Value Chain Mapping for the Construction Materials Industry

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Introduction

Decarbonizing the building and construction industry, "the built environment," is critical to aligning with the United Nations (U.N.) Sustainable Development Goals (SDGs) and achieving the goals outlined in the Paris Agreement. Due to numerous factors, including global population increases, the industry's growth and resulting impacts on emissions and resource depletion are increasing every year.

The global construction materials industry's financial value was $1,320.01 billion in 2023 and is projected to grow to $1,867.16 billion by 2032. Significant environmental challenges accompany this growth. The building and construction sector contributes 37% of global emissions through the embodied carbon of materials extraction, manufacturing, on-site construction, and operational emissions from heating, cooling, and lighting (Abergel et al., 2019).

Our research highlights critical materials, outlines seven stages of the material life cycle, identifies potential risks and impacts, and offers recommendations for a more just and sustainable future in the construction materials industry (Dsilva, 2023). This comprehensive approach aims to understand better the industry's current landscape and actionable insights for driving sustainable practices.

In response to these challenges, BWD Strategic (BWD) tasked the team with creating a number of deliverables that enable them to better advise their clients. The deliverables are fourfold: (1) a value chain map illustrating impacts, risks, and dependencies, (2) identification of relevant environmental, social, and governance (ESG) issues within that visual, (3) advice on prioritizing issues, and (4) recommendations for how businesses in the industry can address identified issues.

Methods

Through extensive research, collaboration, and professional knowledge, the team was able to source relevant information for the deliverables. The team agreed to focus on five key construction materials. Some materials are more prevalent in certain regions than others; however, these five materials account for roughly 56% of the construction materials industry's emissions (Kilgore, 2024; Inemesit, 2024; Enviros Consulting Ltd., 2023). We chose to focus on concrete, glass, steel, timber, and brick. These materials significantly impact the environment and have been prioritized for this research (see Figure 1).

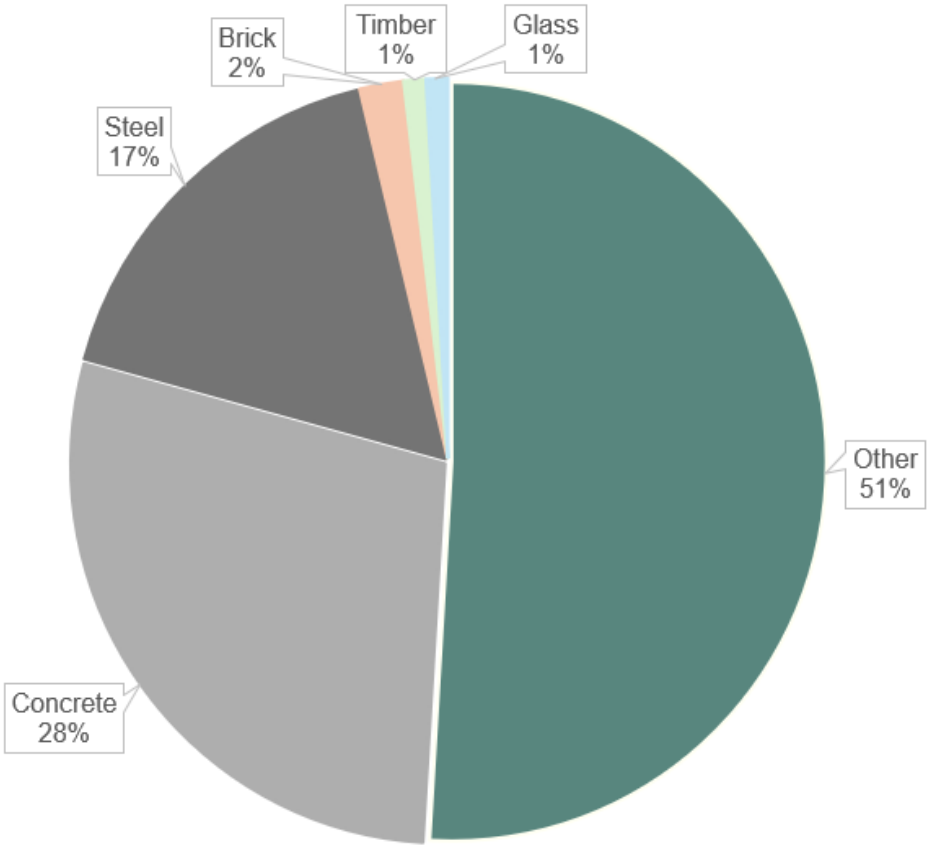


Figure 1. Yearly emissions of materials in the construction industry.

Afterward, the team collaborated to identify seven stages of the construction material value chain through industry research on material origination, extraction, product manufacturing,

and building trends. The value chain visualization was created for BWD by the project team and is available to the client in a PDF format, enabling BWD to zoom in and explore its content. The seven stages of the construction material industry, as defined by the team, are as follows:

1. Extraction of Raw Materials - mining, logging, extraction
2. Material Processing - refining, treating, cutting
3. Manufacturing - creating the components for construction
4. Logistics - transport of materials to wholesalers, customers
5. Construction - construction of structures and systems
6. Operation - use of building, maintenance, and repairs
7. End of Life - demolition or recycling of materials

(Task Group IRP-One Planet Network, 2020)

Materials provided to the team by BWD enabled us to identify risks and impacts along the value chain and determine the recommended actions for BWD clients. Further information regarding methodology will be found throughout the report.

