in the domain of losses rather than gains. In that case, the estimated value should be seen as a willingness to accept (WTA) rather than to pay (WTP; Nguyen et al., 2021). WTA estimates have generally been found to be higher than their corresponding WTP estimates (Horowitz & McConnell, 2002). Nevertheless, even if these values are an overestimate, it is clear that respondents were much more sensitive to changes in CO_2-footprint compared to changes in the share of recycled aggregates. While they would be willing to pay much more than the current market price for CO_2, their average WTP for recycled aggregates does not match the current price premium seen on R-concrete. This striking difference supports the idea that people are aware of climate change issues, while resource scarcity is much less prominent. A similar finding resulted from the study of Robbins and Perez-Garcia (2005). Comparing the general population's WTP for reductions in solid waste emissions and greenhouse gas emissions, the researchers found that the respondents were most sensitive to the latter.

It would be valuable to determine where the money that construction clients are willing to pay for the conservation of the environment is best spent. Based on the estimated average WTP in this study, one Euro could reduce 1.35 kg of CO_2-emissions or save around 71 kg of primary sand and gravel[15]. While both CO_2-emissions and the extraction of sand and gravel produce externalities (e.g., Bendixen et al., 2021; Cai & Lontzek, 2019), only the so-called social cost of carbon has been estimated. Two studies that have tried to quantify the costs of aggregate extraction are from the Department of the Environment, Transport and the Regions and London Economics cited in Willis and Garrod (1999). The values range from 1.06 to 9.00 £, depending on the study and the method used. However, these estimates are from the United Kingdom in 1998 and 1999 and are based on surveys that assess that respondents' WTA and WTP. Thus, the environmental damages and its consequences of mining sand and gravel (in Germany) have

[14] The CO2-footprint was coded in kg per m^3. Therefore, the respective coefficient is negative and thus is the WTP. One could interpret this negative WTP as a willingness to accept (WTA). Here however, we conceptualize the estimates as WTP for savings in kg and therefore have reversed the sign.
[15] A m^3 of concrete has around 1850 kg of aggregates (Knappe et al., 2017).

yet to be objectively priced. Therefore, it is difficult if not impossible at this point to determine which area clients' hypothetical payments are spent most efficiently in.

Generally, WTP estimates from stated preference (SP) studies are to be treated cautiously. The so-called hypothetical bias might inflate estimations, meaning that participants in these studies declare to be willing to pay more than they would in reality. For example, Voelckner (2006) finds that WTP estimates are higher when the price stated is only paid hypothetically than when it is real. Murphy and his colleagues (2005) conduct a meta-analysis on this issue and find a median ratio of hypothetical to real WTP values of 1.35. Overall, they find that choice-based elicitation methods, as is used in the present study, reduces bias. They conclude that hypothetical bias in SP studies might not be as much of an issue as previously assumed. In addition, the differences in WTP between types of clients are independent of the absolute values identified.

4.3 Client group differences

The substantial differences between client groups are worth noting. First, private individuals seem to experience barriers to a higher extent than organizations and developers (see Figure 2). Additionally, they chose the base alternative, the primary concrete, more often than the other two groups did (P: 10 %, O: 6 %, D: 6 %). The marginal effect of increasing the share of recycled aggregates is lowest for private individuals, while the marginal effect of increasing the price is highest in this group (see Table 5). These tendencies present themselves most clearly when comparing the groups' WTP for increasing the share of recycled aggregates. Organizations' WTP per additional percentage point of recycled aggregates is almost 1.5 times that of private individuals. Although the difference is smaller, developers, too, have a substantially higher WTP than private individuals (see Table 6). Some of this discrepancy is ascribable to observed differences between the groups such as their familiarity with R-concrete (66 % of developers and 64 % of organizations but only 23 % of private individuals are familiar with R-concrete). However, even after controlling for familiarity, organizations and developers are still significantly more likely to choose R-concrete compared to private individuals (see model (1) of Table D4 in the appendix). Another difference is the extent to which the groups value sustainability: private individuals score 68 points, while developers and organizations score 74 and 77 points, respectively. Controlling for both familiarity and sustainability explains the difference between private individuals and organizations with respect to their likelihood of choosing R-concrete (see model (2) of Table D4 in the appendix). The difference between developers and private individuals persists, however. These two groups differ somewhat with respect to the extent to which they feel responsible for considering sustainability (P: 75 %, D: 81 %, O: 74 %). Notwithstanding, a marginally significant difference remains between the two groups even after controlling for this feeling of responsibility (see model (3) of Table D4 in the appendix).

The higher WTP for an increased share of recycled aggregates in organizations and developers thus is largely attributable to the familiarity with R-concrete, feeling of responsibility, and value of sustainability in construction. The remaining difference could be explained by the factors these groups are motivated by. As illustrated by the main driving forces, all groups seem to be intrinsically motivated to protect the environment. These ethical considerations are one group of motivations that Diyana et al. (2013) identified for green building. Another one are financial drivers, which are currently still debatable in the case of R-concrete, but would affect organizations, developers, and private individuals to the same extent. The remaining two categories of motivation, image and business strategy thoughts, however, only apply to organizations and developing companies. As the ranking of the respective driver in this study showed, private individuals are much less driven by image concerns. Thus, while organizations and developing companies are motivated to choose recycled material by intrinsic as well as extrinsic aspects, private individuals are only affected by the former. This might explain why this group is least likely to demand and willing to pay for R-concrete. To tackle this issue, additional incentives that address private individuals specifically are necessary. An example could be a subsidy that is granted to individuals who are about to build their family home and apply R-concrete where possible.

Our results also show that private individuals suffer from a lack of awareness of R-concrete more than the other two groups do. Thus, information-based instruments that inform construction clients of the possible alternatives to primary material should be targeted specifically at this group. On the other hand, specific information regarding the application of R-concrete, for example, can be directed at clients more generally, since all groups are hampered by a lack of knowledge. Another notable difference is that image and reputation considerations are much more important for developers and organizations. Consequently, incentives that are based on this driver should be tailored to these client groups, while private individuals should be incentivized to use R-concrete through different mechanisms. These are just some examples of how different client groups should be treated differently. The barriers and drivers, the patterns of choice, the responsiveness to different attributes in the choice situations, and the WTP all show significant differences between the studied groups. Thus, a one-size-fits all approach to stimulate demand is unlikely to be efficient. Policies should instead be designed taking these differences into account.

