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The role of alternatives to primary aggregates in reducing emissions from the construction sector

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1 Executive summary

1.1 Aims

Scotland's construction industry relies heavily on traditional primary aggregates. Lower carbon alternatives such as recycled concrete and incineration bottom ash aggregates are gaining traction. Innovations in recycling technology have improved the feasible quality and consistency of alternatives to primary aggregates, leading to greater acceptance among contractors and suppliers.

This study seeks to investigate the availability of alternatives to primary aggregates and analyse barriers to their uptake through literature review, data collection and stakeholder engagement. We also provide four case studies of where alternatives to primary aggregates have been used in Scotland.

1.2 Findings

We have found that alternatives to primary aggregates can reduce greenhouse gas emissions significantly, with local sourcing further amplifying these benefits. However, logistical and supply chain challenges may limit these benefits when transportation distances exceed certain thresholds. As such, while there are promising pathways for the increased use of alternatives to primary aggregates in Scotland, strategic actions would be required to address existing barriers and to support the transition towards a more sustainable construction sector.

There are three key interrelated challenges to facilitating increased deployment of alternatives to primary aggregates in Scotland. These are technical viability and infrastructure, standards and market demand, and data availability.

- **Technical viability and infrastructure:** Technical viability of alternatives to primary aggregates is improving. Investment in construction and demolition waste (CDW) infrastructure in Scotland has led to improvements in the purity and quality of alternatives to primary aggregates over the last 10 years. Advanced CDW recycling facilities are prevalent across the central belt, but their reach is limited in rural areas due to logistical and operational challenges, limiting uptake in these regions. Similar to the primary aggregates market, the market for alternatives is characterised by low profit margins, with producers of alternative aggregates also facing high investment costs for the development and expansion of recycling infrastructure. Stakeholders proposed incentivising recycling of recovered flat glass from construction and demolition projects through collaboration with the Scottish food and drink sector.

- **Standards and market demand:** Some stakeholders suggested updating procurement specifications and regulations to reflect the advances in recycling technology noted above. Broader use of alternatives to primary aggregates is restricted by industry standards and related concerns regarding structural performance. Clients are generally risk-averse and influenced by uncertainties in technical performance quality. This limits market demand. Demand for alternatives to primary aggregates is also limited by competition from traditional materials.

- **Data availability:** Although aspired to in this study, it was not possible to meaningfully forecast the availability of alternatives to primary aggregates. Low engagement generated limited responses and did not provide a representative dataset of material availability. Without more consistent and granular data, it is not possible to derive a robust definition of the volumes of materials available. That data is not systematically collected and stored as there is no real regulatory or client-led requirement for it, related to the points above. Evidencing the potential for adequate technical performance is difficult when the existing standards are thought by some to not fully reflect what is possible with modern processing techniques. It is difficult to make the business case for investment in a review and potential revision of standards without understanding the potential scale of environmental and economic impact, which is related to the need for more data.

In the context of the Scottish Aggregates Tax and other potential fiscal initiatives, there are two headline takeaways from this work:

- Until robust and reliable Scotland-specific data on volumes of alternatives to primary aggregates is collected, any perceived benefits of tax rate changes will be somewhat speculative.
- Potential subsidies for alternatives to primary aggregates are considered here at high level. Further work would be required to conduct a thorough assessment of the viability of any such scheme, which would, again, necessitate much more complete data than is currently available.

1.3 Further research

We have learned lessons that could inform future research:

- Forecasting the availability of alternatives to primary aggregates in the Scottish construction sector is limited by significant data gaps that prevents meaningful baselining of their use.
- Any future studies should factor in a longer data collection period to improve response rates.
- A technical review of existing standards could be conducted to assess the feasibility of updating the current suite of industry standards to reflect advancements.
- Feasibility studies should assess the expansion of infrastructure to rural regions.

Contents

Abbreviations

Abbreviation	Definition
CDW	Construction and Demolition Waste
CXC	ClimateXChange
CO_2	Carbon Dioxide
GHG	Greenhouse Gas
GWP	Global Warming Potential
LCA	Lifecycle Analysis
MCI	Material Circularity Indicator
RC	Recycled Concrete
SATBAG	Scottish Aggregates Tax Bill Advisory Group

Table 1: Glossary and abbreviations used during report

2 Introduction

2.1 Study context and aims

The Scottish Government has set the target for Scotland to reach Net Zero carbon emissions by 2045, laid out in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 (Scottish Goverment, 2019). To meet this target, they understand that GHG reductions must be made across a number of sectors, including the construction sector, which is widely estimated to generate around half of all of Scotland's waste (Scottish Government, 2024).

In 2023, the Scottish Government commissioned Circle Economy, an international circular economy research body, to map the flow of materials throughout the Scottish economy. The aim of the work was to identify how circular approaches could generate economic benefits and reduce the environmental impacts of waste and material consumption. Their research, among several recommendations, suggests that adopting circular approaches to construction, such as prioritising the use of alternatives to primary materials and aggregates, has the potential to deliver an 11.5% reduction in Scotland's emissions (Circle Economy, 2023).

To support this aim, the Scottish Government is considering how the Scottish Aggregate Tax can incentivise the use of alternatives to primary aggregates by imposing a tax on the extraction and use of primary aggregate materials. This comes at an opportune moment, as the Scottish Aggregates Tax is expected to go-live in April 2026, and is set to become the third fully devolved tax in Scotland, after the Land and Buildings Transaction Tax, and the Scottish Landfill Tax. It will replace the existing UK-wide Aggregates Levy in Scotland through charging a tax on the use of aggregate when it becomes subject to commercial exploitation in Scotland and will be administered by Revenue Scotland.

However, the evidence base for the significance of the role that alternatives to primary aggregates can play in reducing the environmental impact of the Scottish construction industry is not currently sufficiently robust. There has been no systemic data collection focussing on supply versus demand for alternatives to primary materials in Scotland, and therefore the full extent of the potential environmental impact is unknown. There is also uncertainty about how much more deployment of alternatives to primary aggregates is possible and what the potential options are to overcome the barriers to this ambition.

This study aims to develop a fuller understanding of the types, development levels, and potential impact of alternatives to primary aggregates, and the barriers to their increased use in Scotland. It focuses primarily on aggregates used within the construction industry, which are understood as granular building materials, primarily comprising of sand, gravel, and crushed stone and rock. They are often produced through the crushing, screening, and extraction processes within quarries, or produced as a by-product from demolition practices. While they play a critical role in construction projects, forming the basis of concrete, asphalt, and other materials, their use is not exclusively limited to this industry.

Our work included a review of available industry and academic literature on the subject, an investigation into the availability of relevant primary quantitative data, and a series of stakeholder engagement interviews and surveys. The combined insights from these activities are summarised in this report and draw learnings for policymakers to consider in

the further development of the Scottish Aggregate Tax. The methodology followed is discussed in more detail in Appendix A.