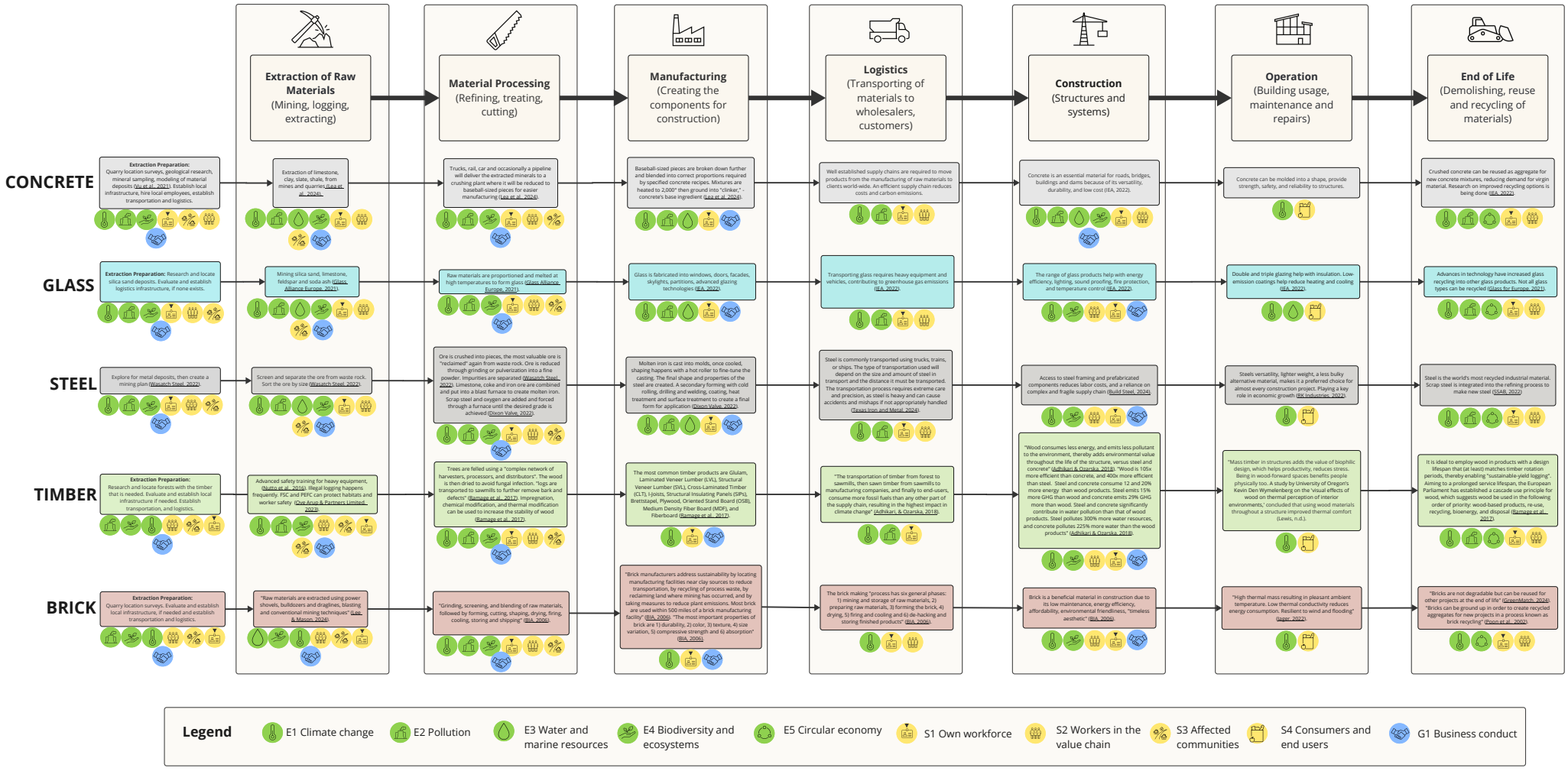
Value Chain Visualization

The seven stages were a foundation for further research of building methods, materials, and regional influences. For example, brick is not commonly used in earthquake-prone regions due to its lack of resistance to earthquakes. Instead, timber and concrete are more suited to these areas for their structural integrity and adaptability (Lin & Grad, 2015).

We focused on each stage of the value chain to better understand each stakeholder's perspective, priorities, process, and the risks and impacts of that stage. The research narrowed our focus to the top five materials and their environmental and social impacts. We decided not to include aluminum as one of our selected materials as its life cycle is similar to steel. Instead, we included brick to give an accurate scope of impact in the construction materials industry. We relied on research and information from academic journals, industry journals, newspaper articles, government websites, and publications, building certification websites, manufacturer websites, union publications, material-specific publications, journals, human rights organizations, labor organizations, industry consultants, and encyclopedias. After, the team evaluated social and environmental risks and impacts per material per stage of the value chain and created visuals for BWD to reference, see appendices C (concrete), D (glass), E (steel), F (timber), and G (brick) for detailed information. Then, a foundation was created to identify the European Sustainability Reporting Standards (ESRS) AR16 potential environmental and social risks and impacts per material per stage (Council of the European Union, 2023a). See Appendix A for more information about the ESRS. A legend accompanies the value chain, enabling the client to easily identify which ESRS AR16 risks and impacts apply to each stage and material by icon. Stages have varying social and environmental risks and impacts, easily identifiable through the number of icons assigned to a material at a value chain stage.

Figure 2

Value chain visualization

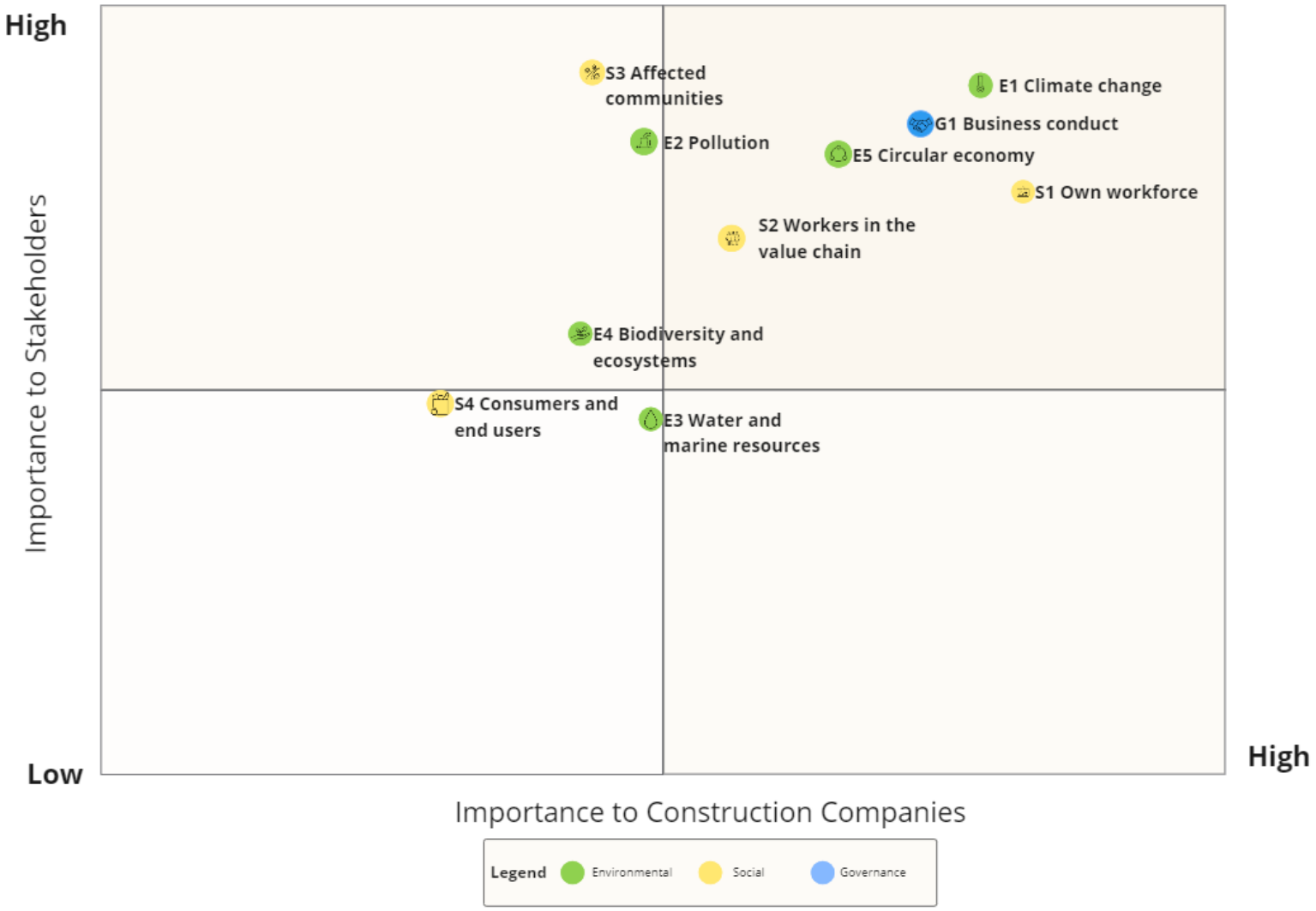


Note. A value chain visualization of the seven stages in the construction materials industry and corresponding ESG impacts and risks.

