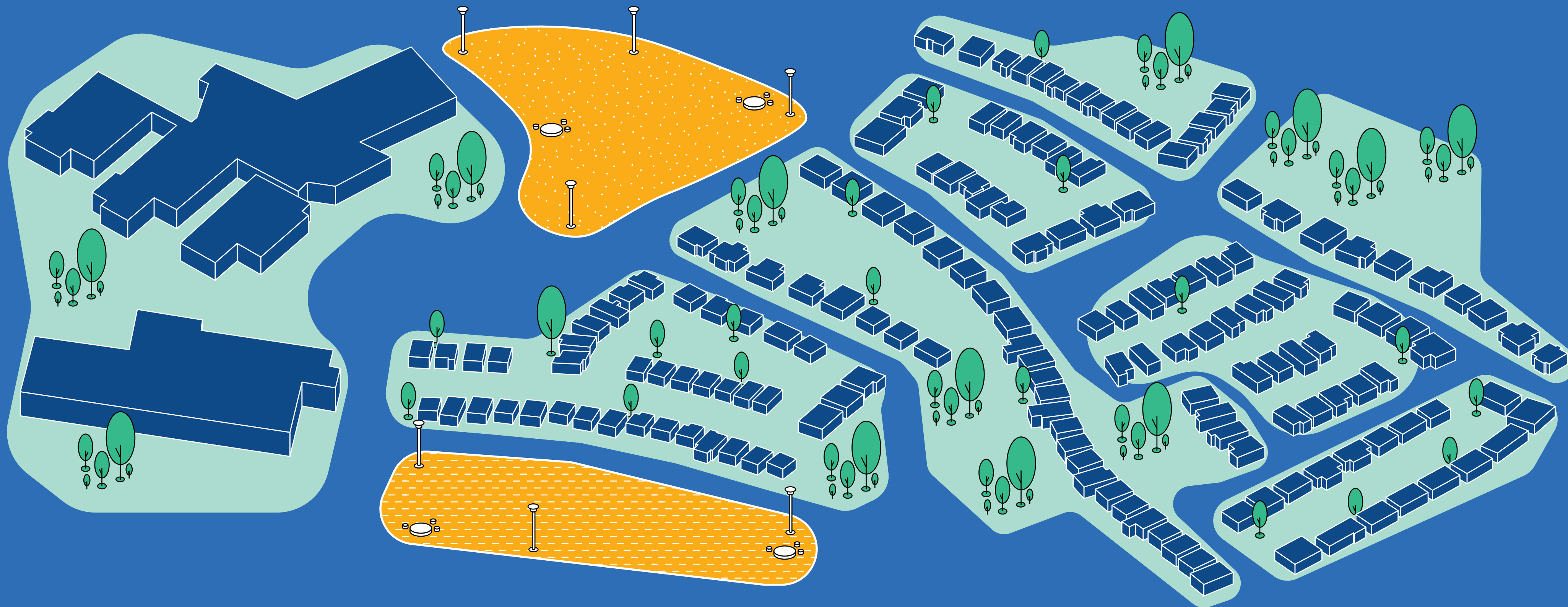
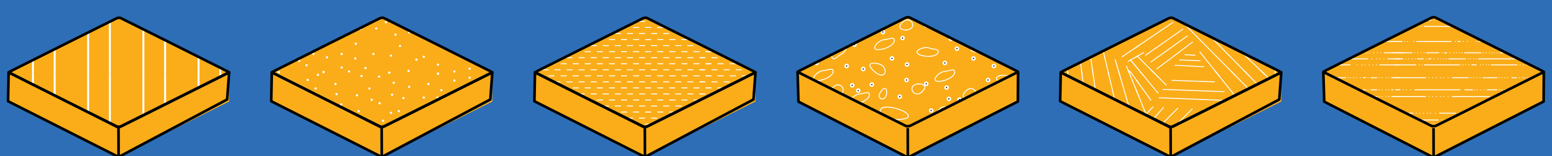


Materials Matter

Designing the Climate Responsible City



Credits + Acknowledgements

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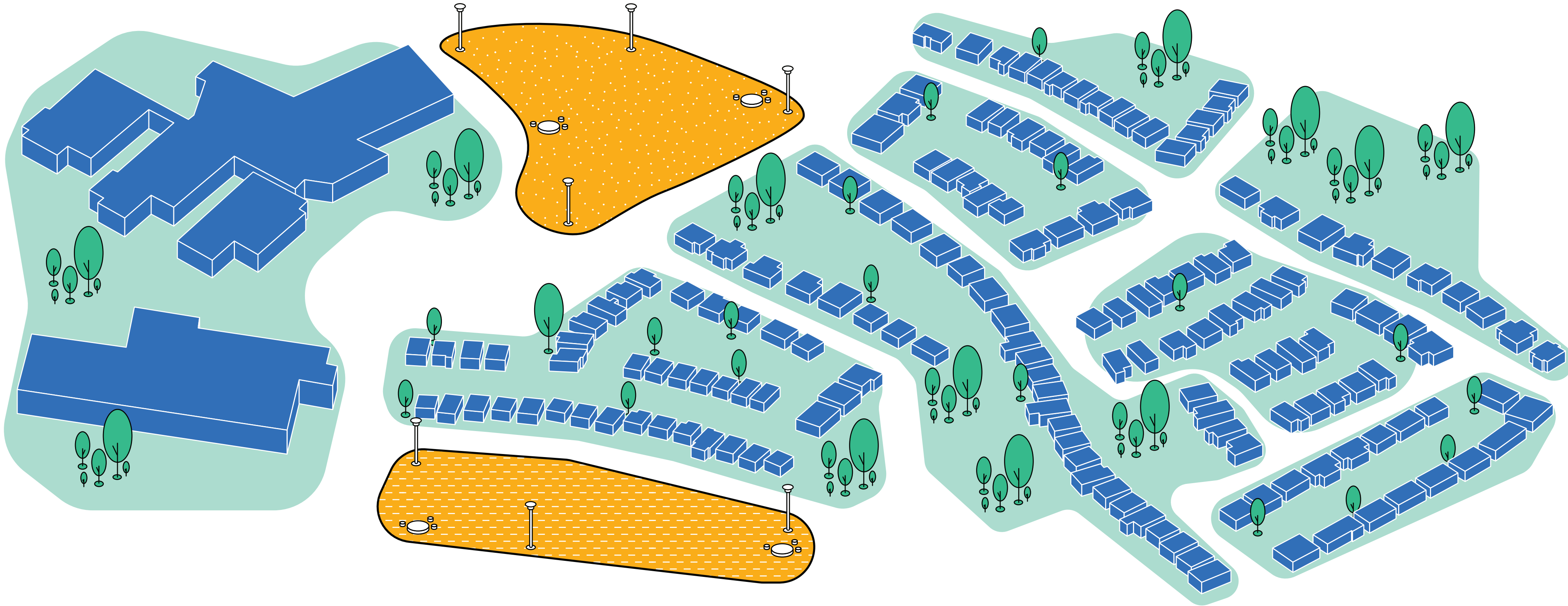
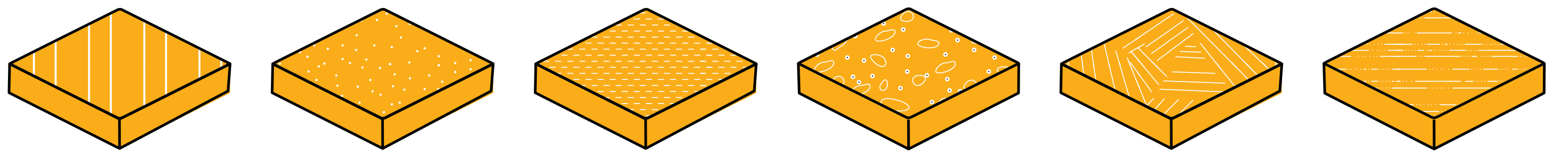


Materials Matter

Designing the Climate Responsible City



Foreword

Following the path of our publication *Designing the Climate Responsible City*, which focused on decarbonization through urban form, in this document Constantine Chrisafis and Briana Weekes present practices for reducing embodied greenhouse gas emissions through materials and processes used in site design. Since construction of streets, landscapes and urban spaces traditionally employs processes and materials that are carbon intensive, new practices and product selections are critically needed to achieve climate-positive design outcomes.

Through their Internship with the UW Green Futures Lab and Schulze + Grassov Urban Design, Constantine and Bri have identified principles for climate mitigative site design, suggested ideal circular construction practices, analyzed manufacturing methods and materials that reduce embodied CO2 and even sequester carbon, and characterized case studies that inspire and prove that site planners and designers can do their part to help solve the climate crisis. Recognizing that decarbonization in site design and materials is an emerging field, they have illuminated construction and manufacturing processes in clear diagrams and drawings, to help designers understand how to pivot from traditional practices to discover and embrace climate-responsible methods and materials.

We are profoundly grateful to the Scan Design Foundation for funding this internship and guide, and hope that it will inform, catalyze and support the important climate-positive work of engineers, urban designers, landscape architects, and site builders. Please do download the booklet from the UW Green Futures website: www.greenfutures.washington.edu, and use it to help create Climate Responsible Cities!

Nancy Rottle

Director, UW Green Futures Lab

Professor Emeritus, UW Department of Landscape Architecture

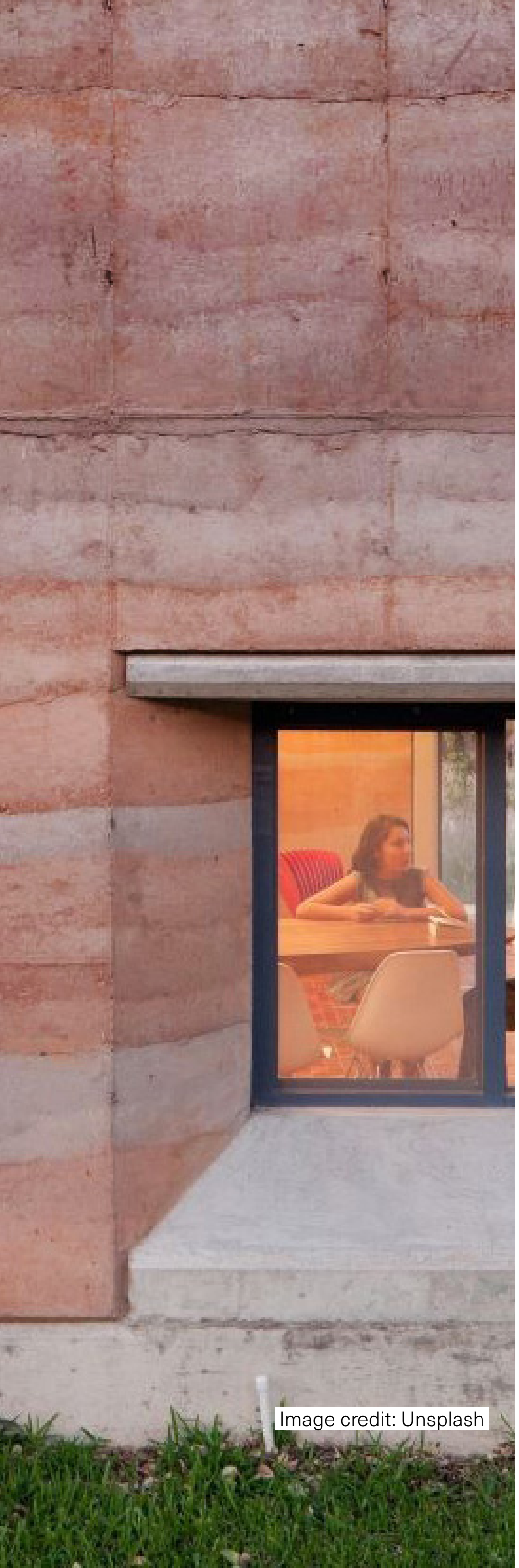


Image credit: Unsplash

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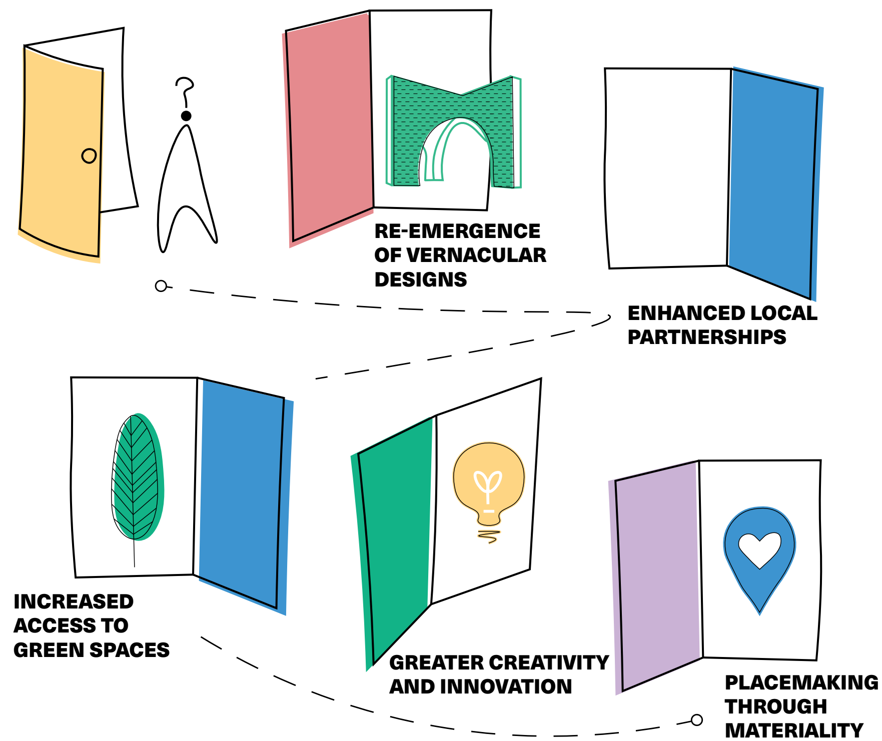
Introduction

Principles

In every project, material selection is a key opportunity for designers to mitigate carbon emissions and contribute to a climate-responsible built environment. By using sustainable materials, landscape architects and urban designers play a vital role in reducing the carbon footprint of urban spaces. This section outlines the principles of climate-responsible material selection that can guide designers in creating impactful, low-carbon projects.