2.2 Traditional primary aggregates use

In Great Britain, approximately 250 million tonnes of aggregates are used annually within the construction industry, with an additional 20 million tonnes in Northern Ireland. Scotland plays a vital role in the UK's aggregate supply chain, both as a significant producer and consumer of materials. In 2022, Scotland produced 21.3 million tonnes of crushed rock, accounting for a substantial share of the UK's total, alongside 4.5 million tonnes of sand and gravel. Additionally, the country produced 1.2 million tonnes of ready-mixed concrete (around 500,000m^3), and 2.5 million tonnes of asphalt. Infrastructure projects dominate Scotland's construction sector, comprising 22% of output and demonstrating a heavy reliance on aggregates (Mineral Products Association, 2024)

The push for sustainable practices in construction has led to growing interest in viable substitutes for traditional primary aggregates. Historically, primary aggregates, sourced from natural materials like rock, granite, and gravel have dominated the market due to their reliability and robust characteristics. Commonly used in applications such as house building and road development, these virgin materials are often chosen by contractors and developers for their proven durability and performance. However, the environmental costs associated with extracting and processing these carbon-intense materials, including significant GHG emissions and the depletion of finite natural resources, present the need for alternative solutions, some of which are set out below.

2.3 Alternatives to primary aggregates in Scotland

In 2021, recycled and secondary sources supplied 28% of total aggregate demand, while the remaining demand was fed from primary aggregate extraction in the UK (Mineral Products Association, 2022).

While there is no definitive categorisation of the different materials which may be classed as 'alternatives to primary aggregates', in this project we apply the following broad understanding:

- Recycled aggregate: Construction and demolition waste (CDW) that has been processed into usable aggregate.
- Secondary aggregate: Materials derived from the process of extracting aggregate or other industrial processes.

The availability of alternatives to primary aggregates plays a critical role in the successful uptake of sustainable materials in the construction sector. Through desk-based research and stakeholder engagement, it was found that there are a range of suppliers actively producing alternatives to primary aggregates in Scotland. The most commonly produced alternatives were found to be:

- Recycled concrete (RC) and washed recycled sand, which are primarily used in building and housing construction applications
- Incineration bottom ash aggregate (IBA), and
- Recycled asphalt plannings which are typically deployed into road construction and infrastructure developments.

2.4 Case Studies

Provided alongside this report are four case studies of project examples where alternatives to primary aggregates have been used in Scotland. These are:

- Case Study 1 - Using alternatives to primary aggregates to extend full fibre broadband across Scotland.
- Case Study 2 - Incinerator Bottom Ash in low-carbon concrete for housing development.
- Case Study 3 - Treatment of hazardous soil and use of by-products for secondary aggregates.
- Case Study 4 - Sustainable development of the haul road to the East Capellie Recycling Wash Plant.

These case studies demonstrate some of the technical innovations and viability points discussed in Sections 3.1 and 3.3. They also highlight some of the outstanding challenges to stimulating wider replication of the examples discussed, such as a lack of publicly available externally verified full environmental impact calculations, and the lack of firm data on available volumes of the alternative materials discussed. These challenges, among others, are discussed in detail in Section 3.4.

3 Findings

In this section we present the combined outputs and insights from our literature review, stakeholder engagement, and data collection exercises, organised into general learning themes. Examples of how the themes explored here can impact specific businesses are illustrated in within the Case Studies referenced in section 3.4.

3.1 Factors driving uptake of alternatives to primary aggregates

During our stakeholder engagement, representatives of Scottish wash plants and producers of construction materials reported that attitudes to alternatives to primary aggregates have changed significantly over the last ten years. While all stakeholders agreed that there will always be demand for primary aggregates, recent innovations demonstrate that alternatives can now be used effectively in more cases than were previously possible.

Factors driving uptake of alternatives to primary aggregates, as discussed in our interviews, include technical innovations and changing attitudes, explored below.

3.1.1 Technical Innovations

There has been significant investment in development of advanced CDW recycling infrastructure across the central belt of Scotland over the last 10-15 years. Interviewees cited an increase in the number of CDW recycling sites equipped with wash plants, multiple crushers and screening technologies which allow for the removal of contaminants and impurities that can negatively impact the strength of concrete produced from recycled aggregates. This is an advancement on mobile crushing plants traditionally used for the management of CDW, which typically involve single crushing and minimal equipment for the removal of unintended constituents (Pacheco & Brito, 2021). Interviewees felt that these

innovations have led to a significant increase in the quality and consistency of the recycled aggregates that can be produced. This view was supported in the interviews by a manufacturer of primary aggregates, a quarry and three operators of CDW recycling and wash plants. Examples of the improved technology are discussed in Case Study 4, provided alongside this report.

When producing concrete, key manufacturers, wash plants and major contractors, are now able to benchmark performance, and grade- and cube test alternatives to primary aggregate. The introduction of these new technologies allows them to understand the compressive strength, relative density and overall quality. Concrete cube testing is an essential process for assessing whether a product meets necessary safety standards and regulatory requirements, and whether they are suitable for different applications within construction. As a result of innovations in wash plant, screening and recycling technologies, these stakeholders are able to produce concrete from alternatives to primary aggregates that are able to meet similar standards and specifications to primary aggregates. This expands the scope of where these materials can be applied.

3.1.2 Changing attitudes

It is acknowledged that the development of Net Zero infrastructure and renewable energy projects, will require a significant increase in concrete production. For some stakeholders, this represented a potential opportunity for greater use of recycled and secondary aggregates. While the rapid growth of renewable energy infrastructure has the potential to reduce overall CO_2 emissions, research has indicated that the increased demand for high impact materials, such as steel and concrete which both have significant carbon footprints, may undermine the environmental benefits of this infrastructure unless otherwise mitigated (Rueda-Bayona, et al., 2022). An interviewed manufacturer of primary aggregates and construction materials noted that they expect this to expand the portfolio of projects where alternatives to primary aggregates may be applied, provided that sufficient quality assurance and standards are in place. They noted that where they had the assets and the capability to supply alternative aggregates, these were being used in nearly every case due to demand from clients motivated by Net Zero targets, such as Tier 1 infrastructure contractors[1], Local Authority or residential clients.

Interviewees also noted that attitudes have been shaped by the negative impacts COVID-19 and Brexit had on the supply of construction materials. Following the easing of lockdown in 2022, construction projects and demand for construction materials surged. These events created scarcity in the availability of construction materials, particularly cement, leading to fluctuations in prices and long lead-in times for primary aggregates. Due to significant shortage of construction materials and significant lead-in times and costs associated with procuring these materials, Tier 1 infrastructure and housebuilding projects looked to recycled/recovered construction materials to fill the gap. Practical experience with recycled aggregates helped to dispel concerns regarding the quality and practical application of recycled materials.

[1] Large construction companies that generally manage the entire construction process for a project, often employing sub-contractors as part of the project delivery team.

3.2 Environmental impact

The construction sector is the world's largest consumer of raw materials. According to UNEP and the World Research Institute, buildings account for 40% of all waste generated by volume, 40% material resource use by volume and between 33-37% of all GHG emissions (World Resources Institute, 2016) (UNEP, 2023). In addition, the extraction of primary aggregates, such as rock, sand and gravel generate significant environmental impacts on local biodiversity and habitats. Open-pit mining necessitates the removal of topsoil and vegetation to access the materials that lie beneath. In the UK, up to 22% of sand and gravel is extracted from marine dredging (Mineral Products Association, n.d.). Whilst controlled and responsible marine aggregate extraction would always seek to minimise adverse impacts, there is widely accepted potential for harm to marine habitats from aggregate extraction (United Nations Environment Programme Finance Initiative, 2022). Both activities generate severe negative impacts on animal and plant species and can contribute to sedimentation and erosion of riverbanks and coastlines (UKGBC, 2025).