Materiality Matrix

Figure 3

Materiality Matrix



Note. Materiality matrix visualization for industry stakeholders and a construction company entity.

Upon completing the value chain, the team identified the top ten risks and impacts to the construction materials industry as categorized by the European Sustainability Reporting Standards (ESRS): E1 Climate change, E2 Pollution, E3 Water and marine resources, E4 Biodiversity and ecosystems, E5 Circular economy, S1 Own workforce, S2 Workers in the value

chain, S3 Affected communities, S4 Consumers and end users, and G1 Business conduct. Based on the ten material risks and impacts, the team created a materiality matrix (Figure 3) to gauge the importance of each risk and impact against industry stakeholders on the y-axis and an example construction company client on the x-axis. The stakeholders we considered include but are not limited to, industry employees, workers, trade and labor unions, suppliers, consumers, customers, end-users, local communities and persons in vulnerable situations, and public authorities, including regulators, supervisors, central banks, and the environment (Council of the European Union, 2023b).

The impacts were assessed, evaluated, and plotted in a materiality matrix based on their degree of impact. These included severity - scale, scope, and irremediable character; financial materiality - "financial position, financial performance, cash flows, access to finance, or cost of capital over the short-, medium- or long-term" (Council of the European Union, 2023c) as suggested by the ESRS. Table 1 provides additional context regarding the ranking of ESRS AR16 on the materiality matrix. Due to the hypothetical nature of this analysis, a particular client will have specific circumstances to consider.

Table 1

Risk & Impact	Importance to Stakeholders (External)	Importance to Construction Company (Internal)
E1 Climate change 	**High** due to regulatory pressure, investor demand, public opinion, environmental activism, and the severity of climate change.	**High** due to operational efficiency, risk mitigation, long-term viability, and financial risks.
E2 Pollution 	**High** due to public concerns about air, water, and soil pollution affecting local communities and regulatory compliance.	**Medium** due to influences on operational practices, compliance costs, and community relations.

E3 Water and marine resources 	**Medium** due to a focus on sustainable water use and protecting marine ecosystems, driven by environmental advocates and regulations.	**Medium** due to the effects on water management practices, operational efficiency, regulatory compliance, and resulting financial implications.
E4 Biodiversity and ecosystems 	**Medium** due to the increasing focus on preserving biodiversity, influenced by environmental NGOs and regulations.	**Medium** due to the impacts of land use practices, resource management, compliance with environmental standards, and potential financial implications.
E5 Circular economy 	**High** due to strong interest from regulators, investors, and customers in waste reduction and resource efficiency.	**High**, it drives innovation, cost savings, and market differentiation.
S1 Own workforce 	**High** due to stakeholders prioritizing employee welfare, health and safety, and fair labor practices.	**High** due to the effects on productivity, compliance, and reputation and the risk of financial implications.
S2 Workers in the value chain 	**Medium** due to the concerns about labor conditions and rights in the supply chain, driven by social justice groups and regulations.	**Medium** due to the influences of supply chain management and compliance with labor standards.
S3 Affected communities 	**High** due to the community impact and engagement are critical for local acceptance and regulatory approval.	**Medium** due to reputation, social license to operate, and community relations.
S4 Consumers and end users 	**Medium** stakeholders are concerned about product safety, transparency, and sustainability.	**Medium** impacts on market differentiation and customer satisfaction.
G1 Business Conduct 	**High** due to ethical business practices, anti-corruption, and transparency concern investors and regulators.	**High**, as it ensures compliance, maintains investor trust, and protects reputation.

Note. Additional context for materiality matrix.

Recommendations

The United Nations Sustainable Development Goals (SDGs) serve as a pillar for all recommendations (United Nations Department of Economic and Social Affairs, n.d.). An overview of the SDGs can be found in Appendix B. To help its clients achieve more sustainable operations, BWD Strategic can consider the following recommendations.

E1 Climate Change:

The most significant contributor to climate change is the release of greenhouse gases into the atmosphere. The construction industry is the largest emitter of greenhouse gases through its production and use of carbon-intensive materials, such as steel and concrete, and the operation of energy-intensive buildings (Ciardullo et al., 2023). To reduce the industry's impact on climate change and in alignment with **SDG 9:** Industry, Innovation, and Infrastructure; **SDG 11:** Sustainable Cities and Communities; and **SDG 13:** Climate Action, the team recommends two actions:

Eliminate Carbon Footprint:

- Prioritize material reuse and recycling. Then, environmentally friendly, low-carbon alternative materials such as green steel, grassland (Crownhart, 2022), and low or no-carbon cement (Gallucci & St. John, 2023) should be used instead of existing materials.
- Regulations mandating energy-efficient and fossil fuel-free construction are becoming more common. Existing buildings should be retrofitted with improved insulation, double and triple-paned windows, smart thermostats, electrified appliances, and renewable energy sources like solar PV or grid-supplied renewables.
- Leadership in Energy and Environment Design (LEED), the Building Research Establishment Environmental Assessment Methodology (BREEAM), International Living

Future Institute, and Passive House certification frameworks ensure that buildings meet stringent environmental and energy efficiency standards.

- Biomimicry, known as biomimetics, is one of the most innovative concepts for achieving a sustainable construction materials industry through circular, nature-based solutions and processes and leveraging nature's strategies for disaster mitigation. Biomimicry can help the industry achieve sustainability and resilience while prioritizing the planet and people.

Resilient Buildings and Infrastructure:

- Newly constructed buildings and infrastructure projects must be designed to withstand climate change, including sea-level rise, flooding, erosion, drought, wildfires, the heat island effect, and intensifying storms. Buildings and infrastructure projects should benefit the communities they serve while protecting the environment and enhancing biodiversity (FAST-Infra, 2023).
- Incorporating natural solutions into infrastructure, such as wetlands, dunes, mangroves, rivers, estuaries, grasslands, and forests, can offer significant environmental benefits as sustainable alternatives to manmade, carbon-intensive options (Apostolovic et al., 2023).

Low-Carbon Alternatives

Reducing the carbon footprint of building materials is a significant step toward sustainable construction practices. Consider incorporating alternative materials with lower embodied carbon throughout projects, below are a few alternatives that may be considered.

- Concrete:
    - Geopolymer Concrete: uses industrial by-products like fly ash or slag.
    - Hempcrete: made from the inner fibers of the hemp plant mixed with lime, creating a lightweight and insulating material (Wong, 2022).
    - Recycled Aggregate Concrete: utilizes crushed concrete from demolition waste as aggregate in new concrete (PCA, n.d.)