6. Conclusion

Concrete with recycled aggregates (R-concrete) offers a way to reduce the use of primary resources on the one hand and to minimize construction and demolition waste on the other. It can be used in almost any application and is considered qualitatively equivalent to its primary counterpart. Nevertheless, it is hardly used in Germany, which, to a significant part, is due to a low demand. This study set out to investigate what the barriers and drivers are for construction clients to demand R-concrete, whether they are willing to pay for it, which factors are of influence, and how different client groups differ in this respect. The main findings are the following: construction clients perceive barriers that arise from a lack of information as the most severe. These are a lack of awareness, of knowledge and experience, and uncertainty about norms and regulations. In contrast, they are driven by their environmental consciousness. A quality label further stimulates private individuals to demand R-concrete, while a positive image effect motivates organizations and developers. All groups are willing to pay for recycled aggregates in concrete, where private individuals have the lowest and organizations have the highest WTP per percentage point increase. Valuing sustainability in construction, being familiar with R-concrete, and feeling responsible for sustainable construction all positively affect the WTP. These characteristics also seem to underlie the finding that clients are generally more likely to choose R-concrete over conventional concrete when these do not differ in their attributes, such as their price. Additionally, demographic characteristics like turnover/income have an influence and there are substantial differences between client groups.

Although we found a positive WTP for R-concrete, the average value does not match the price premium currently seen. We find clients in our sample that are willing to pay this premium, but in order to close resource loops and minimize waste, like it is politically strived for, a broader demand needs to be stimulated. Information provision could help to fulfil this goal. Especially in the form of a quality and/or sustainability label, objective information on R-concrete could tackle some of the main barriers we found and take advantage of those aspects that drive construction clients towards using recycled material. In that sense, information could increase clients' environmental awareness and familiarity with the product, factors we have seen to be positively influential. Apart from information, potential financial incentives could be effective in this regard for private individuals in particular since they are the most price sensitive group. State subsidies could at least temporarily be installed in order to stimulate demand. To increase demand among organizations and developers, the appeal a positive and 'green' image have could be taken advantage of. Municipalities could, for example, award companies that use R-concrete with a certificate that is publicly advertised. These are just a few examples of potential measures to implement in order to increase the demand for R-concrete. Further research should study which of these are effective and under what conditions. One aspect of policy design that this study has demonstrated the importance of is the tailoring of measures to the client groups. The differences we have observed should not be ignored if policies are to be as effective and efficient as possible.

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Appendix A

Interviews & Survey

Table A1: Overview of interviewed experts

Interview number	Interviewed expert	Date	Means
1	CEO for the section of minerals in a union for secondary resources	29.06.2021	video call
2	R&D manager in a recycling company	01.07.2021	video call
3	employee of the German green building council	05.07.2021	video call
4	CEO of a concrete producing company	06.07.2021	video call
5	managing director of economic affairs in a concrete association	08.07.2021	video call
6	construction project manager and city councilor	12.07.2021	video call
7	regional director in a building material producing company	21.07.2021	phone call
8	product manager in a concrete producing company	27.07.2021	video call
9	quality director in a concrete producing company	02.08.2021	e-mail
10	sales manager in a building material producing company	03.08.2021	video call
11	professor for building materials research	03.08.2021	video call

Table A2: Survey transcripts

Question	Wording	Response options
Start		
Consent (filter question)	*Information on the survey and data protection.*	→ I give my consent and wish to participate in this survey. (Survey continues.) → I do not want to participate in this survey. (Survey is terminated.)
Target group – P (filter question)	This survey is targeted at individuals who have built a house in the previous 5 years, are currently building one, or are planning to build one in the near future. Confirm here that you are part of the target group.	→ I built a house in the previous 5 years. → I am currently building a house. → I am planning to build a house in the near future (ca. 1 year). → I do not belong to the target group. (Survey is terminated.)
Target group – BT (filter question)	This survey is targeted at project developers and (employees from) developing companies, who act as clients in construction projects. Housing associations and investors who initiate and finance the project also belong to the target group. Confirm here that you are part of the target group.	→ I am a project developer. → I work at a developing company. → I am an investor and initiate projects. → I work at a housing association. → I am unsure whether I belong to the target group, because: *Text* (Survey continues in all of the above.) → I do not belong to the target group of this study. (Survey is terminated.)
Target group – O (filter question)	This survey is targeted at employees in construction management in organizations / companies, that are <u>not</u> themselves construction or developing companies. Note: the position does not have to carry the name ‘construction	→ I work in the field of construction management for an organization / company, that is not itself a construction or developing company. → → I am unsure whether I belong to the target group, because: *Text*

	management'. Meant are all employees that are involved in the construction of new buildings for their organization / company. *Example.* Organizations can be private as well as non-profit. Local authorities (federal state, states, municipalities) are not part of the target group of this study. Confirm here that you are part of the target group.	(Survey continues in all of the above.) → I do not belong to the target group of this study. (Survey is terminated.)
Sociodemographic information (Private individuals)		
Gender	Which gender are you?	→ female → male → other → not specified
Age	How old are you?	→ 18 – 25 → 26 – 35 → 36 – 45 → 46 – 55 → 56 – 65 → older than 65
Education	Which educational status do you have?	→ no degree → Certificate of Secondary Education → General Certificate of Secondary Education → completed apprenticeship → vocational diploma → general qualification for university entrance → graduate degree → other: *Text*
Employment	Which of the following describes your employment status best?	→ employed, full time → employed, part time → without employment, searching → without employment, not searching → studying → retired → incapable of work → other: *Text*
Income	How high is your monthly net household income?	→ less than 500 € → 500 € to less than 1000 € → 1000 € to less than 2000 € → 2000 € to less than 3000 € → 3000 € to less than 4000 € → 4000 € to less than 5000 € → 5000 € to less than 6000€ → 6000 € to less than 7000 € → 7000 € to less than 8000 € → more than 8000 € → not specified