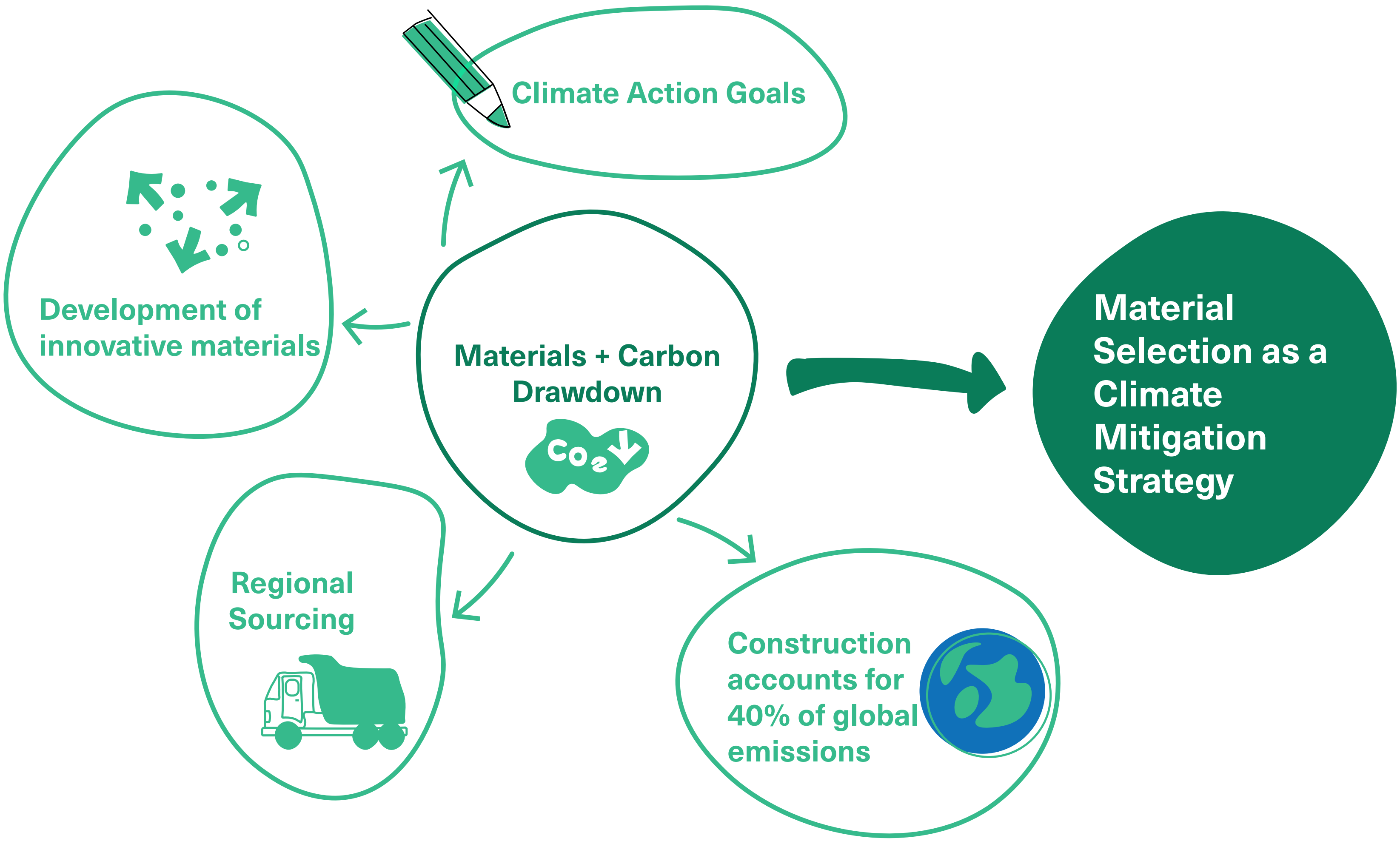
The construction sector is responsible for 40% of global carbon emissions, with material production alone accounting for a significant portion. Each material choice has an impact on emissions, energy use, and resource depletion.

Through selection of climate-mitigative materials, designers can reduce the environmental impact of their projects at every scale, from site-specific interventions to broader urban developments.



Benefits of Climate-Responsible Material Selection

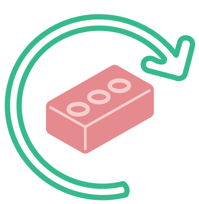
Why Focus on Material Selection for Climate Mitigation?



Principles for Climate Mitigative Material Selection

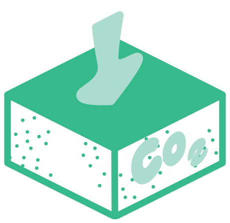
This guide aims to inspire the application of innovative techniques and provide insight into leveraging emerging technologies and methodologies to promote carbon draw-down in the public sphere.

It highlights exemplary cases of material selection and holistic practices based on a set of operational principles described in the following section. These principles serve as a cornerstone in the ever-evolving landscape of carbon-mitigative design.

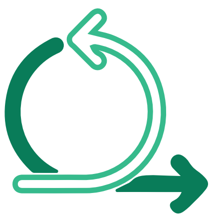


Utilize Secondary Materials

Use Bio-Based Materials



Pursue Innovative Methods for Carbon Sequestration



Create Flexible Designs

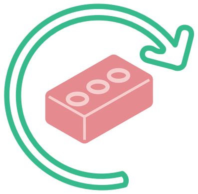
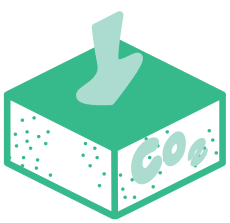
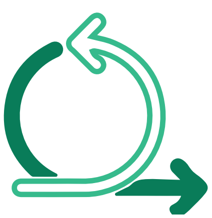
Source from Regional Contexts

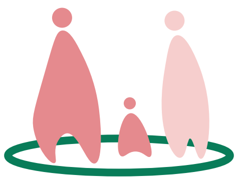
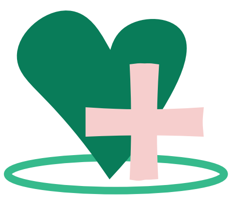
Support Community Identity

Elevate Well-being

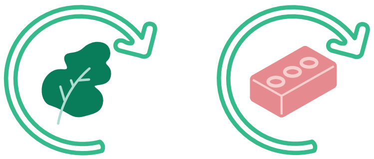
Be an Advocate

Principles for Climate Mitigative Material Selection

Icons	Principle	Description	Characteristics and Evaluation Metrics
	**Utilize Secondary Materials**	Prioritize secondary materials and utilize waste as a resource.	• Percentage of recycled content in design • Proportion of secondary materials to virgin materials • Plans and systems for responsible disposal or recycling of products and materials at the end of their life cycle
	**Bio-based Materials**	Promote renewable and bio-based materials.	• Percentage of bio-based materials in the total material composition of design • Carbon draw-down achieved by using bio-based materials • Certifications for bio-based materials
	**Pursue Innovative Methods for Carbon Sequestration**	When possible, pursue innovative carbon sequestering materials.	• Number of new, innovative materials tested and adopted • Rate of adoption of new sustainable material innovations • Investment in research and development for innovative materials • Policy becoming more flexible to allow incorporation of new innovative materials
	**Create Flexible Designs**	Consider material disassembly within the design to foster longevity.	• Categorize the various uses of the assembled materials • Anticipate potential changes and evaluate how well the design can adapt • Evaluate how easily the design can be disassembled for reuse or recycling

	**Source from Regional Contexts**	Source regionally to reduce impacts from transportation + vernacular representation.	• Percentage of materials sourced regionally • Vernacular representation of materials • Reduction in transportation-related emissions • Contribution to local economy and job creation • Impact on local policy for innovative materials
	**Support Community Identity**	By reusing structures + materials, cultural and historic fabrics of the city remain intact.	• Relate to historic fabrics by reusing materials in cultural landscape • Designs + materials make people feel welcome • Impact on local communities and labor conditions
	**Elevate Well-being**	Non-toxic material choices positively benefit both human and environmental health. Material also affects overall wellbeing.	• Quantify the degree of toxicity in materials to ensure they do not pose health risks • Assess the aesthetic qualities of materials to ensure they contribute to a visually pleasing urban environment • Evaluate the impact of materials on indoor and outdoor air quality
	**Be an Advocate**	Persist and maintain momentum in shifting practice around material use.	• Persistence in material changes • Advocacy initiatives or partnerships • Mentality sharing for more circular practice • Influence on industry and policy changes • Changing standards for firm or city practice

Closing the Loop



Traditional design practices follow a linear approach, where materials are extracted, used, and ultimately disposed of. This extractive mindset has led to significant environmental degradation and carbon emissions, contributing to the climate crisis. To address these issues, we can shift toward circular principles, re-imagining how materials are sourced, used, and re-purposed to create closed-loop systems that prioritize resource efficiency.

Circular Design Principles

Recycling and Reuse

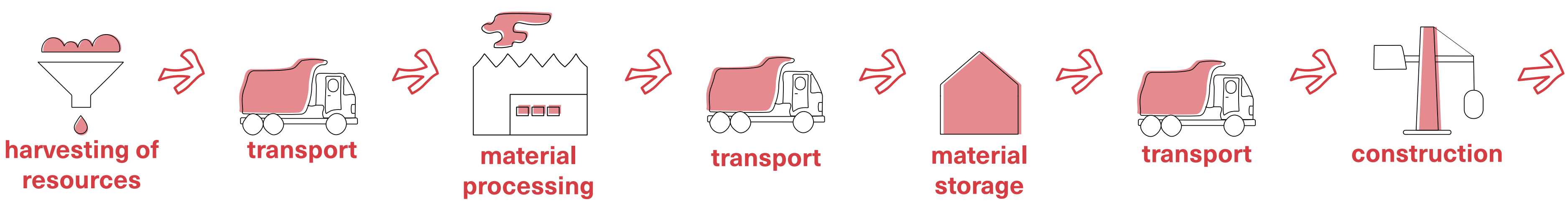
Incorporate recycled or reclaimed materials wherever possible to minimize waste and reduce the need for new resources.

Design for Disassembly

Create designs that can be easily dismantled, allowing materials to be reused or recycled at the end of the project's life.

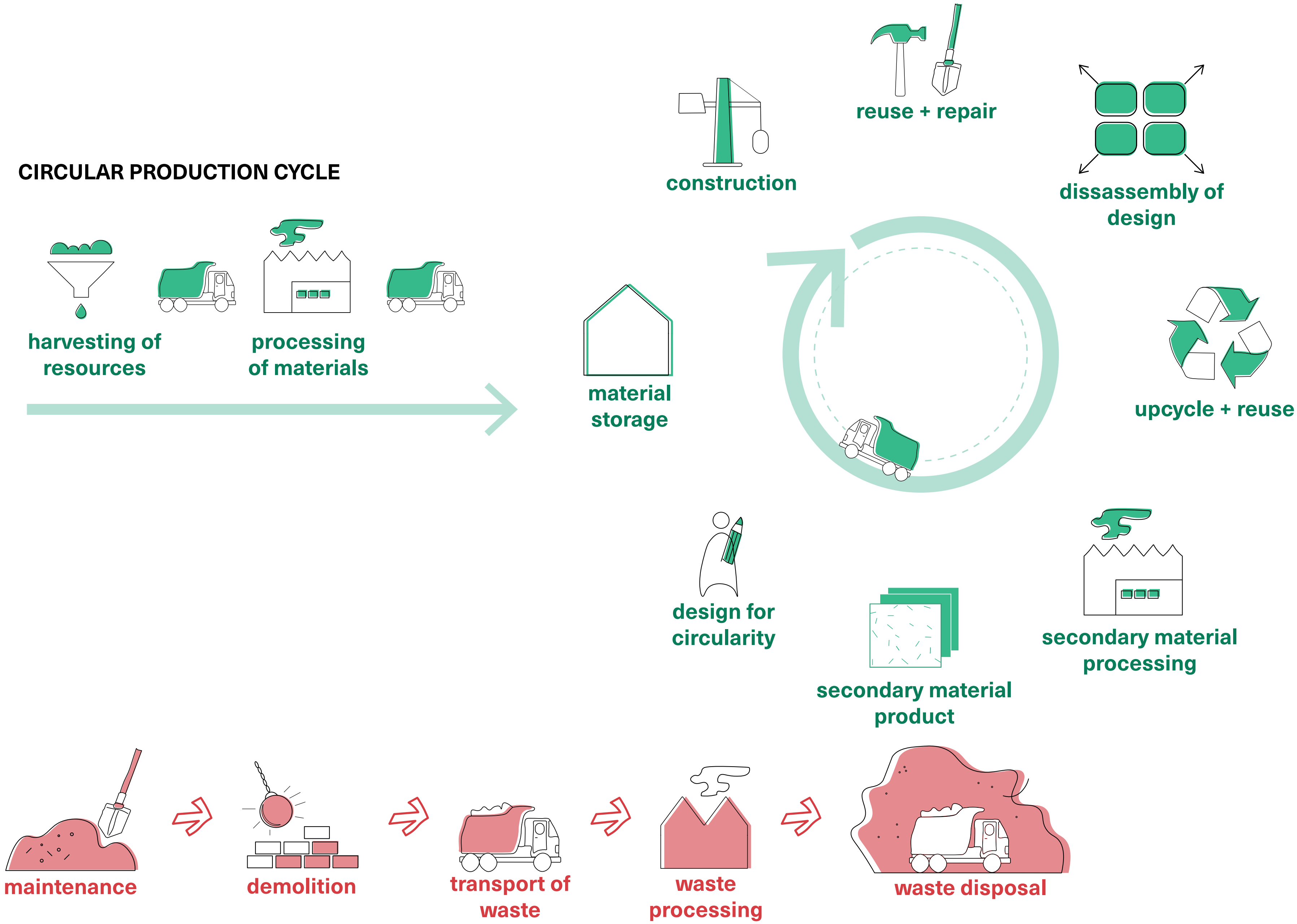
Long-Term Value

Select materials with durability and flexibility in mind, ensuring that they can adapt to changing needs over time without requiring replacement.