There is a growing body of evidence that alternatives to primary aggregates can deliver improved environmental performance compared to traditional materials, particularly offering a lower carbon output. Through a rapid review of the literature, we found evidence on lower emissions associated with carbon-reinforced RC industrial flooring (Luthin, et al., 2023), recycled aggregate concrete (Hasheminezhad, et al., 2024) and concrete mixes (Adesina, 2020).

In a study carried out by Luthin (2023), the sustainability performance of a carbon-reinforced RC industrial floor was measured and assessed during its development using the Material Circularity Indicator (MCI) and Life Cycle Assessment (LCA) methods. These tools were used to evaluate both recycled and virgin materials, respectively. Linear resource flows refer to the traditional approach of resource use, where materials are extracted, used, and then discarded as waste, with minimal or no reuse properties. In contrast, circular resource flows aim to extend the lifecycle of materials by prioritising, reuse, recovery, and recycling, reducing the need for virgin material extraction and waste generation.

The study carried out by Luthin (2023) investigated and analysed the recyclability of a floor that that was produced with an RC mixture as the foundation material for an industrial floor, this was then measured and evaluated upon its strength, performance, and carbon profile. The LCA showed that the reinforced RC industrial floor outperformed traditional concrete in environmental performance, achieving a lower Global Warming Potential (GWP). It was shown that the GWP for producing 1 tonne of RC flooring had an equivalent of 80.3 kg CO_2, compared to 195 kg CO_2 equivalent for 1 tonne of precast slabs (Luthin, et al., 2023).

Additionally, the MCI assessment found that the circular performance reflected a similar result, with the reinforced RC floor accounting for a notably high MCI score of 0.8184 (82%) (with a score of 0 being completely linear, and 1 being completely circular). This score reflects the significant use of recycled materials in its production and the potential for further recycling at the end of its lifecycle. In comparison, a new concrete floor composed entirely of virgin materials would score close to 0 on the MCI scale, as it would rely entirely on linear resource flows, using new raw materials with little to no recycling or reuse involved. The MCI score of 82% demonstrates how effectively the RC floor minimises the use of virgin resources and maximises the use of alternatives. Results like this, however, should be read in conjunction with other aspects of the compared materials. For example,

this study also found that the RC floor would be more expensive to install, and has higher levels of human toxicity than the precast slab option. This highlights that all material choices should be made based on as full a consideration of all factors as possible.

This assessment is supported by Hasheminezhad (2024) who conducted a similar study, reviewing the LCA and environmental performance of RC in comparison to traditional concrete materials. The study aimed to assess and highlight the GHG emissions and energy consumption associated with the entire lifecycle of concrete resources. This included evaluating the impacts across all phases of its use, including material extraction, production, transportation, usage, and end-of-life management (Hasheminezhad, et al., 2024). The study found that recycled aggregate mixtures of concrete do require marginally higher quantities of energy and cement than primary aggregates. This is often required to compensate for the lower strength and higher water consumption of the recycled materials involved. However, the research underlined the substantial environmental benefits of using recycled aggregate mixtures due to lower carbon emissions, especially when the recycled aggregates are sourced locally. This is due to the use of recycled materials significantly reducing the demand for virgin resources, such as natural sand and gravel, while also diverting CDW from landfills, both of which produce significant associated GHG emissions.

The Hasheminezhad et al. (2024) study also highlighted the GWP differences between the two concrete materials, showing that the GWP of RC was lower by up to 15% compared to natural aggregates, particularly when recycled aggregates completely replaced all natural components within the concrete mix. The whole life assessment outlines the importance and influence of energy consumption generated through extraction and transportation practices. With a particular focus on the value-chain of the resource and the importance of locally sourced materials, embodied emissions are a critical factor when assessing the carbon reduction potential of alternative materials. Embodied emissions relate to the GHG emissions associated with a product or material across its entire life-cycle, including sourcing and processing of the materials, and eventual end-of-life treatment. Therefore, these comparisons should factor all impacts associated with extraction, use and disposal.

The importance of reducing emissions in the transportation of aggregates is also highlighted in a review by Adesina (2020). The report recognises the potential for all aggregates to improve their carbon impact, and the major role in emissions profiles of cement content levels. They also note that the construction industry has made steady and effective progress in reducing emissions throughout the lifecycle of concrete mixtures by prioritising the extraction and efficient use of locally sourced aggregates. By adopting a more strategic approach to the processing and transportation of recycled aggregates, the industry can continue to effectively address and mitigate the challenge of high embodied carbon emissions (Adesina, 2020). This potential was emphasised by several of the stakeholder interviewees for this study as an important contributor to Scotland's overall environmental ambitions.

It is also important to consider the environmental impacts generated through the transport of primary and alternative aggregates from their point of extraction or production to their point of use. As discussed in sections 3.1.1 and 3.4.4, wash plants for the recycling aggregates are heavily concentrated in the central belt of Scotland. Therefore, the logistical feasibility of supplying recycled or alternative aggregates is limited by distance, as after a certain distance, it becomes uneconomical to supply these materials via truck due to transportation costs. Similarly, after a certain distance, the environmental benefits of

alternatives to primary aggregates are outweighed by the emissions generated through transport.

The outcome of an LCA assessment of CDW recycling completed by Ricardo in 2021 for Natural Resources Wales[2] found that delivery distances of more than 34km from originating site resulted in higher GHG emissions than were saved from the substitution of virgin materials. This break-even distance will increase as transport is gradually electrified and the electricity grid becomes less carbon intensive. This underlines the point that thorough LCA analysis is the only way to accurately reflect the environmental impacts, positive or negative, of any business decision.

3.3 Technical viability

3.3.1 Academic discussion

As discussed in the challenges section 3.4 below, there is a widely held perception that recycled or secondary materials can struggle to meet performance requirement standards. Whilst this will clearly be true for some materials, it is not the case for all, and it is important to be able to demonstrate successful use with technical data (Dhemaied, et al., 2024). There is a body of research which focusses on strength, durability, and workability of CDW-derived aggregates in infrastructure projects, with many studies showing promising results for specific applications. Examples are discussed below and in the case studies provided alongside this report.

Recycled sand can replace natural sand in certain construction contexts without compromising quality. In the Virgin Media O2 project under Scotland's Full Fibre Charter (Scottish Government, 2022b), sand aggregate derived from CDW was successfully used in telecommunications infrastructure, highlighting the role recycled sand can play in sustainable resource management. Case Study 1 provides more information on this example.

Alternatives to primary aggregates have shown strong potential in asphalt applications, particularly for road construction. The UK's first carbon-neutral road improvement project employed recycled asphalt aggregate to reduce its carbon footprint significantly (Scottish Construction Now, 2021). Additionally, Tarmac's biogenic asphalt deployed in this project uses plant-based binders with recycled aggregate to achieve effective carbon capture, reducing reliance on petroleum-based materials. This innovative approach demonstrates the potential for CDW aggregates to maintain or enhance the mechanical properties needed for asphalt in road applications, supporting a low-carbon, sustainable future for Scottish road infrastructure (Tarmac, 2023).