Family status	What is your current family status?	→ married or civil partnership → widowed or civil partner deceased → divorced or civil partnership terminated → living together → living separately → single → other: *Text*
Children	How many children do you have?	→ 0 → 1 → 2 → 3 → more than 3
Sociodemographic information (Developers & organizations)		
Founding year	What year was your company (D) / organization (O) founded? Give a rough estimate if you are unsure.	*Text*
Employees	How many people does your company (D) / organization (O) employ?	→ less than 10 → 10 – 49 → 50 – 249 → 250 – 499 → 500 – 999 → 1000 – 2499 → 2500 – 4999 → 5000 – 9999 → 10.000 or more → I don’t know.
Type of business (only for O)	What type of business is your organization?	→ private → non-profit → public → I don’t know.
Sector (only for O)	Which sector does your organization belong to?	→ primary (basic production) → secondary (industry and commerce) → tertiary (service) → non-profit → I don’t know.
Turnover	How much turnover did your company (D) / organization (O) roughly generate in 2020?	→ up to 250.000 → up to 1 million € → up to 5 million € → up to 10 million € → up to 20 million € → up to 50 million € → more than 50 million € → I don’t know.
Customers (only for D)	Which of the following describes your customers and the respective projects best? More than one option can be selected.	→ private individuals (one-family homes) → companies (e.g., office and logistic buildings) → public authorities (e.g., schools, hospitals, administrative buildings) → investors

		→ others: *Text*
State	Which state is your company (D) / organization (O) mostly active in?	*List of all German states.* → in more than one state → in all of Germany
Role of sustainability	Which role does sustainability play in your company (D) / organization (O)?	*Slider from 0 (a very small one) to 100 % (a very big one)*
Sustainability goals	Has your company (D) / organization (O) set specific sustainability goals?	→ Yes → No → I don't know.
The building & R-concrete		
Residential area (only for P)	What district does or will your house be located in?	Text → I don't know (yet).
Location (only for P)	Which describes the location of your house best?	→ urban → intermediate → rural → I don't know
Familiarity R-concrete	Have you ever heard of R-concrete before?	→ yes → no → I am unsure.
Usage of R-concrete	Have you (*D:* in your company; *O:* in your organization) considered using R-concrete for the construction… … of your house? (P) … of buildings for your company? (D) … of buildings? (O)	→ Yes, and I (P) / we (D & O) will use it if possible. / Yes, and I (P) / we (D & O) have. → Yes, and we use R-concrete sometimes. *(Only for D & O)* → Yes, but I am (P) / we are (D & O) unsure. → Yes, and I will not use it. / Yes, and I have not used it. (P) / Yes, and we do not use it. (D & O) → No, I (P) / we (D & O) have not (yet). → This decision is/was not mine (P) / ours (D & O).
Barriers & drivers		
Barriers	Please rate to what extent you (O: in your department / organization) experience the following aspects as a barrier to the use of R-concrete for the construction … … of your house. (P) … of buildings. (D & O) *All barriers listed.*	*Slider from 0 (not at all) to 100 % (totally)*
Other barriers	Are there other aspects that you experience as a barrier to the use of R-concrete?	*Text*
Drivers	Please rate to what extent you (O: in your department / organization) experience the following aspects as a driving force to the use of R-concrete for the construction … … of your house. (P)	*Slider from 0 (not at all) to 100 % (totally)*

	… of buildings. (D & O) *All drivers listed.*	
Other drivers	Are there other aspects that you experience as a driver to the use of R-concrete?	*Text*
Treatment		
Information treatment (randomized half of the sample)	Please read the following information carefully. *Information presented.*	→ I have read the information carefully.
Discrete choice experiment		
Discrete choice experiment	*Explanation.* *Orientation example (different ones for P and D/O).* Which concrete would you choose? *6 choice sets with differing attribute levels (see text).*	→ R-concrete A → R-concrete B → R-concrete C → primary concrete → I cannot answer this question.
Factorial survey		
Sustainability & construction		
Construction partners (only for P & O)	How are / did you build(ing) your house? (P) / How are your buildings usually constructed? (O)	→ with an architect (P) / with external architects (O) → buying from a developer → with a general contractor → through separate tenders → differently: *Text*
Sustainability	To what extent does the following statement apply to … … you? (P) … your company? (D) … your organization? (O) In the construction of my house, sustainability is / was) an important criterion. (P) / In the construction of buildings, sustainability is an important criterion. (D & O)	*Slider from 0 (not at all) to 100 % (totally)*
Driving Force	Who is (*P:* / was) the driving force behind considering sustainability in construction of … … buildings? (D & O) More than one option can be selected. Skip this question if sustainability is / was not a criterion.	→ me / us (P) / us as developers (D) / us (the organization; O) → the architect *(only for P & O)* → the developer *(only for P & O)* → the construction company → the requester *(only for D)* → others: *Text*
Responsibility	Who do you consider responsible for considering sustainability in construction? More than one option can be selected.	→ me / us (P) / us as developers (D) / us (the organization; O) → the architect *(only for P & O)* → the developer *(only for P & O)* → the construction company → the requester *(only for D)* → the state → others: *Text*

Appendix B

Sample Descriptives

Table B1: Sample Descriptives – Developers

Target Group	**Count**	**Share**
I work at a developing company.	58	44.96 %
I am an investor and I initiate construction projects.	19	7.75 %
I am a project developer.	41	14.73 %
I work at a cooperative building company.	1	31.78 %
I am unsure whether I belong to the target group.	10	0.78 %
Total	129	100 %
Founding Year		
Min. (earlieast)	1878	
Max. (most recent)	2020	
Mean	1990	
Total	122	100 %
Federal State of Main Activity (top 3)		
Baden-Württemberg	31	27.93 %
North Rhine-Westphalia	21	18.92 %
Bavaria	20	18.02 %
Total	111	100 %
Yearly turnover		
<= 250.000 €	4	3.48 %
250.000 < x <= 1 million €	17	14.78 %
1 million < x <= 5 million €	42	36.52 %
5 million < x <= 10 million €	14	12.17 %
10 million < x <= 20 million €	15	13.04 %
20 million < x <= 50 million €	6	5.22 %
> 50 million €	17	14.78 %
Total	115	100 %
Employees		
< 10	76	59.84 %
10 – 49	33	25.98 %
50 – 249	10	7.87 %
250 – 499	1	0.79 %
500 – 999	2	1.57 %
1000 – 2499	2	1.57 %
2500 – 4999	0	0 %
5000 – 9999	2	1.57 %
> 10000	1	0.79 %
Total	127	100 %
Customers		
Private individuals (single family homes)	79	61.72 %
Organizations (office- or logistic buildings)	32	25 %
Public authorities (schools. hospitals. etc.)	8	6.25 %
Investors	59	46.09 %
Others (e.g., private individuals with apartment buildings)	26	20.31%