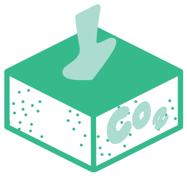


LINEAR PRODUCTION CYCLE

CIRCULAR PRODUCTION CYCLE



Understanding Embodied Carbon Impacts



Different materials have varying levels of embodied carbon, depending on their extraction, manufacturing, and transportation processes. Recognizing the carbon intensity of common construction materials is essential for reducing the overall carbon footprint of a project.

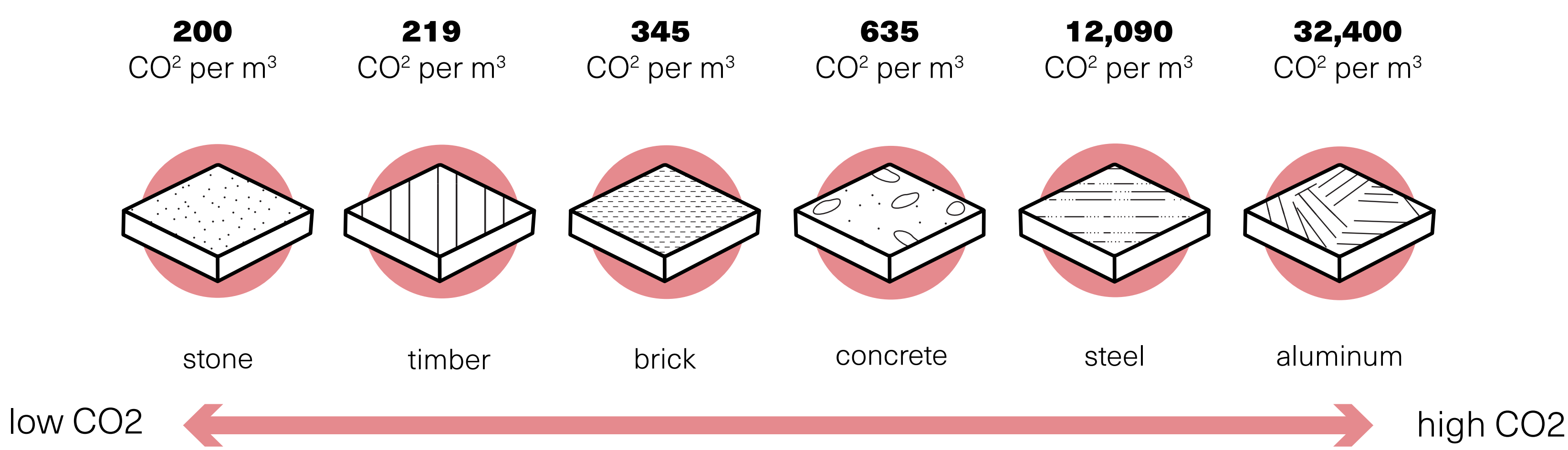
High CO2 Intensity Materials

Steel

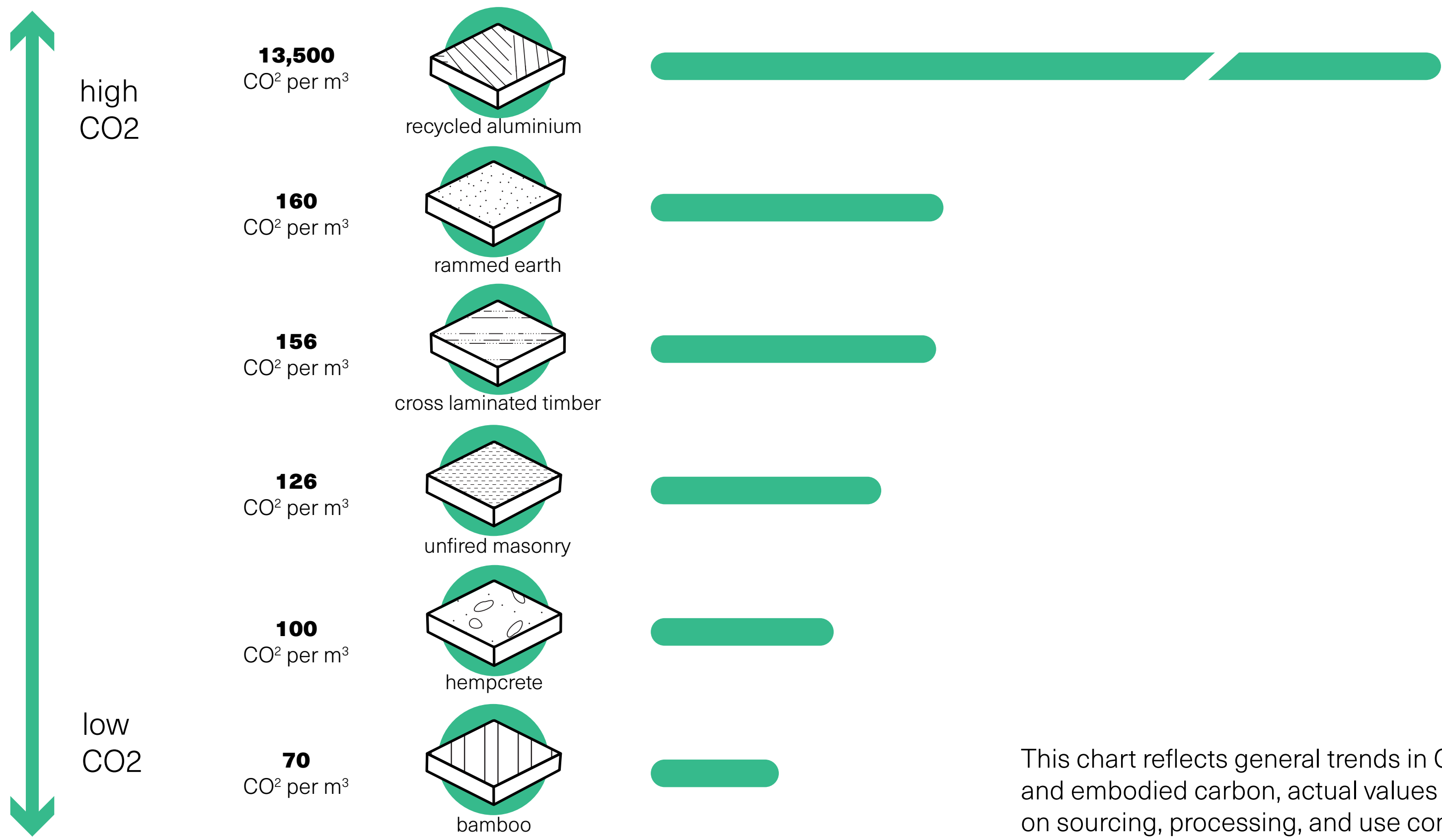
Steel production is energy-intensive, with significant CO2 emissions due to its reliance on fossil fuels for iron extraction and processing.

Concrete

Standard concrete production releases substantial CO2, largely from the heating of limestone and chemical reactions in cement production.



Embodied Carbon



This chart reflects general trends in CO_2 emissions and embodied carbon, actual values can vary based on sourcing, processing, and use conditions.

Low CO2 Intensity Materials

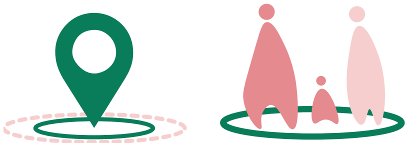
Timber

Sustainably harvested cross laminated timber stores carbon and offers a renewable alternative to carbon-intensive materials like steel and concrete.

Recycled and Bio-Based Options

Materials like recycled aluminium or hempcrete have lower carbon footprints due to reduced energy needs and carbon-sequestering properties.

Reducing Carbon through Local Sourcing



Regional sourcing is an effective strategy for reducing the carbon footprint associated with transportation. By using materials available within a designated radius, designers can limit emissions while supporting local industries and fostering a sense of place in their projects.

Benefits of Regional Sourcing

Locally sourced materials often have unique characteristics that enhance the cultural identity and ecological resilience of a project. By incorporating these materials, designers can create spaces that feel rooted in their surroundings, contributing to sustainability and community pride.

SITES Regional Sourcing Guidelines

50-Mile Radius: Soils, compost, mulch, rocks, and aggregates should ideally be sourced within 50 miles of the project site.

250-Mile Radius: Plants and vegetation native to the region should be prioritized within a 250-mile range.

500-Mile Radius: All other materials, where possible, should be sourced within 500 miles.

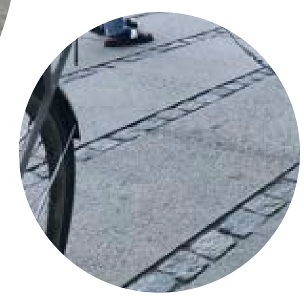


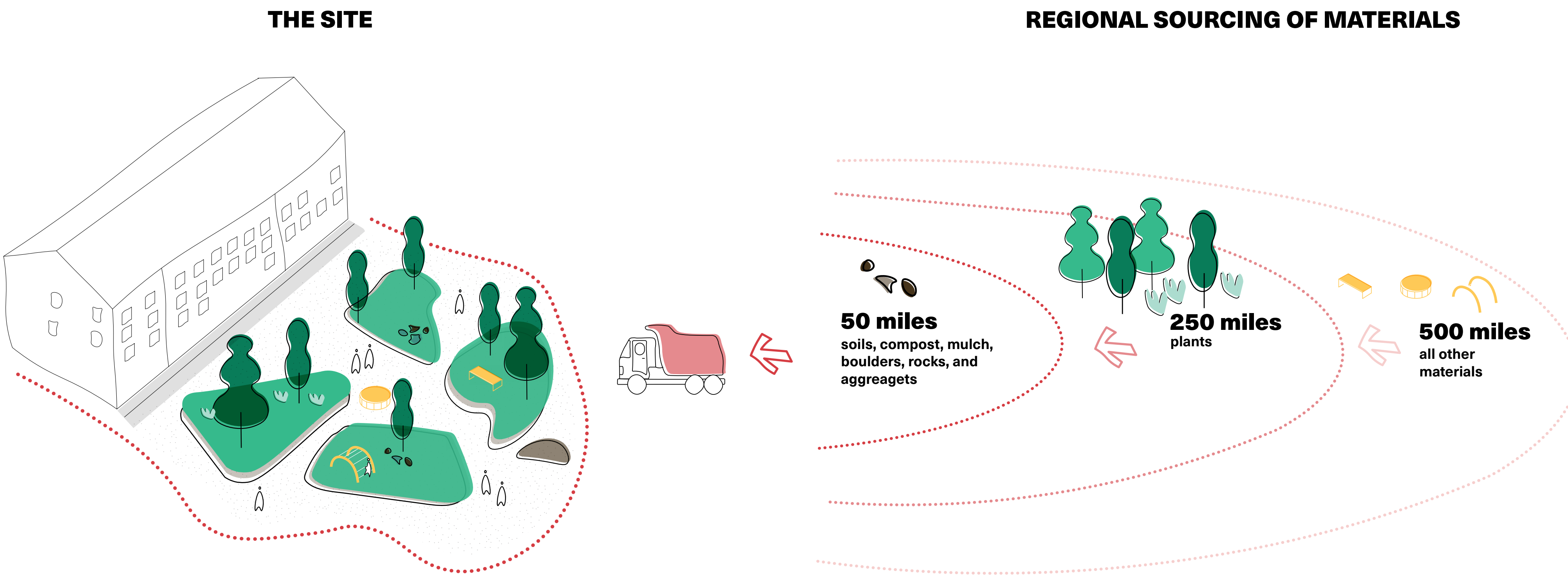
Image credit: Unsplash

Case Study: Copenhagen's Sidewalk Pavers

Copenhagen's standardized sidewalk pavers are a seminal example of designers prioritizing local materials to create contextually relevant urban infrastructure.

These blocks, crafted from locally sourced granite, reflect a conscious choice to minimize transportation emissions and reduce reliance on imported materials. The stone is durable and well-suited to Copenhagen's climate, reducing the need for frequent replacements and maintenance.

SITES Regional Sourcing Guidelines



How Far is Local?