RC is a sustainable construction material, primarily produced as a by-product from construction and demolition activities. It is composed of crushed concrete from structured components such as buildings, roads, and pavements, which is then sorted, cleaned and crushed into aggregate (typically between 2-4mm in diameter). Several studies, as discussed below, confirm the technical feasibility of using CDW-derived aggregates in low-carbon concrete formulations, meeting performance criteria for infrastructure applications while promoting sustainability. According to a review conducted by Han *et al.* (2023), suitably

[2] Unpublished internal report

treated RC can act as a sufficient alternative for virgin concrete materials, with strategic adaptations to mortar content and density in recycled aggregates presenting durability and mechanical benefits to the material. This review highlighted that pre-treatment processes, such as the combined usage of lime soaking and carbonation[3], can also improve the performance and properties of RC within construction. This is both supported and tempered by Thomas *et al*. (2018), who conducted a performance analysis review measuring the technical feasibility of RC, covering parameters such as the strength and permeability of concrete mixed with recycled materials. The review found that while recycled aggregates show great potential in being a suitable alternative to virgin materials, the strength can be compromised should RC aggregate content exceed 25% of the overall material. However, the review explains that this can be adapted through modifications in the concrete mix design phase, which would be necessary to address changes in the material's physical and mechanical properties.

3.3.2 Stakeholder opinion

Amongst the stakeholders interviewed for this study, there was broad agreement that the use of alternatives to primary aggregates has been limited due to concerns among construction companies and potential customers regarding quality and consistency in supply of the materials. It was felt that prior experiences, where the quality of materials used had not delivered the required final functionality, have led to clients being wary and sceptical of specifying for anything other than primary aggregates.

Discussion of the current and future situation, however, revealed a mix of viewpoints. There were several reiterations of the opinion that, beyond uses such as landscaping and backfill of drainage and cable trenches, virgin stone will always be preferable to clients. On the other hand, one producer of both primary and recycled aggregates felt that there has been more market acceptance of recycled products over the last four years. As discussed in section 3.1, this has been driven through the normalisation of alternatives to primary aggregates seen during the COVID-19 pandemic and resulting supply chain difficulties, alongside growing recognition of the fact that modern wash plants can produce very high purity output materials. One producer gave an example of a road construction project on their own site, using entirely recycled materials, which has seen 15,000 truck-loads, conveying 0.5M tonnes of materials, without any quality issues (please see Case Study 4 for more detail). This supports the summarised views from the literature discussed above. While there will continue to be the possibility for impurities and deleterious material to be present in alternatives to primary aggregates, it is not correct to assume this is always the case. It was felt amongst some stakeholders that, were robust testing and certification procedures in place to demonstrate how alternative materials comply with industry quality standards, there would be more comfort in their use for a wider range of applications.

These technical considerations, alongside potential environmental and economic benefits, play a critical role in shaping perceptions. Early involvement of client and design stakeholders in planning and decision-making processes is crucial for addressing specific

[3] Saturating in limewater to introduce calcium into the material, thereby augmenting the carbonation reaction in which CO_2 in the atmosphere is diffused into cement-based material to react with CH and form calcium carbonates. Results in enhanced strength and durability.

concerns about the material's use, while effective communication strategies are essential for securing support from both public and private sector clients and project sponsors.

3.4 Challenges and barriers to the increased uptake of secondary and alternative aggregates

As part of the movement to incentivise the development of sustainable practices within the construction sector, the broader adoption of non-virgin materials relies not only on their availability and relative demand, but also overcoming several barriers and challenges within the industry. The challenges identified through this study, and highlighted in the separately provided case studies, are categorised and discussed below, along with some initial ideas for options to begin tackling them.

3.4.1 Data challenges

The most significant barrier to developing a full understanding of what is both possible and practical is the lack of availability of robust quantitative data on alternatives to primary aggregates in Scotland. One of the initial ambitions of this project was to forecast the potential contribution to GHG reduction targets of an increase in use of recycled or secondary aggregates in the Scottish construction sector. To calculate this, primary data was sought from key producers and sources of alternatives to primary aggregates in Scotland, including established quarries, wash plants and demolition and excavation companies. The aim was to gain a baseline of annual sales in Scotland. This collated dataset would form a baseline of the potential supply of alternatives to primary aggregates, which would then be mapped against expected demand forecasts, both geographically and volumetrically, to calculate a proportion of how much forecast demand could be met. To calculate the GHG emissions associated with these volumes of secondary and recycled materials, we planned to apply GHG emission factors sourced from various standard approaches.

During the data collection phase, a simplified data collection form was sent to 36 suppliers of primary, and alternatives to primary, aggregates and demolition and excavation companies to request data on the types and volumes of materials sold annually. The research team conducted three rounds of emails and two follow-up calls to each identified supplier over a two-month period to request their participation in the study. Engagement with industry stakeholders was supported by ClimateXChange and members of the Scottish Aggregate Tax Bill Advisory Group (SATBAG).

Despite a large number of suppliers being contacted, the research team received minimal complete responses. There were several reasons for this, including:

- Contacted suppliers had limited capacity to provide the requested data due to resourcing constraints or competing deadlines.
- Contacted suppliers were concerned about potential commercial sensitivity in sharing the data.
- Contacted suppliers did not see the commercial value in participating in the study, despite the relevance of the Scottish Aggregate Tax.

As a result, the limited primary data collected would not have been representative or robust enough to form a baseline for forecasting the future supply potential of alternatives to primary aggregates. Therefore, in agreement with ClimateXChange and the Scottish Government, the efforts to develop a GHG reduction forecast were discontinued and replaced by a focus on stakeholder interviews.

The challenge, and importance, of data availability regarding volumes of recycled and alternative aggregates was reiterated throughout our stakeholder interview phase. This interview phase incorporated four suppliers of recycled and alternative aggregate products contacted during the data collection, and seven public sector, industry and regulatory bodies. The purpose of these interviews was to gain in-depth insights into the key challenges facing the uptake of recycled and secondary aggregates (see Appendix A for further details).

During these interviews, it was noted that data availability inhibits the sector's ability to forecast the potential environmental benefits of incentivising these alternative aggregates. It also limits understanding of what is possible and practical to aim for when considering the question of supply versus demand. There was a general consensus across the stakeholders interviewed that understanding the volumes available in the secondary market is key, but that such understanding does not currently exist at a sufficient level of accuracy. The difficulty was highlighted as particularly prevalent in Scotland, where interviewees noted suppliers are not used to being surveyed annually. While it is understood that the British Geological Survey is conducted every four years (e.g., in 2019 and 2023), the granularity of detail regarding the origin and characterisation of primary, recycled and alternative aggregates is not particularly well-defined.

To address this challenge, a systematic and robust data collection and reporting mechanism would enable confident, evidence-based decision making, both for Government and for industry members. Ideally, it should provide sufficient granularity to develop a quantitative local authority-level understanding on CDW arisings and volumes of alternatives to primary aggregates produced, stored and sold. Such a system would be complex and expensive to design and implement. The possibility of successful deployment would be maximised through collaborative public-private development.

3.4.2 Potential limited scope for increased use of alternatives to primary aggregates.

In contrast with the potential positive environmental impact and technical viability of alternatives to primary aggregates, is the belief of some stakeholders that there is minimal scope for a significant increase in their use. The potential for increased use of alternatives to primary aggregates needs to be balanced between what is possible and what is practical. The Mineral Products Association's report, *Aggregates demand and supply in Great Britain: Scenarios for 2035* (2022), posits that recycled and secondary aggregates are unlikely to meet projected demand in alignment with construction trends. This is due to the bulk of their supply being directly tied to demolition activity, and the fact that most suitable CDW is already being reused.