    - CarbonCure Concrete: infuses recycled CO_2 into fresh concrete to improve its strength and reduce its carbon footprint (CarbonCure, n.d.).
- Glass
    - Recycled Glass: made from recycled glass, reducing the need for new raw materials and lowering energy consumption.
    - Smart Glass: can change its properties (like transparency) based on environmental conditions, potentially reducing energy needs for heating and cooling (Singapore Glass Association, 2023).
    - Aerogel Glass: insulating glass units filled with aerogel to enhance thermal performance (SEN, 2023).
- Steel
    - Recycled Steel: made from scrap steel, reducing the need for raw material extraction and energy-intensive processes (SSAB,2022).
    - Aluminum: lightweight and recyclable, aluminum can replace steel in many structural and non-structural applications (The Aluminium Association, 2021).
    - Bamboo: bamboo can be used in place of steel reinforcement in concrete due to its flexible nature (The Constructor, n.d.a).
- Timber
    - Bamboo: rapidly renewable, strong and carbon negative (Tolentino, 2024).
    - Engineered Wood Products (EWP): includes materials like LVL (Laminated Veneer Lumber) and glulam, which are stronger and use timber more efficiently (Nisbet Brower Building Materials, 2023).
    - Reclaimed Wood: wood salvaged from old buildings, or other structures, repurposed for new construction.

- Brick
    - Compressed Earth Blocks (CEBs): made from a mix of soil and a stabilizer, compressed into blocks (Pritchard, 2022).
    - Fly Ash Bricks: Made from fly ash, lime, and gypsum, these bricks are lighter and stronger than traditional clay bricks (The Constructor, n.d.b).
    - Hempcrete Blocks: similar to hempcrete but formed into blocks, providing insulation and strength (Hempitecture, 2023).
    - Mycelium Bricks: made from the root structure of fungi, these bricks are biodegradable and can be grown in molds (Bonnefin, 2022).

E2 Pollution

Pollution is a significant environmental concern in the construction materials industry.

Energy efficiency and building energy management systems support **SDG 7**, focusing on affordable and clean energy. This approach supports **SDG 9** by fostering innovation, reducing waste, and enhancing infrastructure resilience. Building with eco-friendly materials and implementing waste management practices improves urban living conditions and supports **SDG 11**. These initiatives help reduce air pollution, improve indoor air quality, and encourage sustainable urban growth. Sustainable sourcing, recycling, and deconstruction practices throughout the value chain align with **SDG 12**, which emphasizes responsible consumption and production. Additionally, green logistics and enhanced pollution control measures reduce greenhouse gas emissions and mitigate climate change, supporting **SDG 13**. **Raw Material Extraction and Manufacturing**

- Implementing clean technology using electric or hybrid machinery in the concrete sector can significantly reduce emissions during limestone extraction.
- Quarry operations that use advanced electric and hybrid equipment reduce CO_2 emissions significantly (Lea et al., 2024).

- Energy-efficient kilns in brick manufacturing can reduce fossil fuel use.

Logistics, Construction, and Operations

- Optimizes delivery routes, significantly reducing fuel consumption and emissions.
- Collaborating with supply chain partners on green logistics initiatives can significantly reduce transportation-related emissions (Adhikari & Ozarska, 2018).
- Eco-Friendly Materials: Low-VOC materials are used to install glass windows to reduce air pollution.
- Waste Management involves implementing strict waste segregation and recycling protocols on construction sites to minimize landfill waste.
- Regular maintenance of buildings' heating, ventilation, and air conditioning (HVAC) systems ensures they run efficiently and reduce emissions.

E5 Circular Economy

Construction industry companies can contribute to the circular economy through various strategies to reduce waste, reuse materials, recycle resources, and innovate. The team recommends three actions that align with **SDG 9**: Industry, Innovation, and Infrastructure, **SDG 12**: Responsible Consumption and Production; and **SDG 17:** Partnerships for the Goals.

Design for Durability and Disassembly:

- Develop durable and easy-to-dismantle projects at the end of their lifecycle, facilitating reuse and recycling. Durability includes infrastructure that can withstand climate change impacts (Neuroject, 2024).
- Incorporate energy-efficient designs, see E1 Climate change.
- Choose sustainably sourced materials, such as Forest Stewardship Council (FSC) timber, recycled steel, and low-carbon concrete, to reduce embodied carbon emissions (FSC, 2024; Neuroject, 2024).
-
- Life-cycle assessments can evaluate the environmental impacts of different materials

based on a project's region.

- Optimize the use of materials through efficient design and manufacturing processes to minimize waste.
- Establish take-back programs where old materials and products can be returned, refurbished, or recycled into new products.

Waste Reduction and Management:

- Implement processes to reduce waste during production and construction. Establish systems for recycling construction and occupant debris through industry-wide collaboration (First Mile, 2022).
- Implement water-efficiency measures including but not limited to rainwater harvesting and greywater technologies (Construction Management, 2024).
- Design landscaping to manage runoff and improve water infiltration into the soil (Neuroject, 2024).
- Educate building owners and tenants on water-saving measures and promote responsible water use (Neuroject, 2024).

Collaboration and Partnerships:

- Collaboration between government entities, businesses, academic institutions, NGOs, and local communities can expedite the implementation of circular construction methods, encourage innovation, and gather resources for further developing sustainable infrastructure (Neuroject, 2024). This knowledge sharing can be shared through databases, symposiums, etc.

S2 Workers in The Value Chain

The construction materials industry ranges from raw material extraction to end-of-life disposal, requiring specific guidance for each stage. Prioritizing a just culture that emphasizes worker safety, transparency, and continuous learning can greatly benefit all phases of the construction materials process (Chan et al., 2023). To ensure safe and healthy working

conditions across the construction materials value chain, aligning with **SDG 3:** Good Health and Wellbeing, and **SDG 8:** Decent Work and Economic Growth, the team recommends the following actions:

Safe Working Conditions:

- Standardize comprehensive safety training programs for all workers and advanced training for specialty roles in dangerous working conditions.
- Design and prioritize workflows focusing on worker safety.
- Allocate resources to purchase and maintain equipment that enhances worker safety.
- Conduct frequent inspections of sites, facilities, and equipment to identify and mitigate risks.
- Develop systems to monitor potential risks and establish anonymous feedback channels for workers to voice their concerns (Chan et al., 2023).

Equal Treatment and Opportunities For All:

- Pay fair wages that meet or exceed industry and local living standards (International Labour Organization, 2024).
- Ensure supply chains are free of child labor, forced labor, and any exploitative practices (Human Rights Watch, 2016).
- Provide health insurance with affordable premiums (Living Wage Alliance, n.d.).
- Offer benefits for long-term financial planning (LWA, n.d.).
- Promote gender equality in recruitment (UN Global Compact, 2024).
- Foster a diverse and inclusive work environment that does not tolerate discrimination based on gender, age, ethnicity, or disability (U.S. Equal Employment Opportunity Commission, 2023).
- Provide employment opportunities, advancement, and professional development (LWA, n.d.).