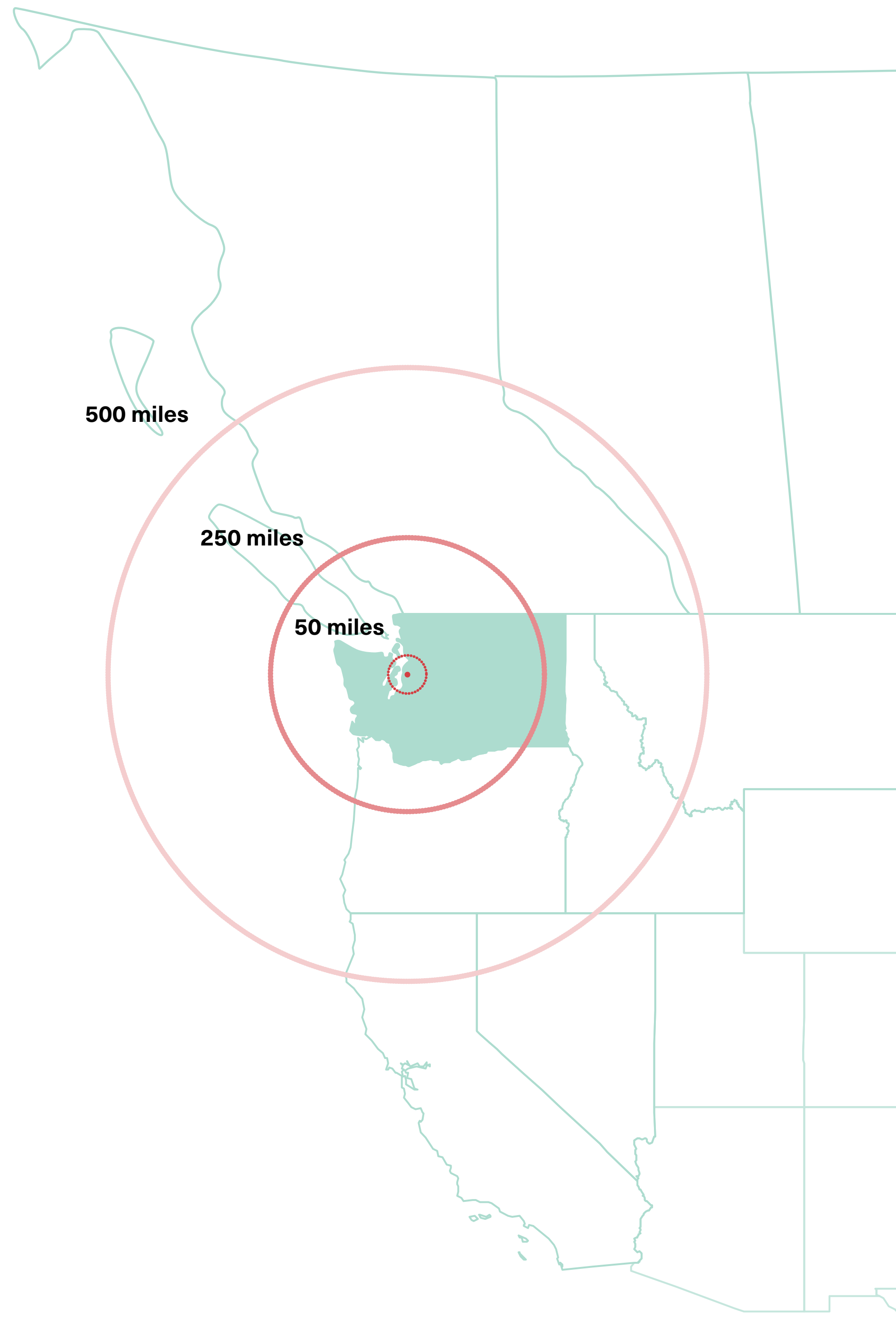
For urban designers focused on carbon reduction, "local" is not a fixed distance but a flexible concept that considers the environmental impact of sourcing materials in each specific context. To illustrate, cities like Seattle and Copenhagen serve as examples.

Case Study: Seattle and Copenhagen

Both Seattle and Copenhagen provide models for defining local sourcing based on geographic context. These maps show how the SITES framework would apply to their respective geographic contexts.

Washington State + Denmark

Washington is about 4x larger than Denmark



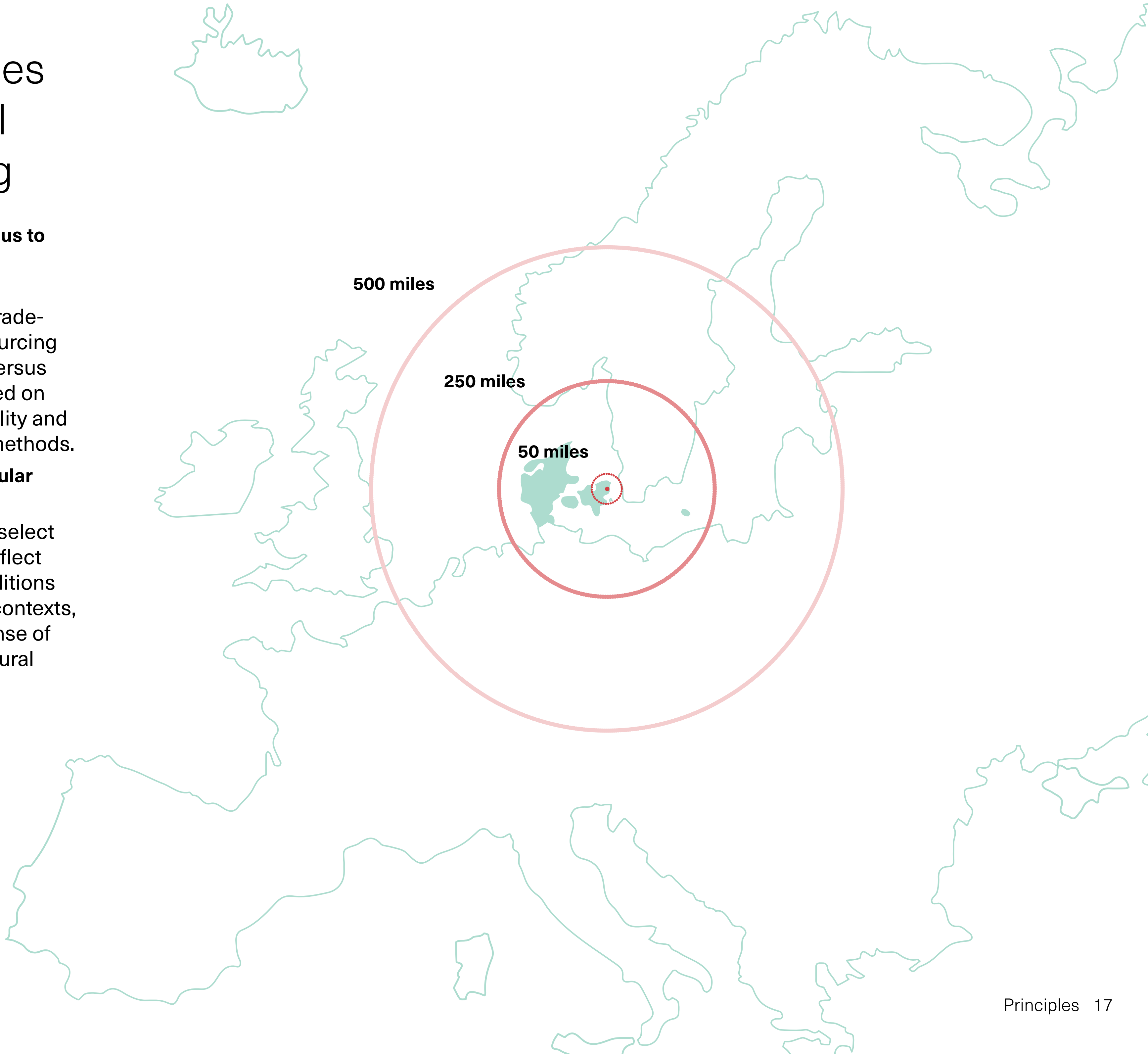
Guidelines for Local Sourcing

Adapt Local Radius to Project Needs

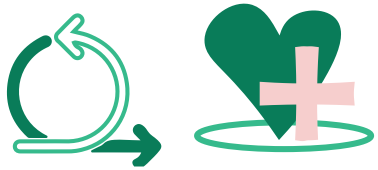
Consider the environmental trade-offs between sourcing within smaller versus larger radii, based on material availability and transportation methods.

Integrate Vernacular Materials

When possible, select materials that reflect local design traditions and ecological contexts, reinforcing a sense of identity and cultural continuity.



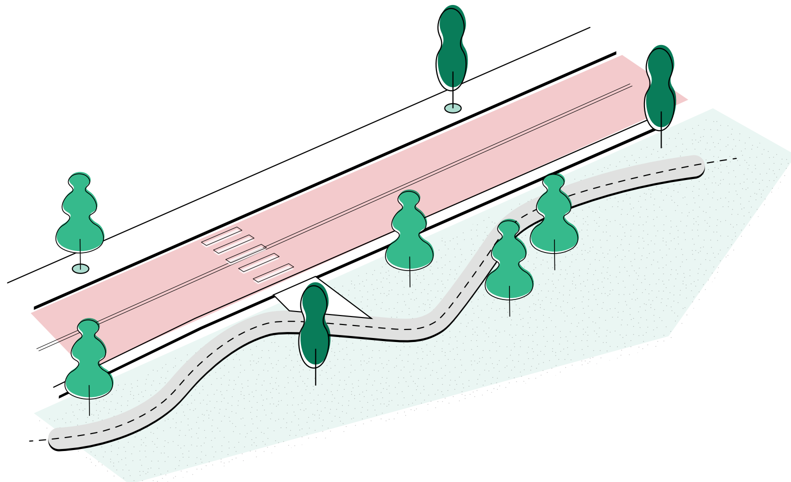
Urban Space Typologies for Climate Mitigation



Urban Typologies for Climate-Responsive Design

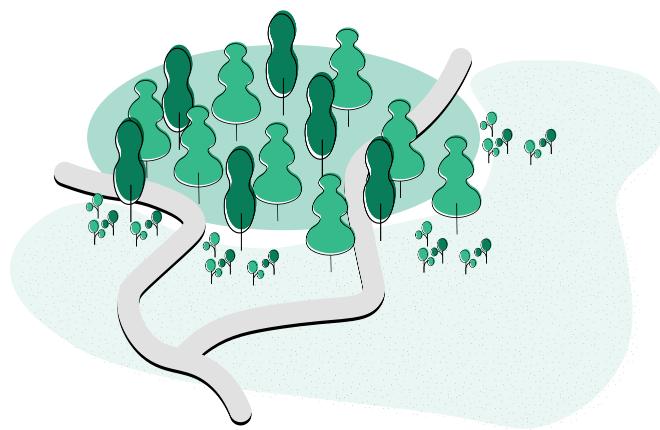
Each urban space typology has unique opportunities for climate-mitigative design through targeted material selection and layout. From transit corridors to wetlands, these spaces can significantly impact urban resilience and carbon reduction.

Climate responsible material selection may differ, depending on these contexts. For example, low carbon concrete alternatives could be useful in urban bike, transit and road corridors, while biogenic additives (such as biochar) could be more useful in applications for urban forests.



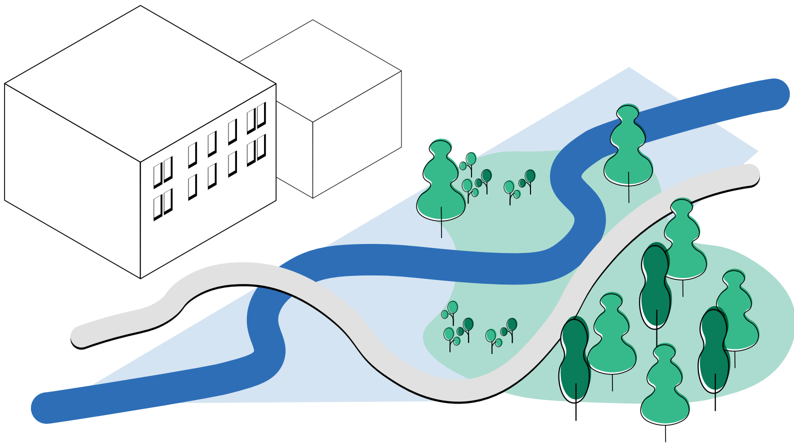
Urban Bike, Transit, and Road Corridors

By designing active transit corridors with permeable, recycled, or low-carbon materials, cities can reduce the environmental impact of transportation infrastructure.



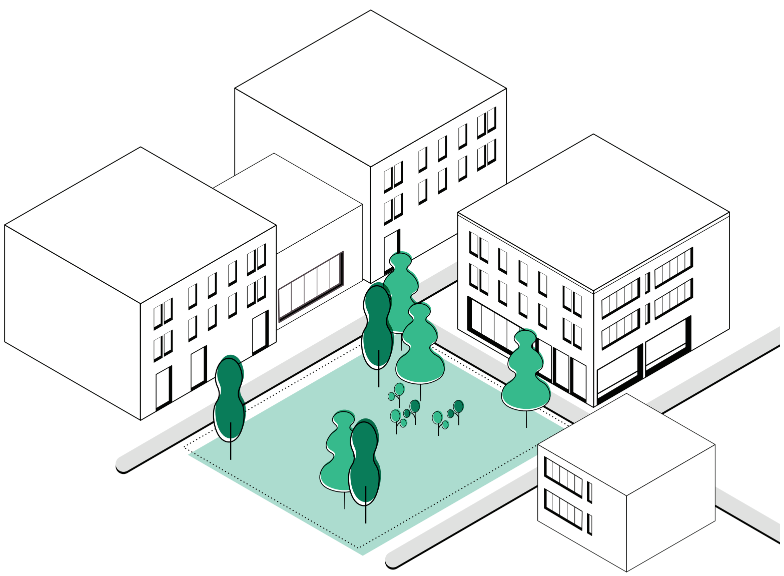
Parks and Urban Forests

Incorporating native tree species and bio-based materials in parks and urban forests supports both carbon sequestration and biodiversity.