Total	128	100 %

Table B2: Sample Descriptives – Organizations

Target Group	**Count**	**Share**
I work in the area of construction management for an organization that is not a construction or developing company	550	88.28 %
I am unsure whether I belong to the target group.	73	11.72 %
Total	623	100 %
Founding Year		
Min. (earliest)	1090	
Max. (most recent)	2021	
Mean	1974	
Total	566	100 %
Federal State of Main Activity (Top 3)		
North Rhine-Westphalia	116	21.52 %
Baden-Württemberg	90	16.7 %
Bavaria	59	10.95 %
Total	539	100 %
Type of Business		
Private	436	72.91 %
Public	73	12.21 %
Non-Profit	89	14.88 %
Total	598	100 %
Yearly turnover		
<= 250.000 €	92	18.81 %
250.000 < x <= 1 million €	88	18 %
1 million < x <= 5 million €	74	15.13 %
5 million < x <= 10 million €	62	12.68 %
10 million < x <= 20 million €	60	12.27 %
20 million < x <= 50 million €	46	9.41 %
> 50 million €	67	13.7 %
Total	489	100 %
Employees		
< 10	176	29.48 %
10 – 49	86	14.41 %
50 – 249	209	35.01 %
250 – 499	37	6.2 %
500 – 999	36	6.03 %
1000 – 2499	29	4.86 %
2500 – 4999	11	1.84 %
5000 – 9999	9	1.51 %
> 10000	4	0.67 %
Total	597	100 %
Industry Sector		
Primary	27	4.6 %
Secondary	121	20.61 %
Tertiary	366	62.35 %
Non-Profit	73	12.44 %

Total	587	100 %

Table B3: Sample Descriptives - Private Individuals

Target Group	**Count**	**Share**
I built a house within the past 5 years.	315	37.77 %
I am currently building a house.	331	39.69 %
I am planning to build a house in the near future (ca. 1y).	188	22.54 %
Total	834	100 %
Gender		
Female	410	50.12 %
Male	400	48.9 %
Other	3	0.37 %
No statement	5	0.61 %
Total	818	100 %
Age		
18 – 25	29	3.56 %
26 – 35	430	52.83 %
36 – 45	217	26.66 %
46 – 55	79	9.71 %
56 – 65	36	4.42 %
> 65	23	2.83 %
Total	814	100 %
Education		
No degree	0	0.0 %
Certificate of Secondary Education	18	2.21 %
General Certificate of Secondary Education	67	8.22 %
Completed apprenticeship	95	11.66 %
Vocational diploma	94	11.53 %
General qualification for university entrance	112	13.74 %
Graduate degree	415	50.92 %
Other	14	1.72 %
Total	815	100 %
Employment		
Working, full time (40h)	572	70.27 %
Working, part time (< 40h)	150	18.43 %
Without employment, seeking work	1	0.12 %
Without employment, not seeking work	10	1.23 %
Retired	24	2.95 %
Incapable of work	1	0.12 %
In education, student	11	1.35 %
Other (e.g., parental leave)	45	5.53 %
Household Income		
< 500 €	1	0.12 %
500 <= x < 1000 €	3	0.37 %
1000 <= x < 2000 €	22	2.74 %
2000 <= x < 3000 €	86	10.7 %
3000 <= x < 4000 €	126	15.67 %
4000 <= x < 5000 €	213	26.49 %
5000 <= x < 6000 €	150	18.55 %

6000 <= x < 7000 €	76	9.45 %
7000 <= x < 8000 €	44	5.47 %
> 8000 €	45	5.6 %
No statement	38	4.73 %
Total	804	100 %
Marital Status		
Married or registered partnership	546	67.16 %
Widowed or registered partner deceased	2	0.25 %
Divorced or registered partnership terminated	9	1.11 %
Separated	2	0.25 %
Single	48	5.9 %
In a permanent relationship	204	25.09 %
Other	2	0.25 %
Total	813	100 %
Number of Children		
0	340	41.92 %
1	179	22.07 %
2	217	26.76 %
3	56	6.91 %
> 3	19	2.34 %
Total	811	100 %

Regarding the role sustainability plays in the developing companies, the mean indication (on a scale from 0 to 100) is 71.91 (SD: 24.72) and 41.18 % of them have sustainability goals in place. For organizations, the mean indication is at 77.03 (SD: 22.17) and around half of them (47.92 %) say they have specific sustainability goals. The difference in the role sustainability plays between developers and organizations is significant (t = 2.27, p = 0.024). Regarding the respondents' familiarity with R-concrete, 41 % of them (P: 22 %, O: 61 %, D: 63 %) stated that they had heard of R-concrete before, while 54 % did not (P: 72 %, O: 35 %, D: 33 %) and the rest was unsure. The differences in this distribution between groups are significant ($\mathcal{X}^2$ (4, N = 1465) = 237.38, p = 0.000). The majority of respondents with 72 % (P: 82 %, O: 66 %, D: 59 %) stated that they had not considered using R-concrete (yet). The respondents who had considered it before, either use it whenever possible (6 %; P: 6 %, O: 5 %, D: 3 %), use it sometimes (4 %; P: -, O: 7 %, 8 %), are still unsure (13 %; P: 7 %, O: 17 %, D: 20 %), or decided against using it (5 %; P: 5 %, O: 5 %, D: 10 %). This distribution is also significantly different between groups ($\mathcal{X}^2$ (8, N = 1108) = 79, p = 0.000).