- Partner with vocational schools to help develop skilled workers (World Economic Forum, 2023).
- Foster constructive engagement with worker representative groups (WEF, 2023).
- Engage with local communities to collaborate on improving the local economy, health, education, and employment opportunities (The Global Goals, n.d.).
- Invest in community infrastructure projects that benefit the community, industry, and schools (TGG, n.d.).

Conclusion

The construction materials industry is vast and intricate, encompassing various products, technologies, and processes. Our exploration into this sector has only scratched the surface of its value chain. For organizations seeking to make a meaningful impact, there are various opportunities to integrate sustainable practices into their projects. However, achieving this requires a holistic, systems-thinking approach.

Understanding the full spectrum of impacts and risks associated with the construction materials industry requires looking beyond supplier claims. While some materials may seem environmentally friendly initially, their long-term sustainability may be questionable. For instance, wood composite, often used for decking, is made of recycled plastic and wood and is often marketed as a sustainable product; however, it is not easily recyclable (Mexy Deck, 2023). The wood composite boasts a heterogeneous composition that makes it non-recyclable at the end of its life cycle, presenting significant disposal challenges and making it a less sustainable material option. To truly assess the sustainability of construction materials, life cycle assessments (LCAs) could be conducted during the planning stages of a project. LCAs comprehensively evaluate the environmental impacts of all stages of a product's life, from raw material extraction to end of life. By incorporating LCAs, organizations can make informed decisions that reflect the true sustainability of their material choices. Consider preparing LCAs for regions across the globe for materials available in that region to provide clients with information about what could be used to build. Having a standardized format and library accessible to clients and collaborative partners could aid in accelerating sustainability in the industry.

Collaboration and partnerships are essential for driving sustainable innovation within the construction materials industry. Working together, organizations can share knowledge, resources, and best practices, accelerating progress toward common goals. Global collaboration can enhance the industry's ability to address complex environmental challenges

and achieve greater sustainability outcomes than any single organization could accomplish alone. In conclusion, while the construction materials industry presents numerous opportunities for sustainable innovation, realizing these opportunities requires a comprehensive and collaborative approach. By embracing systems thinking, conducting LCAs, and fostering partnerships, organizations can navigate the industry's complexities and contribute to a more sustainable future.

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All icons are sourced from Microsoft Word.

Appendix A

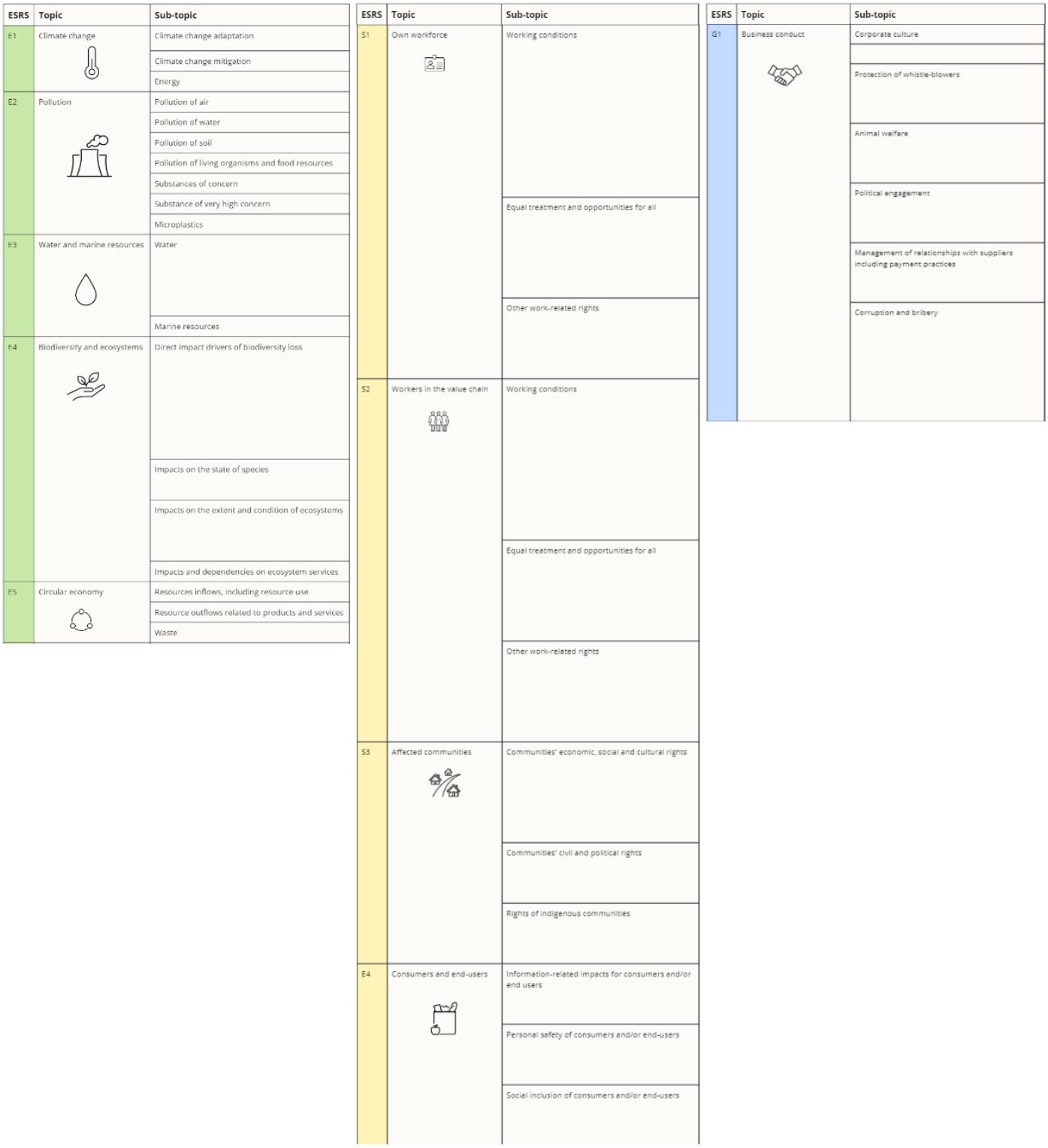
European Sustainability Reporting Standards (ESRS)

The European Sustainability Reporting Standards (ESRS) are guidelines established by the European Financial Reporting Advisory Group (EFRAG) to standardize sustainability reporting for companies operating in the European Union (EU). To promote sustainability within organizations, these standards aim to improve transparency, comparability, and accountability in reporting environmental, social, and governance (ESG) issues. ESRS covers climate change, biodiversity, social and employee matters, human rights, anti-corruption, and diversity (Council of the European Union, 2023). These standards support the EU's sustainable finance initiatives and the Corporate Sustainability Reporting Directive (CSRD), facilitating the transition to a sustainable economy (European Union, 2022).

BWD Strategic tasked the team with utilizing these standards in the final deliverable, as the EU is the frontrunner in sustainability initiatives, and these standards can, therefore, be applied and utilized for clients across the globe. BWD specifically sought impacts and risks associated with section AR 16, see Figure 4, which covers an array of sustainability matters. The covered matters are in the table below and the corresponding icons used throughout the final deliverable.