This sentiment was backed up in some of our interview conversations with sector bodies. They asserted that, in their estimation, 90% of recoverable CDW is diverted from landfill already and therefore opportunities for significant increases in recycled content are limited beyond incremental improvements. Indeed, the point was made by several interviewees

that no-one in any industry likes unnecessary cost and waste, so for many years materials have been reused or repurposed on-site where possible to save costs. As such, construction sites have been adopting the principles of circularity without necessarily reporting it as such. Counter to this, among other stakeholders interviewed with experience in recycled aggregate production, and CDW management in general, there was the opinion that there is still potential for an increase in CDW diversion from landfill. One interviewee confirmed from direct experience that they could easily divert a lot more CDW from landfill and that they have the latent site capacity to process it into recycled aggregate. The only reason this is not done at present is that market demand is not sufficient to warrant the additional processing cost. Another interviewee noted that they have been able to significantly increase capacity since opening their first wash plant in 2017. In this time, they have developed facilities able to handle a much dirtier feedstock and process up to 300,000 tonnes per year at a rate of 150 tonnes an hour.

Addressing the data challenges discussed in Section 3.4.1 should provide clarity on how much scope there is for increased use of alternatives to primary aggregates. If there is found to be additional capacity, then efforts could be made to stimulate demand. These could include championing the role of alternatives to primary aggregates in meeting Net Zero targets through building or collating an evidence base of verified LCA studies or reports which demonstrate positive environmental impact when deployed appropriately.

Another significant opportunity to incentivise the use of alternatives to primary aggregates is through leading-by-example. Through public-sector procurement of relevant projects, mandates and design briefs could be developed to stipulate for, or give appreciable scoring consideration to, the use of alternatives where safe and technically appropriate to do so. The re-released Net Zero Public Sector Buildings Standard (2023) provides an example of how an initiative like this could be developed. While it does provide an embodied carbon (i.e. the emissions embodied in the materials used and construction activities themselves) target for new buildings, it is voluntary and does not stipulate specific measures or materials (Scottish Government, 2023). Opportunities to work within this existing framework, or via other public procurement or planning routes, could be explored and developed.

3.4.3 Challenges due to industry standards

A key factor limiting the uptake of recycled and alternative aggregates was found to be restrictions imposed by industry standards, which are then cascaded into procurement specifications. These established standards are instated to ensure safety, durability, and performance. These standards are designed to regulate the properties and quality of both natural and recycled aggregates across various applications. Key standards are listed in Table 2**Error! Reference source not found.**, below.

Standard	Relevance:
BS EN 12620	Aggregates for concrete, outlining requirements for materials used in concrete production.
BS EN 13242	Aggregates for unbound and hydraulically bound materials, applicable to civil engineering work and road construction.
BS EN 933	Test methods for geometric properties of aggregates, covering particle size, shape, and other physical attributes.
BS 8500-2	Complementary to BS EN 206, this specifies additional requirements for aggregates in UK concrete applications.

WRAP Quality Protocol	Governing the performance standards for recycled aggregates, ensuring their safe and reliable use.
PAS 2050	Focused on assessing the carbon footprint of recycled aggregates.
BS EN 13108	Aggregates for bituminous mixtures, regulating reclaimed asphalt pavement (RAP) for road surfacing and structural layers.
EA Quality Protocol for IBAA	Specific to Incinerator Bottom Ash Aggregate, ensuring environmental safety and suitability for reuse in construction.

Table 2: Key standards relevant to recycled and natural aggregates

It is important to note that these standards have been developed to ensure the structural integrity, durability and safety of built infrastructure. Any increases to these thresholds must be evidence-based, appropriate for the product's application, and supported by industry-wide consultation. These limits have been established due to well-grounded concerns regarding the potential of deleterious and contaminant materials making their way into recycled feedstock, which may compromise the safety of the structures. In addition, it was broadly acknowledged by all stakeholders interviewed that while recycled and secondary aggregates have many good properties, they will not fully replace demand for virgin aggregates, which will still be required for some applications. Nonetheless, there was concern among producers of recycled and secondary aggregates that existing standards and testing regimes no longer reflect the potential quality and performance characteristics of alternative aggregates produced through modern recycling techniques. While industry standards for the use of aggregates set an upper threshold of 30% of recycled content rate within concrete, some stakeholders reported confidence in the potential of increasing this upper limit without compromising the structural integrity of the concrete produced. If a concrete product contains a recycled aggregate content higher than this threshold, they can only be sold as an unspecified product and as such will not meet procurement specifications.

The feeling from interviewed producers of both primary and recycled or secondary aggregates is that these limitations may restrict market demand. This issue is compounded by the fact that, largely, project specifications require aggregates to meet specific quality and industry standards for which it is difficult for recycled and secondary aggregates, and secondary aggregate containing products such as RC, to demonstrate full compliance. It was noted during the interviews that a lack of relevant standards reflecting current industry practice for alternatives to primary aggregates may contribute to concerns around potential liability if a fault occurs following completion of a project. As a result, engineers and planners may be less inclined to approve these materials for use, and contractors and procurers may not integrate these materials into contracts and structural drawings. Nonetheless, while there was broad agreement that under the current suite of industry standards it is not possible to accurately test the suitability of non-primary material for some structural works, standards and testing regimes do exist to assess the suitability of these materials for non-structural works, such as pipe-bedding, cable laying and landscaping works.

Moreover, stakeholders noted that alternatives to primary aggregates are often not explicitly included within procurement specifications for public or private construction projects. This has the effect of limiting market demand. It is possibly due to a lack of appropriate standards and testing regimes to discern between high-quality and low-quality alternatives to primary aggregates, which for some stakeholders may contribute to misconceptions regarding the perceived risk of using recycled aggregates. In some cases, it

was noted that if procurement specifications require a certain percentage of "recycled content" to be used, contractors may feel more comfortable fulfilling this requirement with lower-impact materials used for furnishings (e.g. wood, polypropylene, vinyl flooring), rather than with aggregates, which may deliver greater reductions in GHG emissions.

Almost all stakeholders agreed that the experience of having low-quality recycled aggregate on the market has contributed to misconceptions regarding the purity and performance achievable through innovative modern technological processing techniques. However, significant investment has recently gone into development of quality control processes and technologies to remove contaminants and increase the purity, and therefore quality, of outputs. This improvement and development has thereby expanded their potential uses for other applications.

For example, an operator of a wash plant noted that traditionally contractors used mobile crushers to produce recycled and secondary aggregates from construction, demolition and excavation activities. These crushers often used dry screening to filter out contaminants. However, due to Scotland's wet climate – and, in the case of excavation, the silt and clay material common in Scotland's geology – the crushed feed material would often become sticky, making it difficult to remove contaminants and ultimately reducing the purity of the output. Modern wash plants, on the other hand, are often equipped with multiple crushers, washing and screening technology to crush and effectively segregate aggregates from these contaminants. In the case of excavation activities, this also allows for the collection of the silt and clay as a valuable by-product. Similarly, an interviewed producer of construction materials noted that clients and contractors may not be aware that this sector is rapidly evolving, and that technologies are coming online that can, for example, extract the cementitious properties of concrete and recover the concrete used.