Urban Water and Wetland Systems

Designing wetland systems with bio-based, low-impact materials can enhance water management, mitigate flooding, and improve urban ecology while sequestering atmospheric carbon.



Urban Public Space

Public squares and parks with sustainable paving, seating, and shade structures help reduce heat, foster community connections, and promote a more eco-friendly urbanism.

Current Limitations: Be Part of the Solution

As landscape architects and urban designers strive to integrate climate-responsive materials into their projects, several challenges can impede progress.

By understanding these obstacles, designers can develop a suite of strategies to navigate and overcome them. These fit together, like pieces in a puzzle to help foreground climate responsible material selection across projects.

Market Availability of Carbon-Mitigative Products

Challenge

Many innovative materials are still in early production stages, making them difficult to source in large quantities or at competitive prices.

Solution

Instead of relying on a single emerging material to replace a conventional option, use lower-carbon alternatives and incorporate innovative materials into landscape details or smaller features.

Policy and Safety Requirements for Materials and Products

Challenge

Building codes, safety regulations, and permitting processes can prevent the adoption of new materials, particularly those that haven't been tested in large-scale applications.

Solution

Third-party certified materials (e.g., Cradle to Cradle, EPD-certified products) already meet code requirements and can help in identifying materials that have already been tested. Emerging innovative materials can be easily used in small-scale pilot projects or temporary installations.

Capacity of Firms to Implement New Design Techniques

Challenge

Many firms lack the expertise, budget, or time to experiment with novel material applications, leading them to default to conventional selections.

Solution

Start small, integrate one or two new materials per project, and build internal capacity by attending material workshops, working with suppliers offering technical support, or partnering with research institutions.

Current Limitations

Greenwashing of Products

Challenge

Sustainability has become a marketing buzzword and some materials may be falsely advertised without sufficient transparency about their lifecycle impacts.

Solution

Verify claims through independent databases like the Carbon Leadership Forum's Embodied Carbon in Construction Calculator (EC3), Material ConneXion, or Declare Labels. Conducting basic lifecycle assessments (LCA) and asking manufacturers for Environmental Product Declarations (EPDs) can also provide clarity on a product's true impact.

Practitioner Expertise in Climate Mitigation

Challenge

Many designers are not trained in embodied carbon analysis or circular economy principles, making it harder to confidently specify sustainable materials.

Solution

Leverage free online tools such as the Embodied Carbon in Construction Calculator (EC3), take short courses on life cycle analysis (LCA), or join communities like the Carbon Leadership Forum to stay updated on best practices.

Climate Responsible

Material Library

Material Library

Introduction

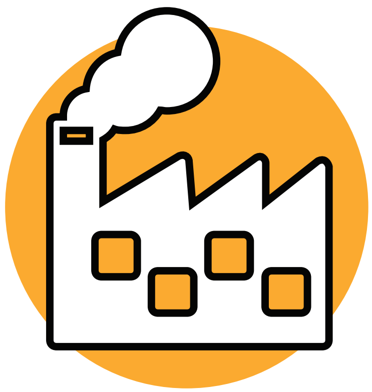
In the pursuit of sustainable urban design, landscape architects and urban designers face a critical challenge: reducing the environmental impact of materials used in the built environment.

Approximately 75% of a built project's carbon emissions arise from material extraction, manufacturing, transportation, and installation processes (Weir, Rempher, and Esau 2023).

Recognizing the urgency of combating climate change, the American Society of Landscape Architects (ASLA) has introduced a Climate Action Plan aiming to eliminate embodied carbon emissions from projects by 2040 (ASLA 2023). Achieving this ambitious goal requires a transformative approach to material selection and specification.

Purpose of the Library

This library highlights a curated selection of low carbon and carbon-sequestering materials, both mineral- and bio-based, to inspire and guide practitioners. Each material entry is designed to:

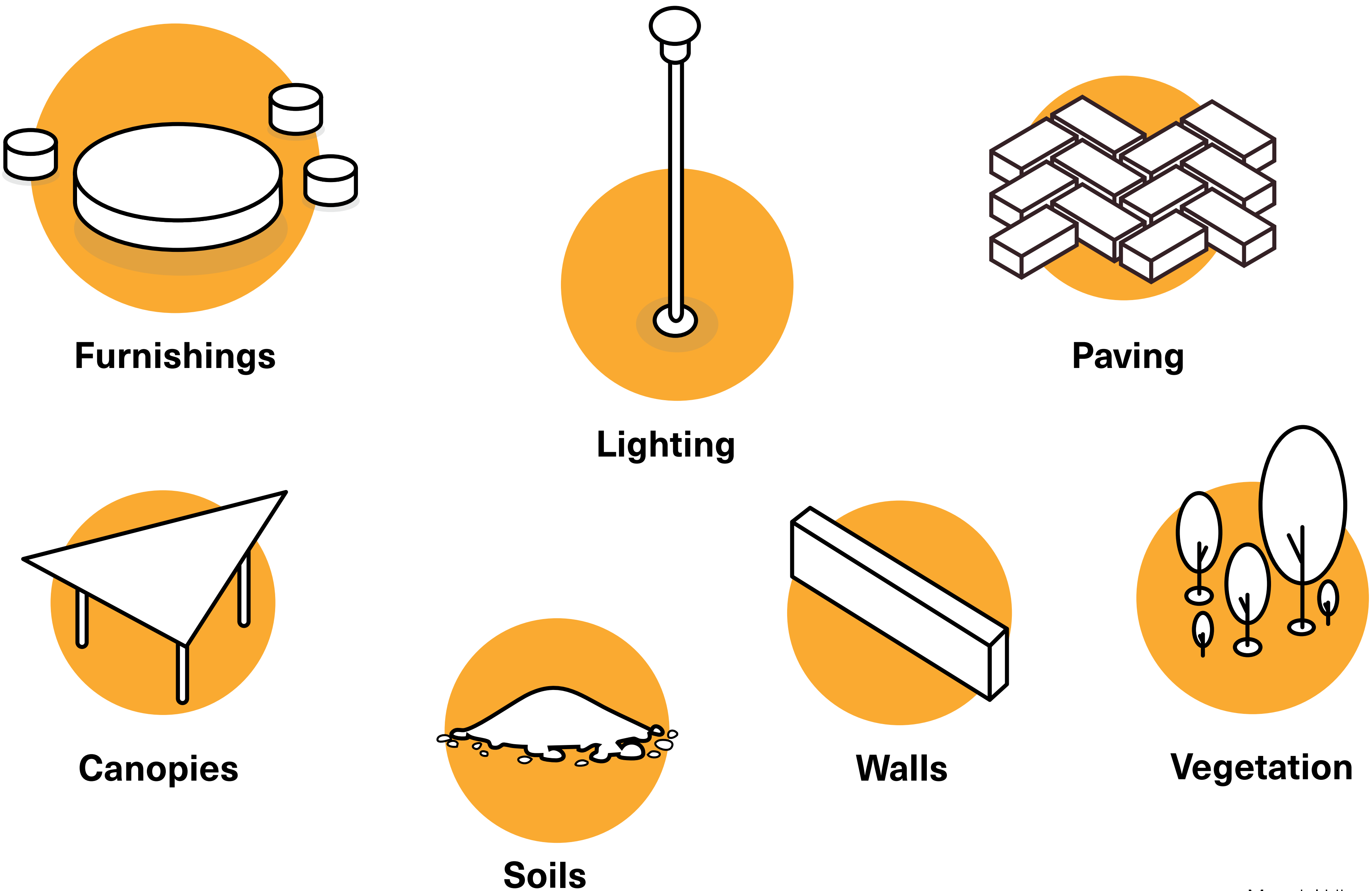


Demystify its production process

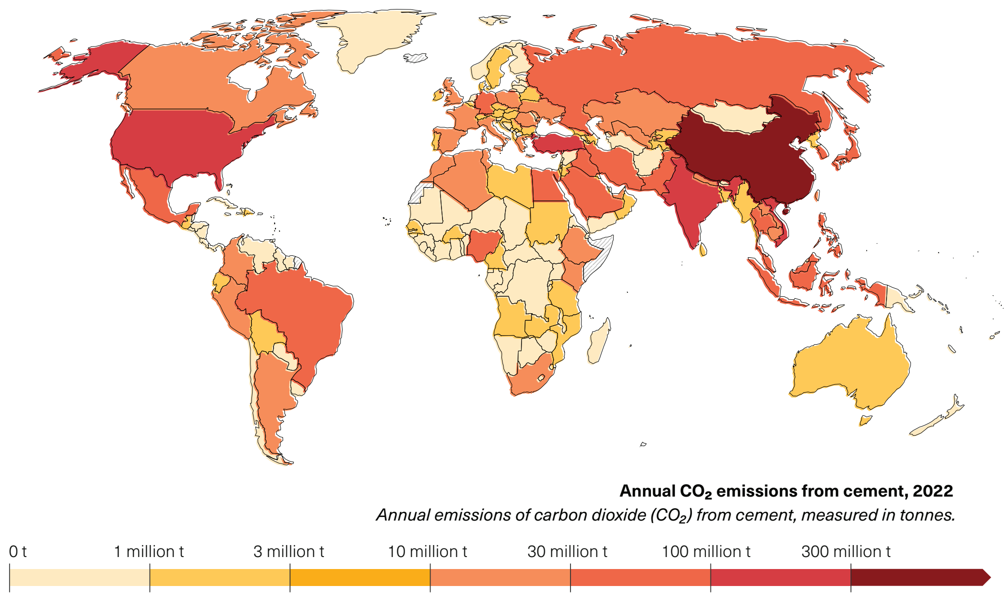
Highlight its climate impacts and potential benefits of alternatives

Illustrate applications in urban design

Material Applications in Public Space



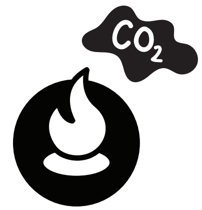
Concrete



Data source: Christopher D. Watson, Cement: Background and Low-Carbon Production, Congressional Research Service, https://crsreports.congress.gov."

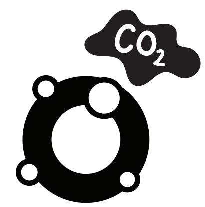
Concrete, the second most utilized material globally after water, plays a pivotal role in landscape and urban design (Scrivener, John, and Gartner 2018). However, its widespread use comes at a significant environmental cost, contributing roughly 8-9% of global CO_2 emissions (Miller, Geyer, and Kendall 2020).

Key Emissions



Kiln Heating

The production of cement requires heating limestone in kilns at extremely high temperatures, releasing significant amounts of CO_2 (Churkina et al. 2020). **This accounts for approximately 40% of cement's total CO_2 emissions** (World Green Building Council 2021).