Figure 4

ESRS AR16 with classification icons used by the team.



ESRS	Topic	Sub-topic
E1	Climate change	Climate change adaptation
		Climate change mitigation
		Energy
E2	Pollution	Pollution of air
		Pollution of water
		Pollution of soil
		Pollution of living organisms and food resources
		Substances of concern
		Substance of very high concern
		Microplastics
E3	Water and marine resources	Water
		Marine resources
E4	Biodiversity and ecosystems	Direct impact drivers of biodiversity loss
		Impacts on the state of species
		Impacts on the extent and condition of ecosystems
		Impacts and dependencies on ecosystem services
E5	Circular economy	Resources inflows, including resource use
		Resource outflows related to products and services
		Waste

ESRS	Topic	Sub-topic
S1	Own workforce	Working conditions
		Equal treatment and opportunities for all
		Other work-related rights
S2	Workers in the value chain	Working conditions
		Equal treatment and opportunities for all
		Other work-related rights
S3	Affected communities	Communities' economic, social and cultural rights
		Communities' civil and political rights
		Rights of indigenous communities
S4	Consumers and end-users	Information-related impacts for consumers and/or end users
		Personal safety of consumers and/or end-users
		Social inclusion of consumers and/or end-users

ESRS	Topic	Sub-topic
G1	Business conduct	Corporate culture
		Protection of whistle-blowers
		Animal welfare
		Political engagement
		Management of relationships with suppliers including payment practices
		Corruption and bribery

Appendix B

Figure 5

United Nations Sustainable Development Goals

Note. U.N. SDGs overview (United Nations Department of Economic and Social Affairs, n.d.). The team utilized the United Nations Sustainable Development Goals (SDGs) to help provide recommendations to BWD. Figure 5 provides a brief overview of the SDGs.

Appendix C

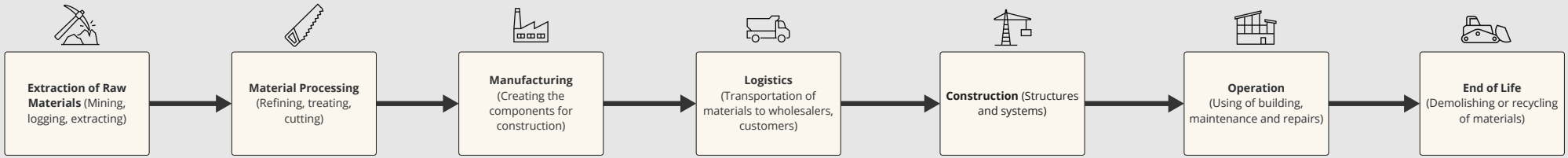
Concrete Value Chain: Notable Risks and Impacts

The team has further elaborated on the value chain visual with additional visuals per material that further illustrate the associated risks and impacts for the client. These include the top risks and impacts per material at each value chain stage. This will give BWD Strategic additional context into the various materials and risks and impacts associated. Additionally, this will provide the client with insight into why the team chose to prioritize E1 Climate change, E2 Pollution, E5 Circular economy practices, and S2 Workers in the value chain and provide recommendations on those topics. Appendices D, E, F, and G contain the other materials' remaining notable risks and impact visuals.

Figure 6
Concrete Value Chain: Notable Risks and Impacts

Appendix C
Concrete Value Chain - Notable Risks and Impacts

Legend: Environment | Social



Extraction of Raw Materials (Mining, logging, extracting)	Material Processing (Refining, treating, cutting)	Manufacturing (Creating the components for construction)	Logistics (Transportation of materials to wholesalers, customers)	Construction (Structures and systems)	Operation (Using of building, maintenance and repairs)	End of Life (Demolishing or recycling of materials)
Site locating, quarrying, and mining raw materials can lead to the displacement of local communities (UNDP, 2024).	Workers are exposed to health hazards such as silica dust, which can lead to silicosis and chemicals that pose various health risks (OSHA, 2023a).	The heavy machinery used in the process also increases the risk of workplace accidents and injuries (OSHA, 2023a).	Heavy trucks contributes to air and noise pollution, negatively impacting nearby communities' quality of life (EPA, 2024).	Heavy machinery and processes involved in concrete production and construction pose significant risks of accidents and injuries (Mehra et al., 2021).	Heavy machinery and equipment involved in concrete operations increase the risk of workplace accidents and injuries (ILO, 2022).	Improper disposal is often located in low-income or marginalized communities, exacerbating existing social inequalities. These communities bear the brunt of the health and environmental consequences, further entrenching social and economic disparities (EPA, 2024).
Raw material extraction can pollute the air, leading to health issues if inhaled (WHO, 2022).	Communities near concrete plants face health and safety concerns from air pollution caused by dust and particulate matter, which contribute to respiratory issues, and noise pollution from machinery and transport vehicles (World Health Organization, 2022).	Communities face health and safety concerns from air pollution and particulate matter, contributing to respiratory issues, and noise pollution from machinery and vehicles (WHO, 2022).	Logistics hubs and transportation routes for concrete can strain local infrastructure, leading to land use conflicts and potentially displacing local communities (UNDP, 2024).	Concrete presents risks and impacts to worker health and safety, from exposure to silica dust and can lead to respiratory disease (OSHA, 2023a).	Effective safety protocols and community engagement strategies are essential to mitigate these social risks and ensure more equitable construction practices (ILO, 2022).	Effective safety protocols, environmental regulations, and community engagement are essential to mitigate these social risks and impacts (EPA, 2021).
The high carbon footprint of the extraction process could lead to future regulation and economic impact (Nature, 2021).	Jobs in this sector can be low-paying, leading to economic inequality (ILO, 2022).	While concrete manufacturing can create jobs and stimulate local economic development, these benefits are often offset by the potential negative impacts on the environment and public health (UNDP, 2024).	While the logistics sector can create jobs, these are often low-paying with limited security, contributing to economic inequality and worker dissatisfaction (International Labour Organization, 2022).	Concrete is a thirsty behemoth, sucking up almost a 10th of the world's industrial water use (Watts, 2019).	Additionally, noise pollution from construction activities can disrupt nearby communities, affecting residents' quality of life (Raffetti et al., 2019).	Concrete waste can lead to illegal dumping, affecting community aesthetics and potentially contaminating local environments (EPA, 2021).
Industry's growth in Asia is accompanied by environmental concerns, such as air pollution and deforestation (Tkachenko, et al., 2023).	Significant source of CO2 emissions due to the calcination process, contributing significantly to global greenhouse gas emissions (International Energy Agency, 2022).	Cement is considered one of the most essential building materials, and cement manufacturing emissions account for around 5% of global carbon dioxide (CO2) emissions (Raffetti et al., 2019).	The transportation process often involves the creation of extensive road networks and infrastructure, leading to habitat disruption and land degradation (EPA, 2024).	In cities, concrete also adds to the heat-island effect by absorbing the warmth of the sun and trapping gases from car exhausts and air-conditioner units (Watts, J., 2019).	Concrete exacerbates the heat island effect, resulting in more challenging living conditions for natural habitats within proximity (NASA, 2009).	Recycling concrete helps divert waste from landfills and minimizes the environmental impacts of new material extraction (IEA, 2022).
the cement industry is the third largest source of industrial air pollution, such as sulfur dioxide, nitrogen oxides (NOx), and carbon monoxide (Singla & Stashwick, 2022).	The combustion of fossil fuels in cement kilns produce pollutants such as sulfur dioxide (SO2), nitrogen oxides (NOx), and volatile organic compounds (VOCs), degrading air quality, and contributing to acid rain (World Health Organization, 2022).	The kiln process is fueled by the "burning of powdered coal, oil, alternative fuels, or gas under forced draft (PCA, 2024).	Trucks emit substantial amounts of carbon dioxide (CO_2) and other pollutants, such as nitrogen oxides (NOx) and particulate matter, contributing to air pollution (EPA, 2024).	Concrete outweighs the combined carbon mass of every tree, bush and shrub on the planet (Watts, J., 2019).	Non-permeable concrete can aid in water depletion on a property or area due to run-off, directly affecting trees, plants, and animals that rely on on-site water (Denchak, 2022).	Improper disposal of concrete waste can lead to land degradation and pollution of soil and water bodies, mainly if hazardous substances are present (Gebremariam et al., 2020).