The mean answer to the question to what extent sustainability is/was a criterion in construction on a scale from 0 to 100 is at 73 (P: 68, O: 77, D: 74) with a standard deviation of 26 (P: 26, O: 24, D: 26). The difference between private individuals and organizations is significant (t = -4.77, p = .000). The driving force behind considering sustainability that was most often selected are the respondents themselves. Choosing who they think is responsible for considering sustainability in construction, private individuals, organizations, and developers chose themselves most frequently, too. A detailed overview of the chosen driving stakeholders and stakeholders responsible for considering sustainability can be found in **Error! Reference source not found.Error! Reference source not found.**.

Table B4: Driving stakeholders and stakeholders responsible for considering sustainability from the different client groups' perspectives

We/us	**Driving**	**Responsible**
Developers	76 %	81 %
Organizations	72 %	74 %
Private Individuals	73 %	75 %
Total	73 %	75 %
The architect		
Organizations	51 %	71 %
Private Individuals	14 %	42 %
Total	33 %	58 %
The developer		
Organizations	22 %	46 %
Private Individuals	14 %	48 %
Total	18 %	47 %
The construction company		
Developers	7 %	40 %
Organizations	7 %	31 %
Private Individuals	19 %	50 %
Total	12 %	40 %
The applicant		
Developers	16 %	34 %
The state		
Developers	-	65 %
Organizations	-	58 %
Private Individuals	-	60 %
Total	-	60 %
Others (e.g.,)		
Developers	18 %	16 %
Organizations	15 %	10 %
Private Individuals	6 %	2 %
Total	11 %	7 %

Appendix C

Complete Regression Results

Table C1: Regression results for developers, organizations, and private individuals including all variables (cmxtmixlogit)

	(1) Developers	(2) Organizations	(3) Private Individuals
Price	-0.0528^{***}	-0.0536^{***}	-0.0569^{***}
	(0.00679)	(0.00331)	(0.00369)
Rec. aggregates	0.0140^{***}	0.0162^{***}	0.0118^{***}
	(0.00227)	(0.00138)	(0.00138)
CO_2-footprint	-0.0359^{***}	-0.0465^{***}	-0.0353^{***}
	(0.00525)	(0.00296)	(0.00281)

Label	1.047***	0.940***	0.893***
	(0.194)	(0.0881)	(0.0929)
ASC	3.042**	1.584***	1.369***
	(0.948)	(0.370)	(0.314)
/Normal			
sd(Rec. aggregates)	0.0112**	0.0162***	0.0184***
	(0.00348)	(0.00190)	(0.00223)
sd(CO_2-footprint)	0.0309***	0.0368***	0.0332***
	(0.00454)	(0.00302)	(0.00286)
sd(Label)	1.271***	1.036***	1.169***
	(0.239)	(0.117)	(0.137)
sd(ASC)	4.254***	2.630***	2.697***
	(0.820)	(0.396)	(0.365)
N	2744	11188	10964

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table C2: Regression results with individual characteristics in the whole sample including all variables

	Basis	
	nlogit	cmxtmixlogit
Price	-0.0398***	-0.0557***
	(0.00343)	(0.00243)
Rec. aggregates	0.0106***	-0.000907
	(0.000968)	(0.00273)
CO_2-footprint	-0.0285***	-0.0415***
	(0.00244)	(0.00203)
Label	0.733***	0.959***
	(0.0691)	(0.0651)
ASC	-1.514***	1.460***
	(0.233)	(0.232)
	R-concrete (nest)	Interaction terms with rec. aggregates
Sustainability	0.0158***	0.000146***
	(0.00181)	(0.0000333)
Familiarity	0.354***	0.00444*
	(0.103)	(0.00174)
Responsibility	0.516***	0.00312

	(0.108)	(0.00199)
N	22896	22896

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix D

Individual Characteristics – Overall Sample

Table D1: Regression results for subsamples separated based on how important sustainability is to them in construction (cmxtmixlogit)

	Sustainability	
	Less important	More important
Price	-0.0641***	-0.0462***
	(0.00381)	(0.00283)
Rec. aggregates	0.0103***	0.0176***
	(0.00112)	(0.00137)
CO_2-footprint	-0.0329***	-0.0471***
	(0.00252)	(0.00281)
Label	0.859***	1.007***
	(0.0856)	(0.0887)
ASC	1.490***	1.895***
	(0.312)	(0.407)
/Normal		
sd(Rec. aggregates)	0.0129***	0.0184***
	(0.00169)	(0.00182)
sd(CO_2-footprint)	0.0299***	0.0374***
	(0.00253)	(0.00277)
sd(Label)	1.011***	1.192***
	(0.118)	(0.124)
sd(ASC)	2.885***	2.910***
	(0.516)	(0.420)
N	11708	12804

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table D2: Regression results for subsamples separated based on their familiarity with R-concrete (cmxtmixlogit)

	Familiarity	
	No	Yes
Price	-0.0593***	-0.0502***

	(0.00346)	(0.00308)
Rec. aggregates	0.0115***	0.0166***
	(0.00119)	(0.00136)
CO_2-footprint	-0.0354***	-0.0450***
	(0.0026)	(0.00282)
Label	1.030***	0.883***
	(0.0917)	(0.0842)
ASC	1.652***	1.564***
	(0.365)	(0.301)
/Normal		
sd(Rec. aggregates)	0.0144***	0.0174***
	(0.00196)	(0.00177)
sd(CO_2-footprint)	0.0322***	0.0357***
	(0.0026)	(0.00275)
sd(Label)	1.212***	1.040***
	(0.128)	(0.114)
sd(ASC)	3.153***	2.316***
	(0.398)	(0.323)
N	11564	12560

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table D3: Regression results for subsamples separated based on their feeling of responsibility for considering sustainability in construction (cmxtmixlogit)

	Feeling of Responsibility	
	No	Yes
Price	-0.0525***	-0.0574***
	(0.00437)	(0.00287)
Rec. aggregates	0.0113***	0.0157***
	(0.00158)	(0.00113)
CO_2-footprint	-0.0315***	-0.0452***
	(0.00298)	(0.00253)
Label	0.800***	0.993***
	(0.100)	(0.0783)
ASC	1.960***	1.325***
	(0.549)	(0.257)
/Normal		
sd(Rec. aggregates)	0.0134***	0.0168***