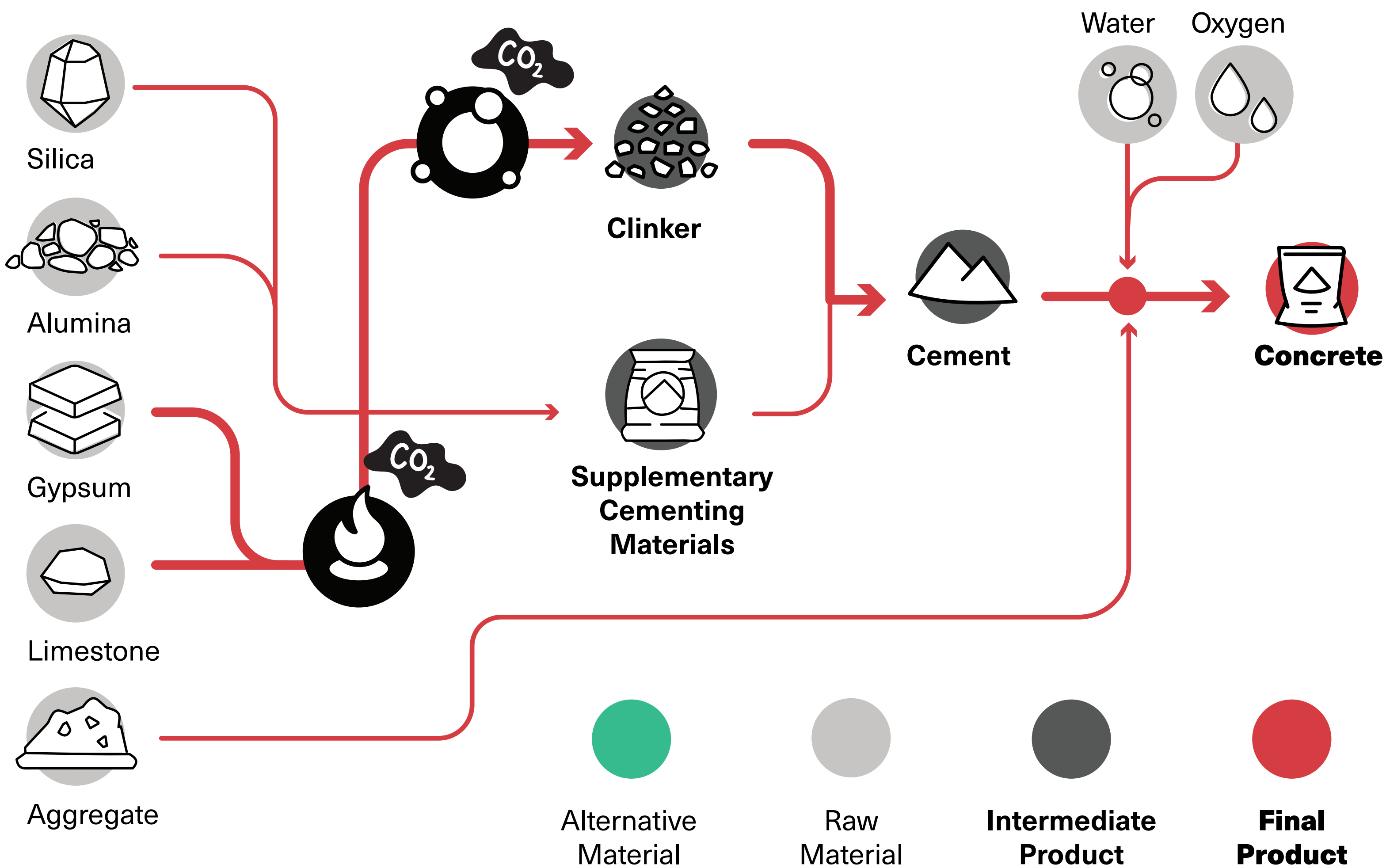


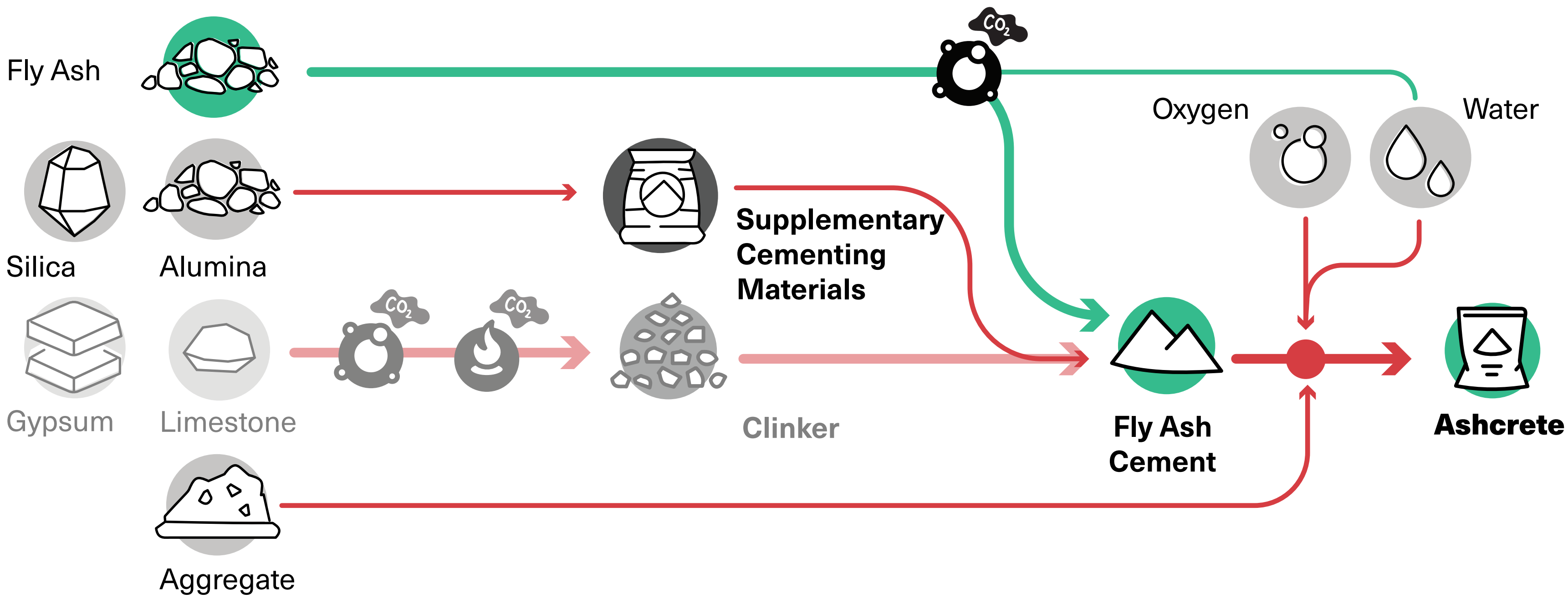
Chemical Reactions

The calcination process, which converts limestone ($CaCO_3$) into lime (CaO), releases large quantities of CO_2 during clinker production, the key ingredient in traditional cement (Scrivener, John, and Gartner 2018). **This reaction alone contributes to 60% of cement-related emissions** (Miller, Geyer, and Kendall 2020).

Concrete

Manufacturing Process





Ashcrete

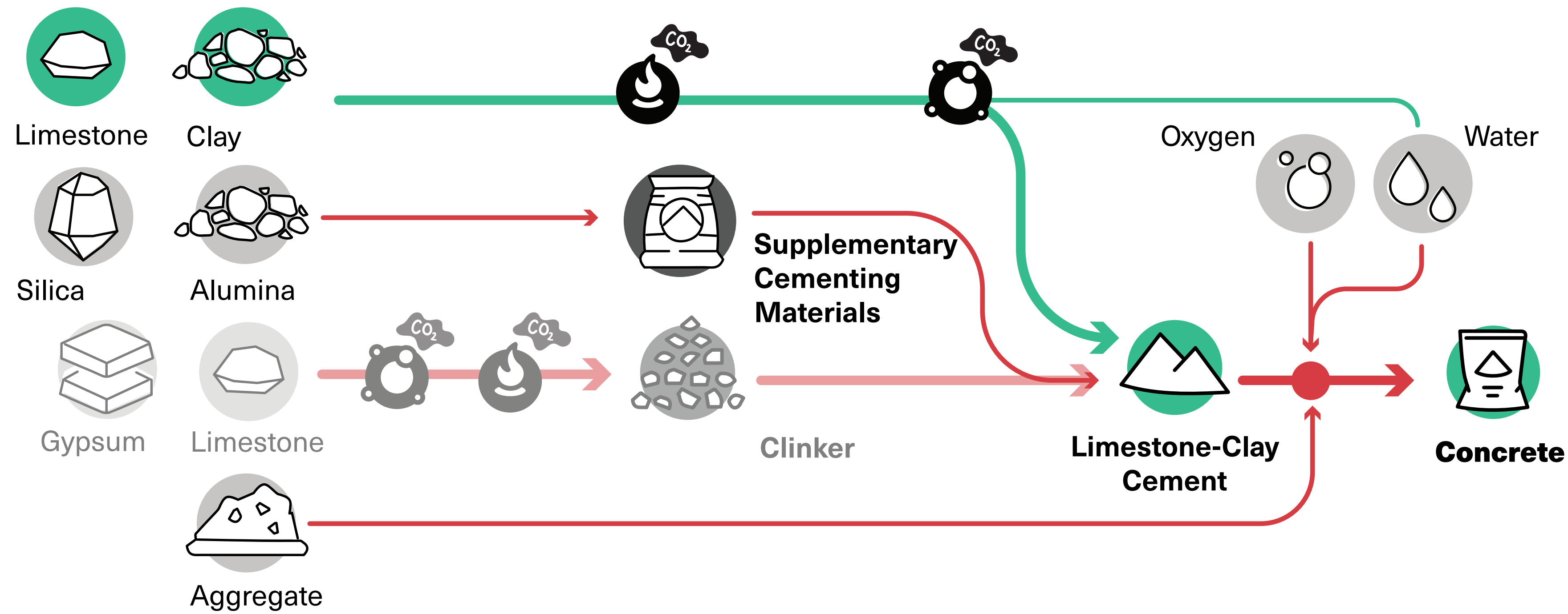
Ashcrete replaces a significant portion of traditional Portland cement with fly ash, an industrial byproduct of coal combustion. By incorporating fly ash as a Supplementary Cementitious Material (SCM), Ashcrete reduces clinker dependency, leading to lower embodied carbon emissions in concrete production (Malhotra 2002). This process enhances material strength, durability, and workability while promoting circularity in material reuse (Joshi and Joshi 2018).

Despite these benefits, concerns remain over sourcing fly ash from coal-fired power plants, as this practice is tied to fossil fuel dependency (American Coal Ash Association 2018).

Pro	Con
+ Reduces clinker dependency, significantly lowering carbon emissions.	– Fly ash, and other incineration residues, come from coal-fired power plants
+ Enhances durability and resistance to chemical attack, improving long-term performance.	– Only partially reduces cement use
+ Utilizes industrial waste, promoting circular economy principles.	

Orange Memorial Park I San Francisco, USA
Marcy Wong Donn Logan Architects
The park’s pavilion utilizes a fly-ash concrete mix along the foundation of the structure, and throughout the park’s paths.

Image credit: ArchDaily



Limestone Clay Cement (LC3)

Limestone Calcined Clay Cement (LC3) is a low-carbon cement alternative that replaces a portion of traditional clinker with calcined clay and limestone. This composition significantly reduces CO_2 emissions, up to 40% compared to conventional Portland cement, while maintaining strength, durability, and workability (Bishnoi et al. 2018).

LC3 is especially promising for hot and humid climates, where it enhances resistance to sulfate attack and improves long-term durability (Scrivener, John, and Gartner 2018). Additionally, the use of locally sourced clays and limestone makes it a more accessible and scalable solution compared to other low-carbon alternatives.

Pro

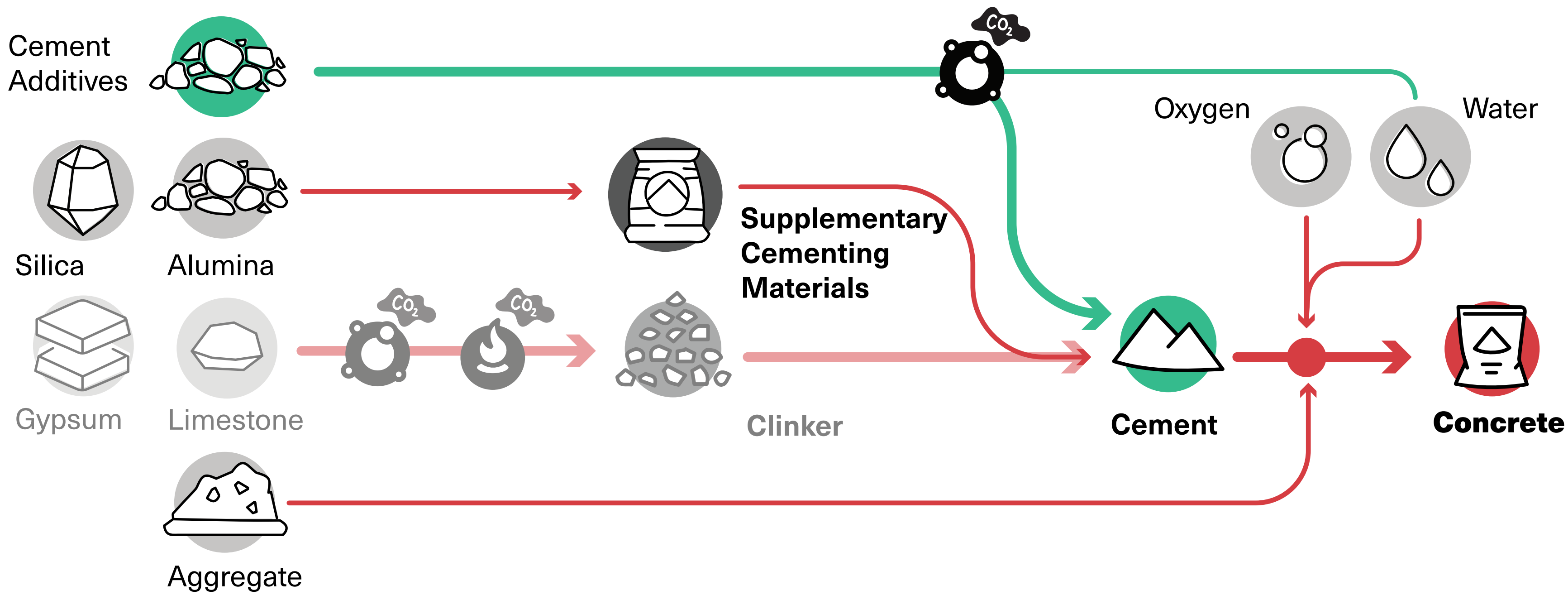
+ Cuts CO_2 emissions by 30-40% compared to traditional cement.
+ Reduces clinker demand, lowering dependence on high-carbon cement production.
+ Utilizes abundant materials (clay and limestone), making it a more scalable and affordable option.
+ Improves sulfate resistance, particularly in coastal and humid environments.

Con

- Requires specialized calcination equipment.
- Initial strength gain is slower than Portland cement, requiring adjusted curing times.
- Limited awareness and adoption.

Green Concrete Demonstration Projects I Lolland, Denmark
Technical University of Denmark
A series of three bridges were developed by the Technical University of Denmark and constructed by the Road Directorate of Denmark and Banedanmark. They used a Limestone Calcined Clay Cement mixture that is estimated to have reduced the CO2 emissions from materials production by 30% in comparison to traditional concrete (Technical University of Denmark).

Image credit: Technical University of Denmark



Cement Additives

Cement additives are supplementary materials incorporated into concrete to reduce clinker content, enhance durability, and lower carbon emissions.