In conclusion, current standards and specifications for recycled and secondary aggregates are felt by industry stakeholders to be outdated or restrictive, failing to support the technological innovations and resultant industry confidence. As noted above, while demand for recycled and secondary aggregates has traditionally been lower than primary aggregates due to concerns regarding quality and consistency in supply, there is a sentiment among some interviewees that this has changed as a result of research and development investment and innovation, leading to significant improvements in the quality of materials that can be produced from CDW. While the structural integrity of built infrastructure must not be compromised, to enable broader recycled and secondary aggregate adoption, updates to standards and specifications are essential to reflect current practice and provide guidance on the materials' structural performance.

To address these challenges, there is an opportunity to review current industry standards, to understand if there is scope to develop and update them to better reflect modern recycling capabilities and the quality of alternative aggregate products they can produce. Additionally, as with the option to develop a library of proof of environmental performance discussed in Section 3.4.2, a suite of case studies could be built or collated to demonstrate good practice and the technical appropriateness of alternatives to primary aggregates.

3.4.4 Operational and market challenges

There was broad disagreement among the stakeholders interviewed for this study regarding the need to provide additional support for the uptake of alternatives to primary aggregates. This was due to contrasting views regarding the perceived 'saturation' of recycling and wash

plants across the central belt of Scotland, the operational barriers of expanding aggregate recycling facilities to rural areas, and the challenges in segregating CDW at source.

It was felt that the saturation of state-of-the-art facilities (e.g. wash plants), combined with a lack of demand for non-primary aggregates for reasons discussed above, means some of these businesses are sitting on significant amounts of washed concrete, recycled sand and gravel, with no off-take market (i.e. customers to buy their product). Indeed, four interviewees noted they could significantly increase their recycled output if there was sufficient market demand to justify it.

Within this context, some stakeholders representing primary aggregate suppliers felt that if the Scottish Government used financial or legislative support such as increasing the tax rate applicable under the Scottish Aggregates Tax to generate market demand and incentivise the use of recycled or alternatives to primary aggregates, the primary aggregate sector would be placed at a competitive disadvantage. These state-of-the-art facilities require millions of pounds of investment, which creates a barrier to entry for primary aggregate suppliers seeking to move into the recycled aggregate market due to sustainability and Net Zero benefits. In addition, these stakeholders felt that as some recycled aggregate companies operate their own fleets, they may be more readily able to drop the price of the recycled aggregates in order to sell excess stock, which may contribute to increased market volatility and reduce the competitiveness of primary aggregates.

On the other hand, producers of recycled- and alternatives to primary aggregates felt that their competitiveness was overstated due to the operational and geographic limitations of their business models. It was noted that traditional quarrying allows significant volumes of primary aggregates to be sourced (e.g. through drilling and blasting) and sent out for delivery with lower overheads and lower investment in infrastructure. This allows them to compete favourably against producers of recycled aggregates that require investment in high-specification wash plants, trash screens, and technology to grade and segregate feedstocks.

In addition, suppliers of alternatives to primary aggregates interviewed noted they were also constrained geographically, as their infrastructure needs to be situated in a catchment area where there is a high volume of CDW being generated. This makes competition with traditional primary aggregate suppliers challenging. This is especially true in rural regions outside of Scotland's central belt, where it is currently not commercially viable to operate wash plants or supply non-primary aggregates due to a lack of non-primary material inputs, and the haulage and fuel costs associated with transporting these to customers. One interviewee noted the fuel costs may be subject to change, if they were able to transition their fleet to electric vehicles supplied by renewable sources. However, this remains a significant operational barrier.

It was generally agreed by interviewed stakeholders and within the supporting literature, that to maximise the financial and environmental benefits of using alternatives to primary aggregates, these should be used as close to the source as possible (e.g. demolition sites or construction sites) (Wang & al., 2024) (Santolini & al., 2024). However, there was concern that availability of recycled and secondary feedstock was also often constrained by

resistance within construction and demolition companies to appropriately segregate materials at source, due to concerns regarding feasibility and costs. There was broad agreement that this was due to the structural and commercial pressures that construction and demolition companies face when delivering a contract. It was explained that demolition contracts tend to be awarded for efficiency and speed to avoid financial penalties for not completing a project within the timeframe set by the agreed upon planning permissions. This can lead to a tendency for operators to make business decisions based on the belief that the removal of specific structural elements and the use of screening technology to facilitate reuse and recycling of aggregates will be time consuming and generate additional, unwanted costs.

One specific example is the lack of on-site removal and screening being a key barrier to the recycling of flat glass. Currently, the Scottish Landfill Tax provides little financial incentive to recycle flat glass recovered from buildings as this material qualifies for the lower rate of landfill tax of £4.05/ tonne from 1 April 2025 (previously £3.30/tonne). As a result, recovered glass is crushed for use as a low-value input for aggregates in road construction or landfilled. British Glass (an industry body representing the UK glass industry) noted this is a significant lost opportunity to maximise the value generated from glass recycling, minimise avoidable waste, and reduce GHG emissions. Glass can be continuously recycled and remelted into new glass products without loss of quality, provided it is appropriately segregated to avoid impurities. Their estimates indicate up to 200,000 tonnes of flat glass is generated by the UK demolition and construction sector. If flat glass was diverted from landfill and remelted into new glass products, this could save 60,000 tonnes of CO_2 per year. Replacing virgin raw materials with 10% recycled glass saves 3% of furnace energy when producing glass products (British Glass, 2024).

While there are currently no flat glass recycling facilities in Scotland, British Glass emphasised that there is significant market demand from the Scottish food and drink manufacturing sector, particularly Scottish whisky and gin distilleries, for recycled glass materials in order to reduce their Scope 1 emissions (those that are directly generated through their operations). As such, they underlined the clear synergies and shared economic benefits of greater cross-sector collaboration for the recovery and segregation of flat glass products (e.g. windows) for recycling by the food and drink sector into glass packaging (e.g. bottles). This would only be feasible if appropriate on-site practices were implemented by stakeholders within the construction and demolition sector.

To mitigate these operational challenges, stakeholders interviewed felt that the costs of the segregation and processing of recovered aggregates and glass could be passed onto the client, especially if this was mandated or supported by legislation. A change in planning permissions or adjustments to the Scottish Landfill Tax that increases the cost of disposal were both suggested as potentially significant levers for change.

Finally, it should be noted that several interviewees reflected the view that wash plants should be seen as complementary to, and not competitive against, the existing producers of primary materials. Through sector collaboration it was perceived that increasing use of alternatives to primary aggregates would contribute to the extension of the useful lifetime

of quarries, while producing materials that may not directly compete with materials derived from hard rock quarries, such as clean crushed stone.

The market stimulation efforts and ideas to tackle challenges due to industry standards discussed in the above two sections would go some way to tackling the challenges discussed here as well. To address the issue of alternatives to primary aggregates only really making environment and commercial sense if used relatively closely to where they are produced, effort could be made to support the development of recycling infrastructure in areas away from the already well-served central belt of Scotland.

3.5 Fiscal factors

There was broad agreement among stakeholders that, currently, the cost of purchasing alternatives to primary aggregates is comparable to that of primary aggregates. Yet, despite this similarity in pricing, there is a preference for primary aggregates in the market. Our findings indicate this is driven by the quality issue perceptions discussed above and the associated costs and challenges of ensuring compliance with required standards (e.g., screening, sorting, testing). However, there could be two areas of flexibility that could support a shift of this market dynamic in favour of alternatives to primary aggregates.