	(0.00232)	(0.00150)
sd(CO_2-footprint)	0.0252***	0.0378***
	(0.00338)	(0.00231)
sd(Label)	0.655***	1.252***
	(0.162)	(0.101)
sd(ASC)	3.792***	2.090***
	(0.59)	(0.299)
N	5740	17920

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table D4: Regression results with the effect of client groups (nlogit)

		nlogit	
	(1)	(2)	(3)
Price	-0.0352***	-0.0400***	-0.0399***
	(0.00320)	(0.00342)	(0.00343)
Rec. aggregates	0.00949***	0.0107***	0.0106***
	(0.000902)	(0.000968)	(0.000969)
CO_2-footprint	-0.0251***	-0.0286***	-0.0285***
	(0.00227)	(0.00243)	(0.00244)
Label	0.663***	0.736***	0.733***
	(0.0647)	(0.0690)	(0.0691)
ASC	-0.0431	-1.337***	-1.567***
	(0.193)	(0.229)	(0.234)
R-concrete			
Client Groups[16]			
Developers	0.393*	0.386*	0.377+
	(0.180)	(0.194)	(0.195)
Organizations	0.332**	0.171	0.191
	(0.109)	(0.116)	(0.117)
Familiarity	0.326**	0.272*	0.268*
	(0.104)	(0.111)	(0.112)
Sustainability		0.0174***	0.0154***
		(0.00178)	(0.00184)
Responsibility			0.518***
			(0.109)

[16] Private individuals are the base category.

N	24124	22896	22896

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix E

Regression Results in the Separate Client Groups

Table E1: Regression results with individual characteristics in the sample of developers including all variables

		Developers	
	nlogit (1)	nlogit (2)	cmxtmixlogit
Price	-0.0416***	-0.0418**	-0.0525***
	(0.0116)	(0.0134)	(0.00742)
Rec. aggregates	0.0115***	0.0119**	0.249^{+}
	(0.00333)	(0.00400)	(0.132)
CO_2-footprint	-0.0281***	-0.0276**	-0.0362***
	(0.00780)	(0.00889)	(0.00614)
Label	0.874***	0.851**	0.995***
	(0.257)	(0.287)	(0.183)
ASC	0.0853	-30.83*	2.939**
	(0.798)	(12.27)	(1.124)
	R-concrete (nests)		Interaction terms with rec. aggregates
Founding year		0.0161**	-0.000120^{+}
		(0.00616)	(0.0000655)
Yearly turnover		1.604**	0.00557
		(0.505)	(0.00502)
Employees		-0.254	-0.0111*
		(0.513)	(0.00542)
Role of sustainability	-0.000283	-0.0218*	0.0000971
	(0.00783)	(0.0111)	(0.0000997)
Sustainability goals	0.503	0.757	-0.00265
	(0.431)	(0.535)	(0.00589)
N	2560	2272	2272

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E2: Regression results for developing companies separated based on their turnover (cmxtmixlogit)

	Developers	
	Yearly turnover	
	< 5 million €	> 5 million €
Price	-0.0502***	-0.0543***
	(0.0101)	(0.00944)
Rec. aggregates	0.0141***	0.0127***
	(0.00350)	(0.00350)
CO_2-footprint	-0.0298***	-0.0399***
	(0.00795)	(0.00794)
Label	0.731**	0.994***
	(0.240)	(0.259)
ASC	3.564+	2.015*
	(2.019)	(0.828)
/Normal		
sd(Rec. aggregates)	0.00931	0.0155*
	(0.00655)	(0.00614)
sd(CO_2-footprint)	0.0316***	0.0313***
	(0.00637)	(0.00918)
sd(Label)	1.068**	0.991**
	(0.371)	(0.322)
sd(ASC)	5.310+	1.704***
	(2.882)	(0.459)
N	1272	1184

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E3: Regression results with individual characteristics in the sample of organizations including all variables

	Organizations		
	nlogit (1)	nlogit (2)	cmxtmixlogit
Price	-0.0358***	-0.0354***	-0.0537***
	(0.00482)	(0.00565)	(0.00381)
Rec. aggregates	0.0116***	0.0106***	-0.0173
	(0.00158)	(0.00174)	(0.0599)
CO_2-footprint	-0.0314***	-0.0313***	-0.0492***
	(0.00417)	(0.00494)	(0.00358)
Label	0.676***	0.662***	0.957***
	(0.0989)	(0.115)	(0.103)

ASC	-0.463	-3.630^{+}	1.649***
	(0.396)	(2.206)	(0.397)
		R-concrete (nest)	Interaction terms with rec. aggregates
Type of business[17]			
Non-profit		0.489	-0.00718^{+}
		(0.372)	(0.00431)
Public		-1.096***	-0.00338
		(0.272)	(0.00587)
Founding year		0.00177^{+}	0.0000135
		(0.00106)	(0.0000292)
Yearly turnover		0.835**	-0.00349
		(0.285)	(0.00473)
Employees		-0.578^{+}	-0.000496
		(0.313)	(0.00514)
Role of sustainability	0.0103**	0.00841^{+}	0.000126
	(0.00379)	(0.00451)	(0.0000801)
Sustainability goals	-0.0669	-0.147	0.000252
	(0.182)	(0.219)	(0.00336)
N	10380	8276	8276

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E4: Regression results for organizations separated based on their turnover (cmxtmixlogit)

	Organizations Yearly Turnover	
	< 5 million €	> 5 million €
Price	-0.0465***	-0.0643***
	(0.00483)	(0.00575)
Rec. aggregates	0.0173***	0.0146***
	(0.00226)	(0.00221)
CO_2-footprint	-0.0447***	-0.0522***
	(0.00437)	(0.00509)
Label	1.020***	0.940***
	(0.134)	(0.146)
ASC	2.507**	0.869*

[17] Base category: private organizations.