Figure 7

Glass Value Chain: Notable Risks and Impacts

Appendix D
Glass Value Chain - Notable Risks and Impacts

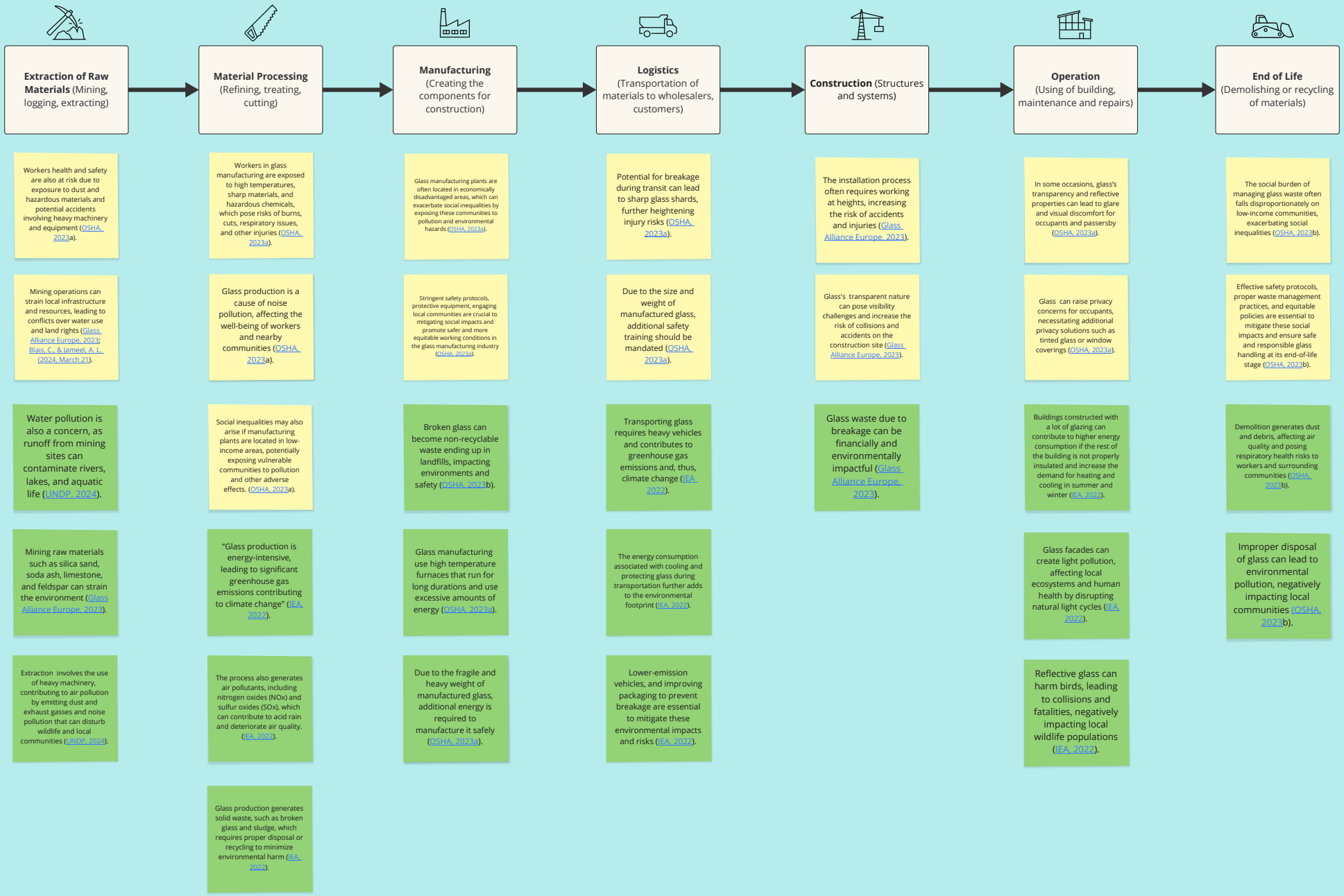
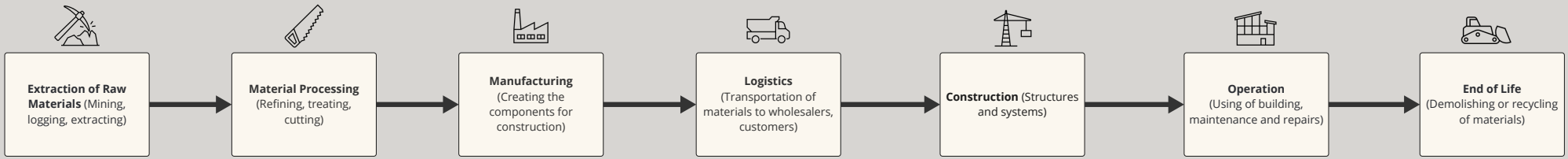