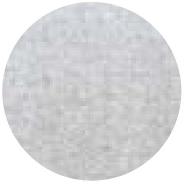
These additives can be industrial byproducts (GGBFS, fly ash), nanomaterials (graphene), or reinforcements (fiber cement, glass concrete). Each provides unique benefits, from reducing CO_2 emissions to improving structural performance (Dimov et al. 2018; Gong et al. 2019).

Pro	Con
+ Reduces cement demand, cutting down CO_2 emissions.	– Longer curing times for some additives (e.g., glass concrete, GGBFS).
+ Improves durability and longevity, reducing maintenance needs.	– Graphene and fiber reinforcement increase upfront costs.
+ Utilizes industrial waste, promoting circular economy practices.	– Material sourcing challenges due to regional availability of additives.
+ Graphenecrete and fiber cement allow for thinner, lighter structures.	

Other Cement Additives

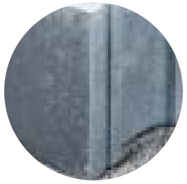
Graphenecrete

Introduces graphene nanoparticles, increasing compressive strength by 30-50%, which allows for reduced cement content and steel reinforcement (Dimov et al. 2018).



Fiber Cement

Uses synthetic, mineral, or cellulose fibers to enhance tensile strength, enabling a 10% reduction in Portland cement use and lowering thermal energy requirements (ACI Committee 2014).

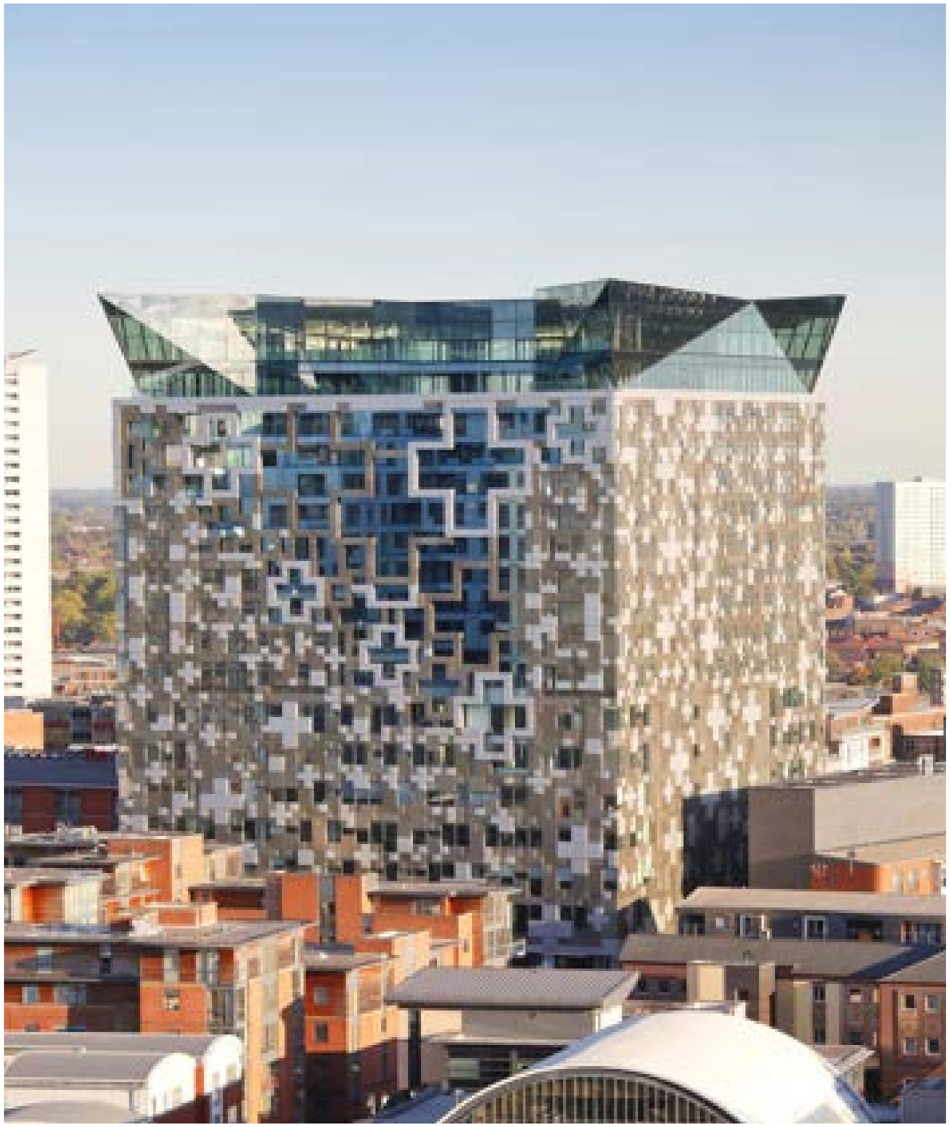


Ground Granulated Blast Furnace Slag Cement

Derived from steel manufacturing byproducts, GGBFS replaces Portland cement in varying percentages, improving durability while lowering embodied carbon (Juenger et al. 2019).

Glass Concrete

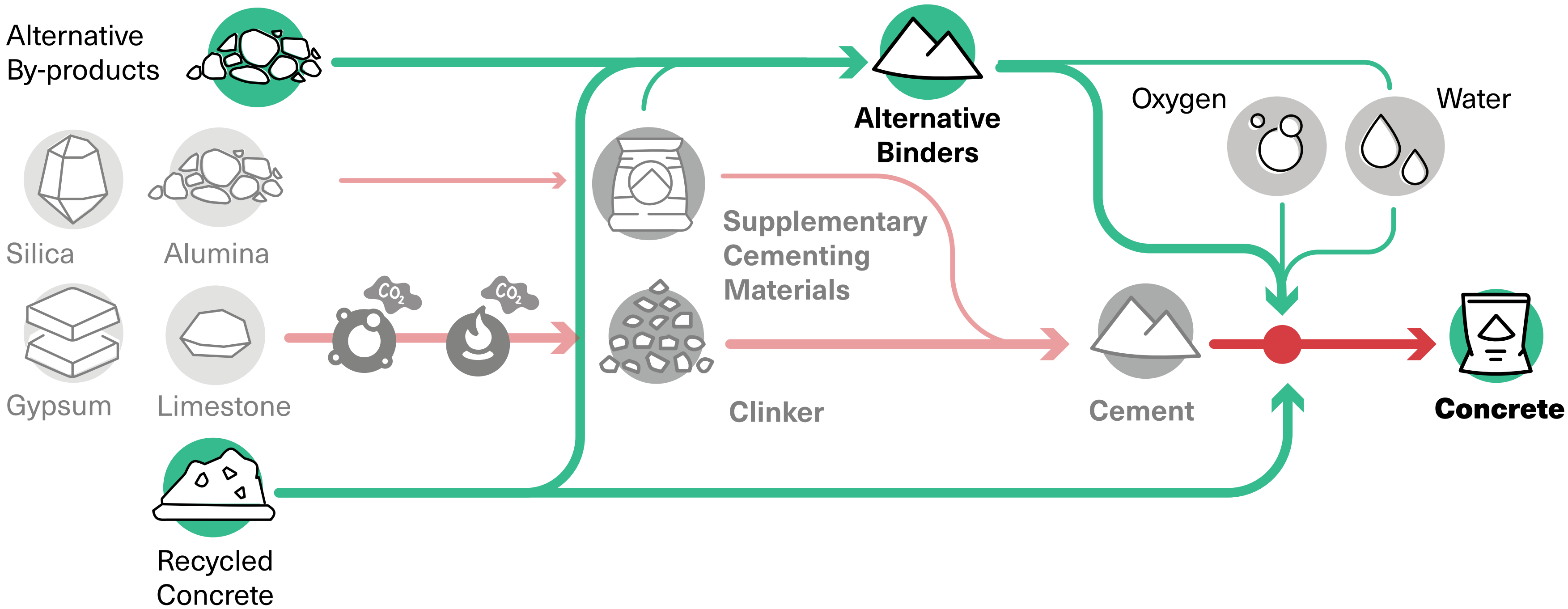
Incorporates crushed or recycled glass as a partial clinker replacement, reducing cement use (Schwarz and Wang 2021).

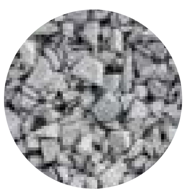


The Cube I Birmingham, United Kingdom
Make Architects

Image credit: ArchDaily

A 23-story mixed-use development, The Cube integrates residential, office, retail, and hospitality spaces in Birmingham's city center. The project incorporates 50% Ground Granulated Blast Furnace Slag (GGBFS) cement.





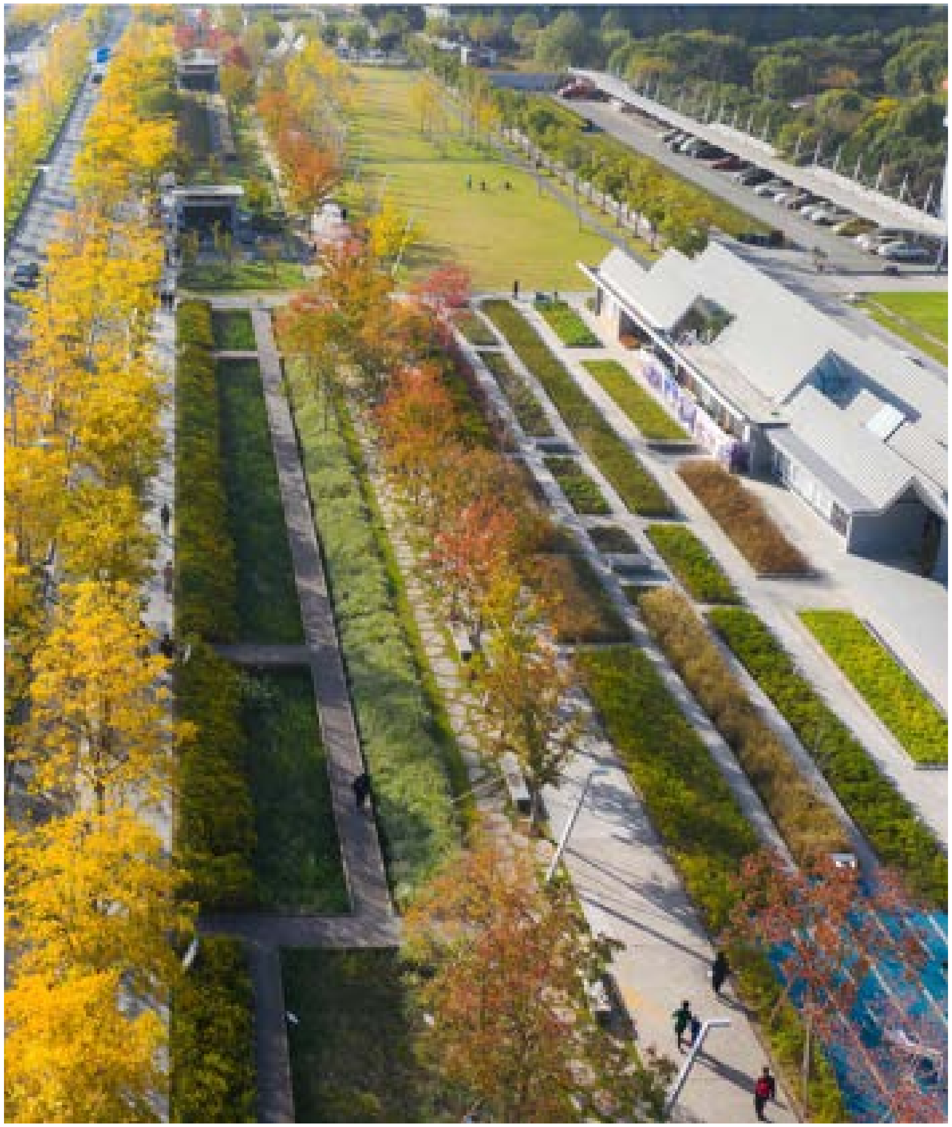
Recycled Concrete

Recycled concrete is created by crushing and reusing waste concrete from demolition and construction sites, reducing reliance on virgin aggregate.

It is widely used in road construction, foundations, and new concrete blends, with the potential to significantly lower the carbon footprint of concrete production (Tam et al. 2013).

The use of recycled aggregate concrete (RAC) supports a circular economy by keeping valuable materials in use, reducing landfill waste, and cutting down extraction of natural resources (Silva et al. 2016). However, challenges such as transportation emissions and achieving optimal mix designs limit its adoption in high-performance applications (Katz 2003).

Pro	Con
+ Reduces landfill waste, supporting circular economy principles.	– Transportation can offset environmental benefits, especially over long distances.
+ Can be used with cement-based or alternative binder systems, increasing versatility.	– Achieving optimal mix designs can be challenging for strength consistency.
+ Lowers the demand for virgin aggregates, preserving natural resources.	– Reduced structural strength compared to traditional concrete, requiring reinforcement strategies.