	(0.857)	(0.362)
/Normal		
sd(Rec. aggregates)	0.0165***	0.0156***
	(0.00288)	(0.00285)
sd(CO_2-footprint)	0.0330***	0.0396***
	(0.00440)	(0.00508)
sd(Label)	1.009***	1.021***
	(0.173)	(0.216)
sd(ASC)	3.380***	1.702***
	(0.837)	(0.349)
N	4508	4596

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E5: Regression results for organizations separated based on their type (cmxtmixlogit)

	Organizations Type of Business Private	Non-Profit	Public
Price	-0.0530***	-0.0513***	-0.0587***
	(0.00394)	(0.00815)	(0.00784)
Rec. aggregates	0.0164***	0.0153***	0.0173***
	(0.00170)	(0.00328)	(0.00353)
CO_2-footprint	-0.0476***	-0.0387***	-0.0467***
	(0.00349)	(0.00730)	(0.00787)
Label	0.947***	1.026***	0.827***
	(0.101)	(0.283)	(0.224)
ASC	1.160***	4.979**	1.725+
	(0.351)	(1.647)	(0.928)
/Normal			
sd(Rec. aggregates)	0.0154***	0.0151***	0.0195***
	(0.00218)	(0.00326)	(0.00539)
sd(CO_2-footprint)	0.0357***	0.0354***	0.0395***
	(0.00335)	(0.00655)	(0.0107)
sd(Label)	0.949***	1.505***	0.798*
	(0.139)	(0.308)	(0.364)
sd(ASC)	1.962***	5.535***	3.426***
	(0.427)	(1.250)	(0.859)
N	8076	1564	1500

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E6: Regression results with individual characteristics in the sample of private individuals including all variables

	Private Individuals	
	nlogit	cmxtmixlogit
Price	-0.0397***	-0.0583***
	(0.00529)	(0.00382)
Rec. aggregates	0.00890***	0.0149*
	(0.00129)	(0.00333)
CO_2-footprint	-0.0234***	-0.0363***
	(0.00310)	(0.00295)
	0.672***	0.922***
Label	(0.0981)	(0.101)
	0.467	1.434***
ASC	(0.322)	(0.348)
	-0.0397***	-0.0583***
	R-concrete (nest)	Interaction terms with rec. aggregates
Male	-0.282^{+}	-0.00213
	(0.150)	(0.00259)
Age	0.113	0.00536^{+}
	(0.158)	(0.00302)
Graduate degree	0.722***	0.00610*
	(0.147)	(0.00283)
Household income	-0.392*	-0.00753*
	(0.162)	(0.00317)
Children	-0.529**	-0.00304
	(0.165)	(0.00307)
N	10108	10108

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E7: Regression results for private individuals separated based on their income (cmxtmixlogit)

	Private Individuals	
	Household Income	
	< 4000 €	> 4000 €
Price	-0.0461***	-0.0623***
	(0.00587)	(0.00468)

Rec. aggregates	0.0155***	0.0103***
	(0.00270)	(0.00159)
CO_2-footprint	-0.0257***	-0.0406***
	(0.00428)	(0.00368)
Label	1.076***	0.823***
	(0.189)	(0.115)
ASC	1.908**	1.315***
	(0.679)	(0.351)
/Normal		
sd(Rec. aggregates)	0.0181***	0.0161***
	(0.00371)	(0.00246)
sd(CO_2-footprint)	0.0278***	0.0350***
	(0.00496)	(0.00347)
sd(Label)	1.286***	1.131***
	(0.245)	(0.188)
sd(ASC)	2.806***	2.565***
	(0.685)	(0.458)
N	3204	7124

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E8: Regression results for private individuals separated based on their gender (cmxtmixlogit)

	Private Individuals	
	Gender	
	Female	Male
Price	-0.0473***	-0.0680***
	(0.00458)	(0.00581)
Rec. aggregates	0.0109***	0.0130***
	(0.00175)	(0.00209)
CO_2-footprint	-0.0318***	-0.0399***
	(0.00344)	(0.00444)
Label	1.023***	0.789***
	(0.139)	(0.130)
ASC	1.772***	1.109**
	(0.520)	(0.404)
/Normal		
sd(Rec. aggregates)	0.0143***	0.0226***
	(0.00241)	(0.00359)

sd(CO_2-footprint)	0.0279***	0.0395***
	(0.00357)	(0.00442)
sd(Label)	1.203***	1.110***
	(0.187)	(0.227)
sd(ASC)	2.594***	2.722***
	(0.693)	(0.544)
N	4912	6024

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E9: Regression results for private individuals separated based on their age (cmxtmixlogit)

	Private Individuals Age 18-35	 > 35
Price	-0.0572***	-0.0564***
	(0.00497)	(0.00532)
Rec. aggregates	0.00998***	0.0144***
	(0.00172)	(0.00223)
CO_2-footprint	-0.0319***	-0.0400***
	(0.00335)	(0.00477)
Label	0.769***	1.111***
	(0.110)	(0.167)
ASC	1.843***	0.815+
	(0.460)	(0.486)
/Normal		
sd(Rec. aggregates)	0.0169***	0.0197***
	(0.00260)	(0.00356)
sd(CO_2-footprint)	0.0291***	0.0390***
	(0.00330)	(0.00484)
sd(Label)	0.981***	1.390***
	(0.189)	(0.221)
sd(ASC)	2.883***	2.387**
	(0.533)	(0.727)
N	6064	4900

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E10: Regression results for private individuals separated based on their educational attainment (cmxtmixlogit)

	Private Individuals Graduate Degree	
	No	Yes
Price	-0.0547***	-0.0607***
	(0.00584)	(0.00462)
Rec. aggregates	0.00982***	0.0142***
	(0.00194)	(0.00197)
CO_2-footprint	-0.0309***	-0.0398***
	(0.00404)	(0.00398)
Label	0.901***	0.911***
	(0.137)	(0.133)
ASC	0.860*	1.912***
	(0.376)	(0.561)
/Normal		
sd(Rec. aggregates)	0.0163***	0.0197***
	(0.00283)	(0.00277)
sd(CO_2-footprint)	0.0333***	0.0347***
	(0.00413)	(0.00376)
sd(Label)	1.101***	1.255***
	(0.218)	(0.192)
sd(ASC)	2.549***	2.866***
	(0.523)	(0.675)
N	4552	6220

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E11: Regression results for private individuals separated based on their number of children (cmxtmixlogit)