Figure 8
Steel Value Chain: Notable Risks and Impacts

Appendix E
Steel Value Chain - Notable Risks and Impacts

Legend: Environment | Social



Extraction of Raw Materials	Material Processing	Manufacturing	Logistics	Construction	Operation	End of Life
Steel production contributes significantly to global CO2 emissions, impacting climate change (Shao & Zhang, 2022).	High energy consumption contributes significantly to CO2 emissions and climate change (Fente & Tsegaw, 2024).	Highly energy-intensive, leading to significant greenhouse gas emissions (Goyal et al., 2020).	Greenhouse gas emissions from transportation by road, rail, and sea (Suneja, 2022).	High energy usage and greenhouse gas emissions from steel construction (Kachomba et al., 2024).	Emissions from maintenance activities contribute to climate change (Kachomba et al., 2024)	Recycling steel reduces the need for new raw materials (Hemmati et al., 2024).
Air, water, and sHigh demand for iron ore and coking coal leads to deforestation and land use issues (Shao & Zhang, 2022).	Emissions of sulfur dioxide (SO2) and nitrogen oxides (NOx) degrade air quality (Fente & Tsegaw, 2024).	Emissions of sulfur dioxide (SO2) and Pollutants such as SO2 and NOx affect air quality (Goyal et al., 2020).	Environmental contamination from runoff at storage sites (Suneja, 2022).	Pollution from construction site waste, including metal and packaging (Kachomba et al., 2024).	Improper disposal of materials contaminates soil and water (Kachomba et al., 2024)	Demolition activities release pollutants and greenhouse gases (Hemmati et al., 2024).
Mining activities result in water pollution due to the discharge of industrial waste (Shao & Zhang, 2022).	Water contamination from heavy metals and toxic chemicals (Fente & Tsegaw, 2024).	Water pollution from industrial waste discharge (Goyal et al., 2020).	High energy consumption during transportation (Suneja, 2022).	Oil spills and noise pollution from heavy equipment use (Kachomba et al., 2024).	High energy use for operations and repairs (Kachomba et al., 2024)	Contaminants from demolished structures can pollute soil and water (Hemmati et al., 2024).
Poor working conditions and safety risks for miners (Fu et al., 2024).	Workers face hazardous conditions and long hours (Fente & Tsegaw, 2024).	Poor working conditions and health risks from hazardous materials (Fu et al., 2024).	Poor working conditions and low wages for logistics workers (Suneja, 2022).	Poor working conditions and low wages, especially in countries with lax labor laws (Kachomba et al., 2024).	Hazardous working conditions for maintenance workers (Kachomba et al., 2024).	Health hazards for demolition workers from exposure to harmful substances (Hemmati et al., 2024).
Displacement of local communities causing social unrest (Fu et al., 2024).	Low wages and inadequate safety measures (Fente & Tsegaw, 2024).	Long working hours and inadequate safety measures (Fu et al., 2024).	Increased accidents and fatalities on hazardous routes (Suneja, 2022).	Health risks from exposure to hazardous materials (Kachomba et al., 2024).	Need for skilled labor, leading to exploitation in regions with weak labor laws (Kachomba et al., 2024).	Improper waste handling can lead to community health issues (Hemmati et al., 2024).
Child labor and forced labor in regions with weak labor regulations (Fu et al., 2024).	Health risks from exposure to dangerous materials (Fente & Tsegaw, 2024).	Displacement of local communities due to large-scale plants (Fu et al., 2024).	Need for fair labor practices and safe working environments (Suneja, 2022).	Displacement of communities due to large construction projects (Kachomba et al., 2024).	Implementation of fair work practices to safeguard workers' rights (Kachomba et al., 2024).	Recycling industry can provide jobs but poses health and safety risks (Hemmati et al., 2024).

Figure 9
Timber Value Chain: Notable Risks and Impacts

Appendix F
Timber Value Chain - Notable Risks and Impacts

Legend Environment | Social

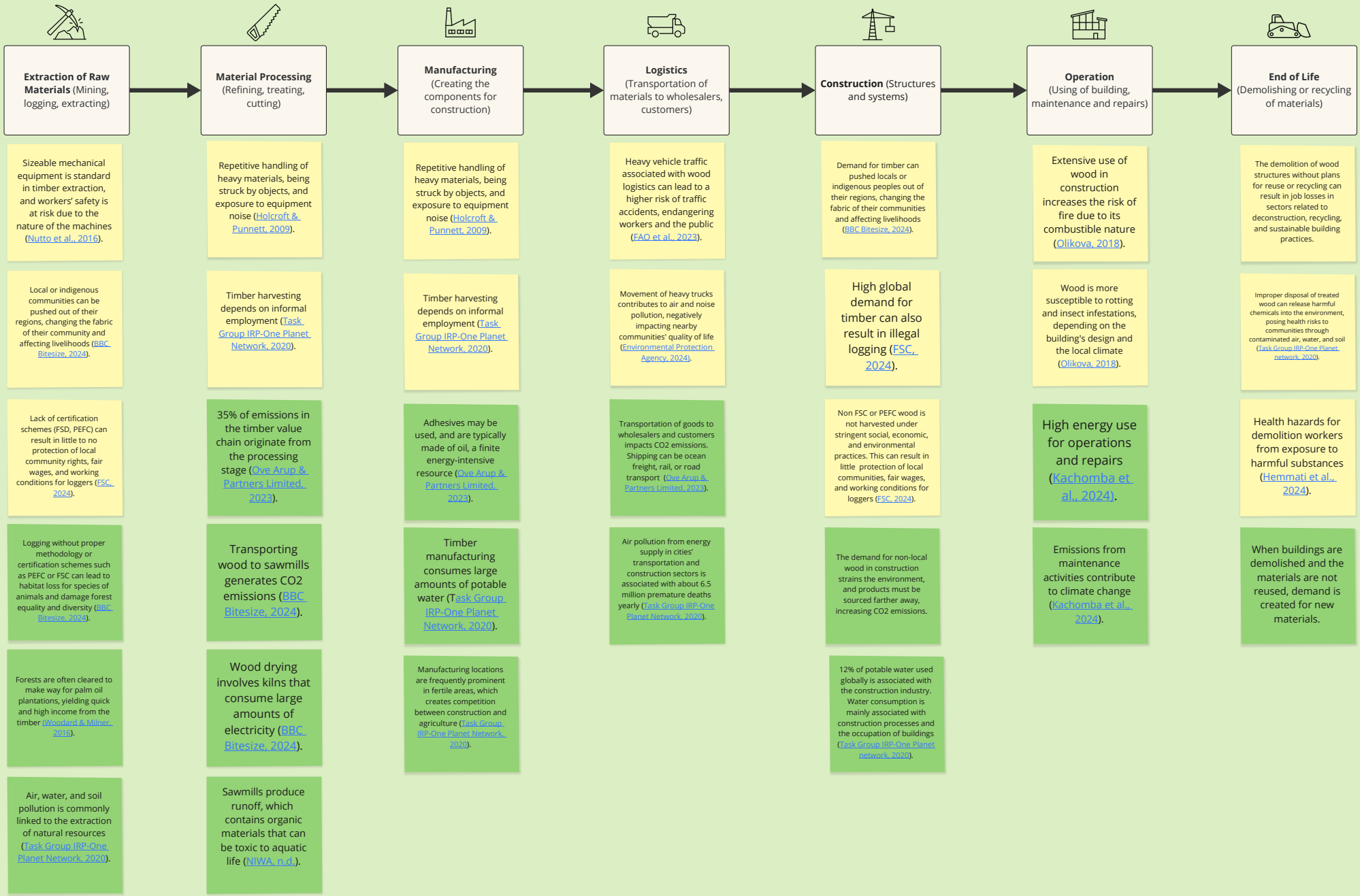


Figure 10
Brick Value Chain: Notable Risks and Impacts

Appendix G
Brick Value Chain - Notable Risks and Impacts

Legend Environment Social