These are:

1. **Tax rate adjustments for primary aggregates**: The Government could choose to raise the tax rate on primary aggregates to further strengthen the incentive to use alternatives to primary aggregates.

2. **Subsidies for alternatives to primary aggregates**: Businesses that reduce the use of primary aggregates by incorporating alternatives into their operations could be made eligible for a subsidy scheme. Payments could enable businesses to lower their costs and for these cost savings to be passed on to customers. This could lead to more competitive pricing for products made with alternatives compared to those made with primary aggregates.

3.5.1 Tax rate adjustments for primary aggregates

The Scottish Government's review of evidence and policy options for the Scottish Aggregates Tax (2020b) conducted an illustrative modelling exercise (based on tax rates at the time) for four tax rate scenarios:

- Option 1 – High levy rate (Tax increase scenario): Under this option, the Scottish Aggregates Tax rate is set above the UK levy rate.
- Option 2 – Low levy rate (Tax decrease scenario): Under this option, the Scottish Aggregates Tax rate is set below the UK levy rate.
- Option 3 – Scottish Government baseline (No tax scenario): The levy rate is set to zero under this option, to model the impacts of a 'do nothing' approach.
- Option 4 – New landfill tax band for aggregates (Landfill scenario): The levy rate is kept at the same level as the UK levy rate, while creating an additional band of landfill tax for aggregates which is higher than the rate for landfilling inert materials.

The results of this modelling are reproduced in Table 3 below.

	BaU	Option 1	Option 2	Option 3	Option 4
Aggregates levy rate	£2.00	£2.50	£1.50	£0.00	£2.00
Landfill tax for inert materials	£2.90	£2.90	£2.90	£2.90	£2.90
New landfill tax band for aggregates	-	-	-	-	£3.80
Demand for aggregates	-	Decrease	Increase	Increase	Unchanged
Production of primary aggregates	-	Decrease	Increase	Increase	Decrease
Imports	-	Decrease	Increase	Increase	Decrease
Exports	-	Increase	Decrease	Decrease	Unchanged
Production of recycled aggregates	-	Increase	Unchanged	Unchanged	Increase

Table 3: Modelled tax rates and impacts under different policy scenarios (reproduced from (Scottish Government, 2020b))

Unsurprisingly, the modelled outcomes for raising the tax rate for primary aggregates and for introducing additional costs for landfilling of aggregates (Options 1 and 4 respectively) show a decrease in the use of primary aggregates and an increase in the use of alternatives. These are expected results for the unambiguous financial interventions into the market modelled. However, the level of redistribution of total demand between primary and alternatives aggregates that is actually possible, and the resultant worth of that compared to additional administrative costs, remains unclear. The 2020 Scottish Government review highlights that 87% of CDW is already recycled in Scotland, and the challenges discussed in Sections 3.4.1 and 3.4.2 above corroborate and augment this note of caution. Until robust and reliable Scotland-specific data on volumes of alternatives to primary aggregates is collected, any perceived benefits of tax rate changes will be somewhat speculative.

3.5.2 Subsidies for alternatives to primary aggregates

While alternatives to primary aggregates will be already be exempt from the Scottish Aggregates Tax, there is the potential to further incentivise their use by offering a subsidy. Potential recipients, such as those economic operators placing alternatives to primary aggregates on the market, would need to comply with any systems set up to verify amounts being claimed, so introducing some administrative burden.

The potential impacts and costs of introducing a subsidy system which aims to offer a positive incentive for using alternatives to primary aggregates are impossible to robustly estimate without access to granular volume data. Any potential scheme itself could require claimants to collect, store and report data on alternatives deployed. This potentially could include volumes and rates of CDW reused on site, capturing material which is not currently reflected in standard waste reporting as it never officially becomes waste. While this would incentivise the use of alternative aggregates and avoid the negative associations of disincentivising primary aggregates through the use of a tax increase, it would necessitate increased administrative and resource burden on both the scheme administrator and

relevant claimants. Further work would be required to conduct a thorough assessment of the viability of any such scheme, which would, again, necessitate much more complete data than is currently available.

4 Summary learnings and next steps

The learnings drawn from the evidence review and potential actions for policymakers are summarised below:

- **Alignment with net zero targets:** The Scottish Aggregates Tax could emphasise the potential role of alternatives to primary materials in meeting net zero targets in the construction sector. This could be relevant for other sectors that may have a use for these materials, such as food and drink manufacturing. This is particularly relevant for the GHG reduction potential of recycled aggregates, as well as for the recycling of flat glass. These environmental benefits can be evidenced through lifecycle assessments, which demonstrate the carbon savings potential of using recycled aggregates and glass.
- **Data accessibility and transparency:** Significant data gaps exist in the monitoring of CDW generation and resultant availability of materials that could be used as alternatives to primary aggregates. This might complicate the implementation of any potential future Scottish Aggregates Tax rate changes and generate reasoned resistance from affected stakeholders. Robust data on waste arisings generated from CDW projects, and the types, quantities and value of alternatives to primary aggregates produced and sold, would enable policymakers to more accurately monitor and understand market dynamics for these types of materials. Given the resource demands of additional data collection, we suggest that systems and processes would need to be developed collaboratively between government and industry partners to promote engagement and adherence.
- **R&D investment:** Continued investment in advanced recycling infrastructure can improve the quality of recycled aggregates. Public-funded R&D could support existing recycling facilities and develop recycling capacity among primary aggregate suppliers, particularly in underserved rural areas.
- **Addressing quality perceptions:** Sector wide misconceptions regarding secondary and recycled materials, often based on historic experience, limit market demand. Public sector and industry partners could seek out targeted opportunities to emphasise successful case studies and promote quality assurance practices.
- **Updating standards and specifications:** Industry standards restrict the use of alternatives to primary aggregates. Investment in R&D to review and potentially update industry standards could better reflect modern recycling capabilities. This could also contribute to addressing the quality perceptions discussed above. This could be complemented by engagement with standards bodies, such as British Standards, National Highways and Transport Scotland.
- **Capacity building and market demand:** Policymakers could capitalise on latent capacity for recycling facilities could increase their capacity by implementing mandates and incentives to require and encouraging the use of alternatives to primary aggregates (e.g. in public sector procurement), where safe and technically appropriate to do so.

- **Facilitate cross-sector collaboration:** Policymakers could support innovation to incentivise cross-sector collaboration for the recovery and recycling of flat glass from construction and demolition projects.

Policymakers should continue to effectively engage with key stakeholder groups within the aggregate industry to ensure any measures, including changes to tax rates and provision of financial incentives, are feasible and accepted. Additionally, the majority of the barriers discussed in this report will require engagement and the development of a mutual understanding with wider stakeholder groups. These include:

- Private sector customers of primary and alternatives to primary aggregates, including Tier 1 contractors, homebuilding contractors, landscapers and relevant trade associations.
- Public sector customers of primary and alternatives to primary aggregates, including local authorities and relevant public sector procurement representatives.
- Relevant industries that may benefit from recycled aggregates, such as the Scottish food and drink sector for the recycling and valorisation of recovered flat glass.
- Relevant industry standards bodies and research institutions to review feasibility of updating existing standards for alternatives to primary aggregates.