	Private Individuals Children	
	No	Yes
Price	-0.0552***	-0.0579***
	(0.00586)	(0.00464)
Rec. aggregates	0.0112***	0.0121***
	(0.00200)	(0.00186)
CO_2-footprint	-0.0323***	-0.0371***
	(0.00395)	(0.00396)

Label	0.924***	0.860***
	(0.138)	(0.125)
ASC	1.869***	1.105*
	(0.538)	(0.456)
/Normal		
sd(Rec. aggregates)	0.0168***	0.0190***
	(0.00294)	(0.00337)
sd(CO_2-footprint)	0.0302***	0.0351***
	(0.00437)	(0.00387)
sd(Label)	1.118***	1.213***
	(0.212)	(0.189)
sd(ASC)	2.862***	2.663***
	(0.555)	(0.653)
N	4604	6360

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E12: WTP estimates of various subgroups of private individuals (based on cmxtmixlogit)

	WTP Rec. Aggregates (1%)	Lower limit	Upper limit
Gender			
Female	0.23	0.16	0.31
Male	0.19	0.13	0.25
Age			
18 – 35	0.17	0.11	0.23
> 36	0.26	0.17	0.34
Household income			
< 4000 €	0.34	0.22	0.45
> 4000 €	0.17	0.11	0.22
Graduate degree			
Yes	0.23	0.17	0.30
No	0.18	0.11	0.25
Children			
Yes	0.21	0.14	0.28
No	0.20	0.13	0.27

Table E13: Marginal effects of changes in education and income of private individuals for different shares of recycled aggregates in percentage points

	10 % rec. agg.	**55 % reg. agg.**	**100 % reg. agg.**
Graduate degree (no/yes)	+ 1.5	+ 6.6	+ 7.5
Income (</> 4000 €)	- 1.9	- 9.4	- 14.0

Table E14: Regression results for orgnaizations who value sustainability ($\geq \bar{x}$), feel responsible, and are familiar with R-concrete (cmxtmixlogit)

	Organizations (*Sust*, *Fam*, *Resp*)
Price	-0.0377^{***}
	(0.00493)
Rec. aggregates	0.0189^{***}
	(0.00262)
CO_2-footprint	-0.0523^{***}
	(0.00577)
Label	0.934^{***}
	(0.150)
ASC	2.017^{**}
	(0.741)
/Normal	
sd(Rec. aggregates)	0.0171^{***}
	(0.00271)
sd(CO_2-footprint)	0.0375^{***}
	(0.00524)
sd(Label)	0.793^{***}
	(0.210)
sd(ASC)	2.332^{***}
	(0.651)
N	3488

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix F

Robustness Checks

Table F1: Regression results (nlogit)

	Basis
Price	-0.0343^{***}
	(0.00309)
Rec. aggregates	0.00913^{***}
	(0.000862)

CO_2-footprint	-0.0244***
	(0.00218)
Label	0.631***
	(0.0613)
ASC	0.315+
	(0.178)
N	24896

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table F2: Robustness checks including all variables (cmxtmixlogit)

	Robustness Checks					
	(1) Basis	(2) DEG Time 100	(3) DEG Time 50	(4) Time RSI	(5) Finished	(6) DCE Complete
Price	-0.0551***	-0.0559***	-0.0594***	-0.0562***	-0.0555***	-0.0590***
	(0.00231)	(0.00238)	(0.00251)	(0.00238)	(0.00244)	(0.00256)
Rec. aggregates	0.0141***	0.0144***	0.0153***	0.0141***	0.0144***	0.0150***
	(0.000907)	(0.000926)	(0.00101)	(0.000923)	(0.000936)	(0.000982)
CO2-footprint	-0.0405***	-0.0412***	-0.0442***	-0.0414***	-0.0414***	-0.0436***
	(0.00192)	(0.00197)	(0.00218)	(0.00197)	(0.00204)	(0.00213)
Label	0.937***	0.920***	0.950***	0.930***	0.928***	0.953***
	(0.0607)	(0.0625)	(0.0666)	(0.0612)	(0.0645)	(0.0665)
ASC	1.632***	1.470***	1.362***	1.438***	1.601***	1.420***
	(0.232)	(0.219)	(0.217)	(0.208)	(0.226)	(0.224)
/Normal						
sd(Rec. aggregates)	0.0167***	0.0163***	0.0176***	0.0168***	0.0157***	0.0170***
	(0.00127)	(0.00134)	(0.00135)	(0.00130)	(0.00123)	(0.00133)
sd(CO2-footprint)	0.0350***	0.0353***	0.0373***	0.0350***	0.0347***	0.0359***
	(0.0019)	(0.00198)	(0.00209)	(0.00196)	(0.00201)	(0.00202)
sd(Label)	1.129***	1.099***	1.144***	1.096***	1.097***	1.174***
	(0.0833)	(0.0857)	(0.0902)	(0.0856)	(0.0895)	(0.0904)
sd(ASC)	2.784***	2.472***	2.286***	2.424***	2.498***	2.526***
	(0.187)	(0.242)	(0.236)	(0.217)	(0.240)	(0.274)
N	24896	23568	21192	23880	22388	22752

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table F3: WTP estimates for different robustness checks

	Basis	DEG Time 100	DEG Time 50	Time RSI	Finished	DCE Complete
Rec. Aggregates (1%)	**0.26**	**0.26**	**0.26**	**0.25**	**0.26**	**0.25**
Lower limit	0.18	0.19	0.19	0.18	0.20	0.19
Upper limit	0.33	0.33	0.32	0.3	0.32	0.32

Appendix G

WTP estimates for CO_2-footprint and Label

Table G1: WTP estimates for a sustainability label for the different client groups

	Developers	Organizations	Private Individuals
CSC-R Label	**19.83**	**17.54**	**15.70**
Lower limit	11.33	13.97	12.21
Upper limit	28.33	21.11	19.20

Table G2: WTP estimates for saving a kg of CO2-emissions for the different client groups

	Developers	Organizations	Private Individuals
WTP CO_2-footprint (1kg)	**0.68**	**0.87**	**0.62**
Lower limit	0.48	0.75	0.53
Upper limit	0.87	0.98	0.71