In summary, while there is a bank of academic, grey literature and stakeholder-opinion evidence that alternatives to primary aggregates can play a practicable and impactful role in reducing GHG emissions in Scotland, there is not universal agreement in the industry on these points. There are significant challenges and knowledge gaps to overcome. There are questions about the feasibility of increasing the proportion of alternatives to primary aggregates deployed, from both the available supply and market demand angles. There are deeply held reservations about the ability of alternatives to primary aggregates to provide the required technical performance, compounded by a sentiment that industry standards do not accurately reflect current recycling capabilities. Finally, there is a clear lack of robust, granular, Scottish-specific data to provide unequivocal clarity on several of the contested points. This study has detailed the key points of these challenges, their roots, and suggested some potential options to begin tackling them to facilitate a move to a more circular economy and sustainable construction sector in Scotland.

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6 Appendices

Appendix A : Methodology

In the completion of this report, the research team completed the following activities:

- Task 1: Policy drivers workshop
- Task 2: Literature review
- Task 3: Data collection
- Task 4: Stakeholder interviews

These activities are described in more detail below.

Task 1: Policy Drivers workshop:

Following inception of the project, a workshop was held with representatives of the Scottish Government, CXC, Ricardo and members of the Scottish Aggregates Tax Bill Advisory Group (SATBAG). This workshop was used as springboard to discuss the aims and objectives of this research project, establish a common understanding of:

- The taxation and regulatory context as it pertains to the Scottish Aggregates Tax and Scottish Landfill Tax, including:
    - The potential and feasibility of different tax rates to remove barriers to the use of alternatives to primary aggregates.
    - Relevant regulations and potential exemptions that might influence their use.
    - SEPA's potential role in providing data and regulatory input into the research.
- Barriers to the use of secondary and alternatives to primary aggregates, including discussion of: market perceptions, commercialisation issues, cost considerations, and relevant regulations.
- Environmental considerations, including: the environmental impact of recycling and potential unintended considerations, alongside policy drivers to minimise waste arising from construction.
- Future research and data need to address potential data gaps and requirements to facilitate survey and evidence gathering.
- Industry engagement to develop a clearer picture of how tax and regulatory changes will affect different parts of the industry, as well as consideration of cross-border traffic of aggregates between Scotland and other areas, which could impact the effectiveness of any tax or regulatory changes.
- Expected impacts and considerations, including price sensitivities to assess the long-term impacts of a policy shift, and the need to carefully balance the economic impact on industries that rely on primary aggregates with the environmental goals of promoting secondary aggregates and minimising waste.

Task 2: Literature review:

An in-depth literature review was undertaken of academic, grey and white paper sources relating to the economic and environmental impacts of the use of alternatives to primary aggregates and their use. The scope of the review primarily focused on Scottish and UK-related studies, and was expanded to cover international best practice studies, particularly as they pertain to life-cycle assessments of alternatives to primary aggregates. These

findings were collated in an Excel Document Register to facilitate the identification and analysis of key themes relevant to the study. The sources identified are summarised in Table 4, below.

Task 3: Data collection and analysis:

Following the literature review, the research team progressed to primary data collection from relevant industry stakeholders involved in the supply of alternatives to primary aggregates in Scotland. The purpose of this activity was to gain a baseline understanding of the availability of alternatives to primary aggregates being sold in Scotland. This was then to be used to forecast the potential contribution to GHG reduction targets of an increase in use of recycled or secondary aggregates in the Scottish construction sector. To do this, the research team conducted desk-based research to identify up to 36 suppliers of aggregates, which included: manufacturers of primary aggregates, wash plant operators, construction and demolition waste recyclers, and demolition and excavation companies. Once identified, the collection of primary data was split into two sub-tasks: data collection surveys, and long-form interviews:

Sub-task 3.1: Data collection surveys:

The research team sent out data collection surveys to request the following information for the periods Jan-Dec 2021, Jan-Dec 2022, Jan-Dec 2023:

- Material types supplied
- Manufacturing locations
- Quantities of material produced per year (tonnes)
- Associated standards and quality control measures
- Challenges associated with either collecting or increasing supply of each material type.

Due to data challenges described in section **Error! Reference source not found.**, the research team received insufficient primary data to accurately forecast the potential availability of alternatives to primary aggregates.

Sub-task 3.2: Stakeholder interviews:

The research team conducted 4 interviews with relevant private companies and industry groups, listed in Table 5, for a duration of 45-60 minutes. The purpose of these interviews was to complement the data collection surveys and gather qualitative data to be used in Task 4, described below.

Research activity	Count	Research activity	Count
Building standards	8	Suppliers contacted for primary datasets	36
Academic and industry papers reviewed	19	Stakeholder interviews/surveys	10

Table 4: Research activities completed

Task 4: Investigate barriers and solutions to the supply of alternatives to primary aggregates:

Following the literature review and data collection phase, the research team conducted a series of interviews with relevant stakeholder groups to discuss any challenges or barriers to the uptake of alternatives to primary aggregates, and to assess potential fiscal or regulatory levers that could be used to mitigate these.

The aim of this phase was to facilitate a deeper understanding of how government and industry can work together to use environmental levies and associated instruments to affect the best possible climate impact and identify any barriers that may negatively impact their implementation. An interview script was developed to gain stakeholder inputs on the following topics:

- Perceptions and attitudes toward alternative materials to primary aggregates
- Operational considerations related to the supplying of alternatives to primary aggregates
- Technical, regulatory and market barriers to the uptake of alternatives to primary aggregates
- The policy and regulatory environment related to the application of alternatives to primary aggregates

To ensure that a broad range of viewpoints were considered, 10 interviews were conducted with relevant stakeholder groups identified from the SATBAG and during stakeholder engagement activities in Task 3. These stakeholders are recorded in Table 5.

Stakeholder Group	Organisation	Interview-/Surveyed
Private company	Brewster Bros	Interviewed
Public sector organisation	British Geological Survey	Interviewed
Industry body	British Glass	Interviewed
Industry body	Chartered Institute of Taxation	Interviewed
Local Authority lobbying body	Convention of Scottish Local Authorities	Surveyed
Industry body	Institute of Chartered Accountants Scotland	Interviewed
Private company	J&M Murdoch	Interviewed
Industry body	Mineral Products Association	Workshop
Private company	NWH	Interviewed
Government body	Revenue Scotland	Interviewed
Private company	Tarmac	Interviewed
Private company	Tillicoultry Quarries	Workshop
Industry body	The British Aggregates Association	Interviewed

Stakeholder Group	Organisation	Interview-/Surveyed
Private company	W H Malcolm	Workshop
Government representative	William Carlin, Scottish Government	Interviewed

Table 5: Stakeholders engaged

Each interview was recorded and the transcript was cleaned and recorded in an Excel matrix to facilitate objective comparison and analysis of each stakeholder group's perspective on the above noted topic areas.

Task 5: Synthesising results and report writing

Following completion of Tasks 1-4, the research team reviewed all evidence gathered throughout the study to identify key themes, areas of consensus, and areas where evidence or viewpoints may diverge or contradict each other. These were then mapped against the key objectives of the research project and grouped according to theme. This provided the basis of section **Error! Reference source not found.** in this report. Following this initial review, an interim report was developed and presented to CXC and representatives of the SATBAG to gain their input and ensure all viewpoints are objectively recorded within the body of the report.

Appendix B: Case studies

Provided as a separate document: Appendix B: Case studies - The role of alternatives to primary aggregates in reducing emissions from the construction sector

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