Xuhui Runway Park I Shanghai, China
Sasaki

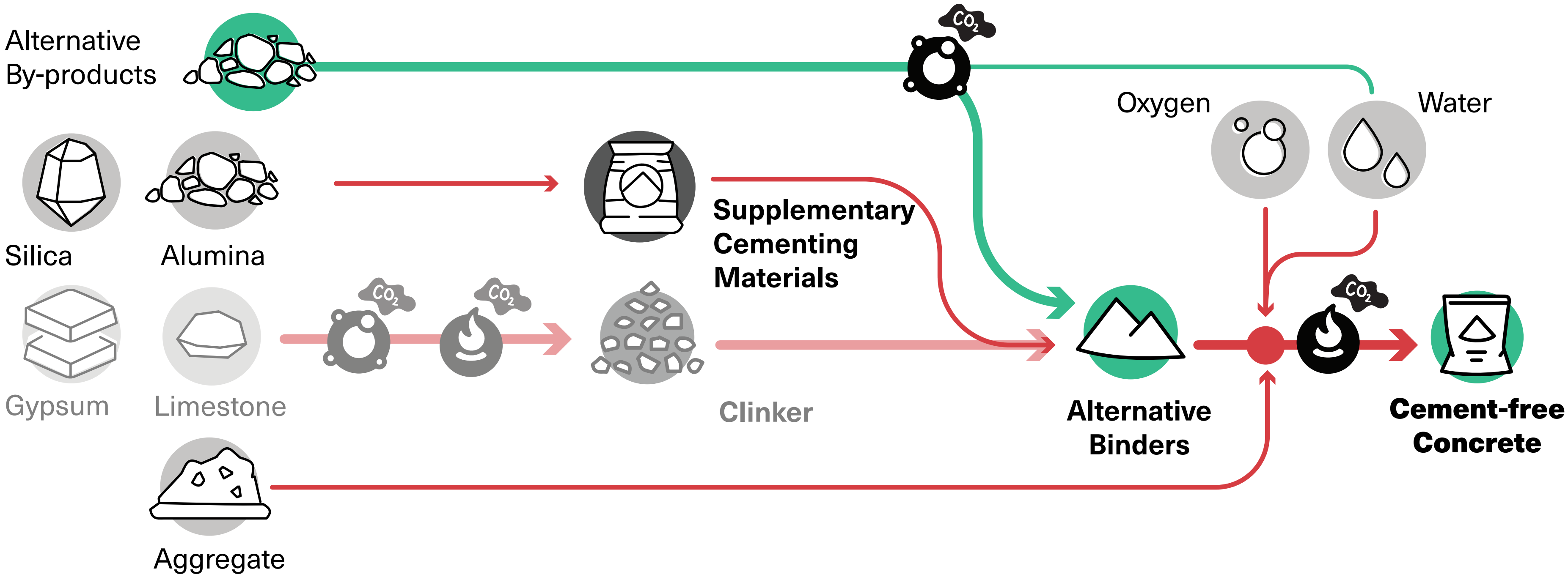
Image credit: Sasaki

The site is constructed on a former airport. The park's walking paths and paving surfaces utilize concrete from the former runway. This original concrete was incorporated throughout the park. Along the main path, large concrete panels form the runway were preserved in place, while crushed recycled concrete was used along tertiary paths.

Phoenix Bridge I Lyon, France
Zaha Hadid Architects

Image credit: ArchDaily

Using 10 tons of recycled materials, including recycled concrete aggregates from the previous bridge's blocks, the bridge boasts a 40% lower CO2 footprint compared to its predecessor. The Phoenix bridge foregrounds innovative recycled concrete materials, is designed for easy disassembly and recycling, and utilized 3D printing in the assembly process.



Portland Cement-free Concrete

Portland cement-free concrete eliminates traditional clinker-based cement, relying instead on alternative binders such as geopolymers, magnesium-based cements, or calcium sulfoaluminate (CSA) cements.

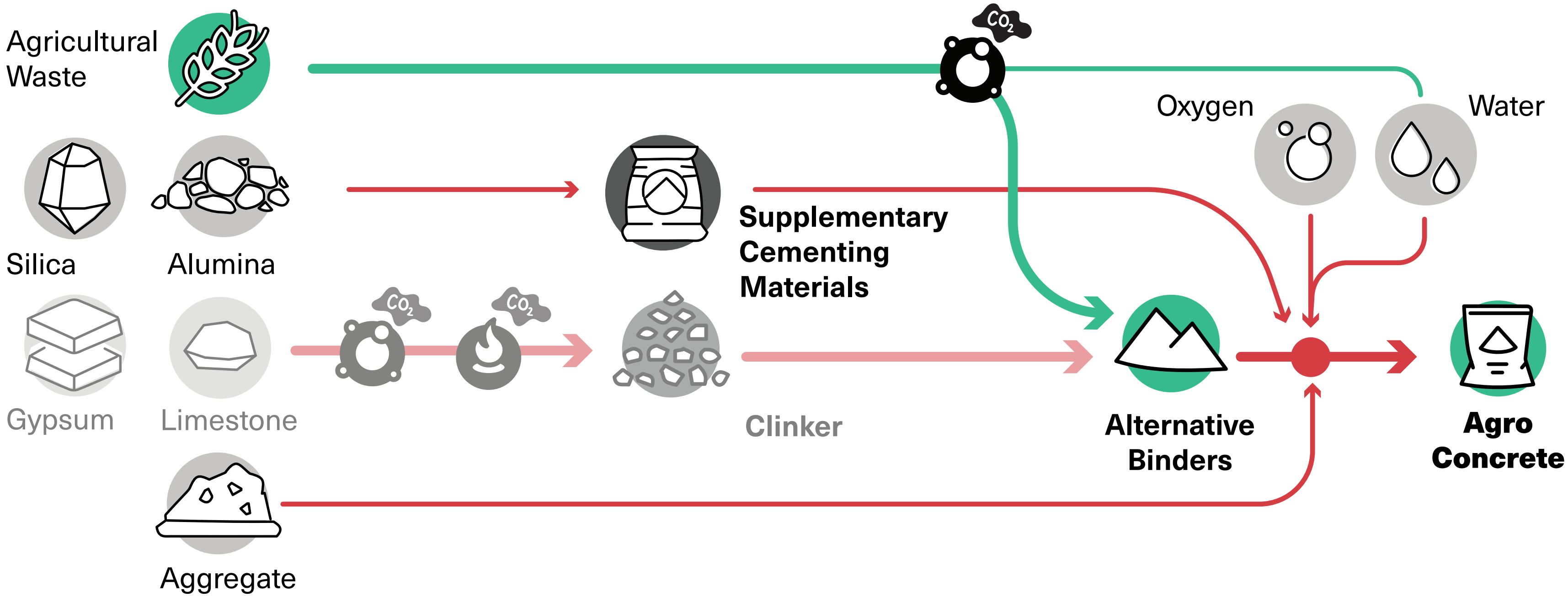
These alternatives can reduce CO_2 emissions by up to 80%, as they avoid the high-temperature kiln processes required for Portland cement (Provis 2014).

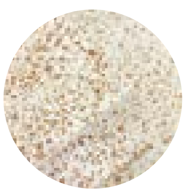
Geopolymer concrete, for example, uses industrial byproducts like fly ash or slag to create a chemically bonded structure that is durable, sulfate-resistant, and lower in embodied carbon (Juenger et al. 2019). However, scalability and supply chain limitations currently restrict widespread adoption (Mehta 2001).

Pro	Con
+ Eliminates traditional Portland cement, reducing embodied carbon.	– Limited commercial availability, restricting large-scale applications.
+ Utilizes industrial byproducts, promoting circular economy practices.	– Requires specialized production methods, increasing initial costs.
+ Geopolymer and CSA cements offer improved sulfate resistance and durability.	– Workability challenges compared to traditional cement mixes.

Green Experience Center I Mannheim, Germany
Bez+Kock Architekten
Uses Portland cement-free concrete for landscape retaining walls and pavement.

Green Experience Center in Luisenpark
Image credit: ArchDaily





Agro-concrete

Agro-concrete is an organic-based concrete alternative that incorporates agricultural waste products such as sugarcane bagasse (Sugarcrete), cork granules (Corkcrete), oyster shells (Oystercrete), and rice husk ash (Ricecrete) as partial or full replacements for traditional aggregates or binders.

These materials reduce reliance on virgin resources while offering lightweight, insulating, and carbon-sequestering properties (Jones et al. 2020). Many agro-based concretes are highly porous, improving thermal and acoustic performance, though their lower compressive strength limits their use in load-bearing applications (Wang et al. 2021).

Pro	Con
+ Utilizes agricultural waste, reducing landfill waste and supporting circular economy principles.	– Lower compressive strength, restricting structural applications.
+ Lightweight and thermally insulating, improving energy efficiency in buildings.	– Material consistency varies, requiring careful quality control.
+ Some variants (e.g., Oystercrete, Ricecrete) offer improved water resistance and durability.	– Limited commercial availability, slowing widespread adoption.

Agro-Concrete Types

Sugarcrete

Composed of waste sugarcane bagasse, a byproduct of sugar production, which is combined with a chemical binder to create a durable and lightweight material. Its production process involves grinding the bagasse into fine particles, mixing it with natural or recycled binders, and curing the mixture to achieve the desired hardness (Jones et al. 2020).

Corkcrete

Combines cork granules with traditional concrete to lessen the need for aggregates and clinker. Cork, harvested from the bark of cork oak trees, enhancing the concrete's overall flexibility and reduces its density, making it lighter and easier to work with compared to conventional types (Wang et al. 2021).

Oystercrete

Utilizes crushed oyster shells as a replacement for traditional aggregates, offering improved durability, sulfate resistance, and enhanced carbonation for coastal infrastructure (Kumar 2022).

Ricecrete

Created by blending rice husks, a byproduct of rice milling, with cement and other ingredients. The process begins with the collection and cleaning of rice husks to remove impurities. These husks are then mixed with cement, sand, and water to form a composite material. Unlike traditional concrete, which relies on sand and gravel as aggregates, Ricecrete substitutes a significant portion of these aggregates with rice husks (Kumar 2022).

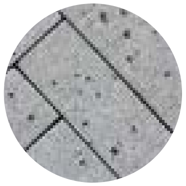
Concrete
Emerging Alternatives

Emerging alternative concretes leverage biogenic processes, industrial byproducts, and natural fibers to create low-carbon or carbon-negative building materials.

These alternatives aim to replace or minimize Portland cement use while sequestering carbon sequestration, reducing emissions, and enhancing durability (van Wijngaarden et al. 2020). Challenges related to scalability, regulatory approvals, and mechanical properties remain key barriers to widespread adoption (Lehmann 2021).

Sifang Art Museum I Nanjing, China
Steven Holl
Bamboo-formed concrete and Bamboocrete used on retaining walls.

Image credit: Sifang Art Museum.

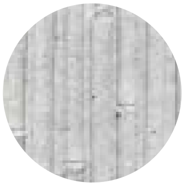


Biogenic cement

Instead of using heat-intensive kilns, biogenic cement is made using bacteria that produce calcium carbonate, naturally binding aggregates together. This process avoids fossil fuel emissions from cement production while sequestering carbon as part of the curing process (van Wijngaarden et al. 2020).

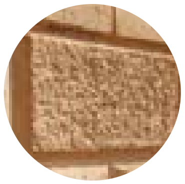
Biocharcrete

Biochar, a carbon-rich material made by burning organic waste with limited oxygen, is mixed into concrete, locking away atmospheric carbon while improving moisture control and insulation (Lehmann 2021). This method turns agricultural and forestry waste into permanent carbon storage.



Bamboocrete

Bamboo fibers or resins are blended with concrete or alternative binders to create a lighter, more flexible material that withstands shocks and movements, making it ideal for seismic zones. Bamboo grows quickly and absorbs CO_2 during its lifecycle, offsetting construction emissions (Ahmad 2021).

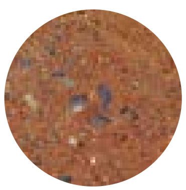


Timbercrete

Sawdust or cellulose fibers are combined with cement or clay-based binders to create a lighter, insulating concrete alternative. Because it locks in the carbon stored in wood fibers, Timbercrete has a lower carbon footprint than standard masonry while improving thermal performance (Berard 2022).

Hempcrete

A mix of hemp fibers, lime, and water, Hempcrete acts more like an insulating plaster or block rather than a structural concrete. As hemp grows, it absorbs large amounts of CO_2, and the lime binder continues sequestering carbon over time by reabsorbing CO_2 during curing (Berard 2022).



Ferrockcrete

Made from waste steel dust and silica, Ferrock is stronger than concrete and hardens by absorbing CO_2 from the air during curing, making it carbon-negative. Since it repurposes industrial byproducts, it also helps reduce landfill waste (Destaillats et al. 2021).

Delatite Cellar Door I Mansfield, Australia
Lucy Clemenger Architects
Timbercrete is used for steps and for decorative and grading walls.

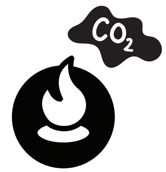
Image credit: Lucy Clemenger Architects

Steel

Steel is an essential structural material in urban design, yet its production is responsible for nearly 11% of global carbon emissions (World Steel Association 2023). The steel industry relies heavily on coal-based blast furnaces, which require high-energy inputs and release large amounts of CO_2 during the conversion of iron ore into steel.

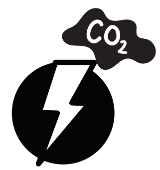
Gwangyang Steel Works
Gwangyang, South Korea
The Steel Works in Gwangyang is the largest steel plant in the world. Its production capacity averages about 18 million tons per year.

Key Emissions



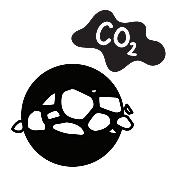
Blast Furnaces

The traditional method of producing steel, utilizing coke (from coal) to remove oxygen from iron ore, generating 70-80% of steel's CO_2 emissions (Material Economics 2021).



Electric Arc Furnace (EAF)

The electric arc furnace is a more modern, energy-efficient method for steel production, primarily used in the recycling of scrap steel. It results in lower emissions than blast furnaces, dependent on energy source

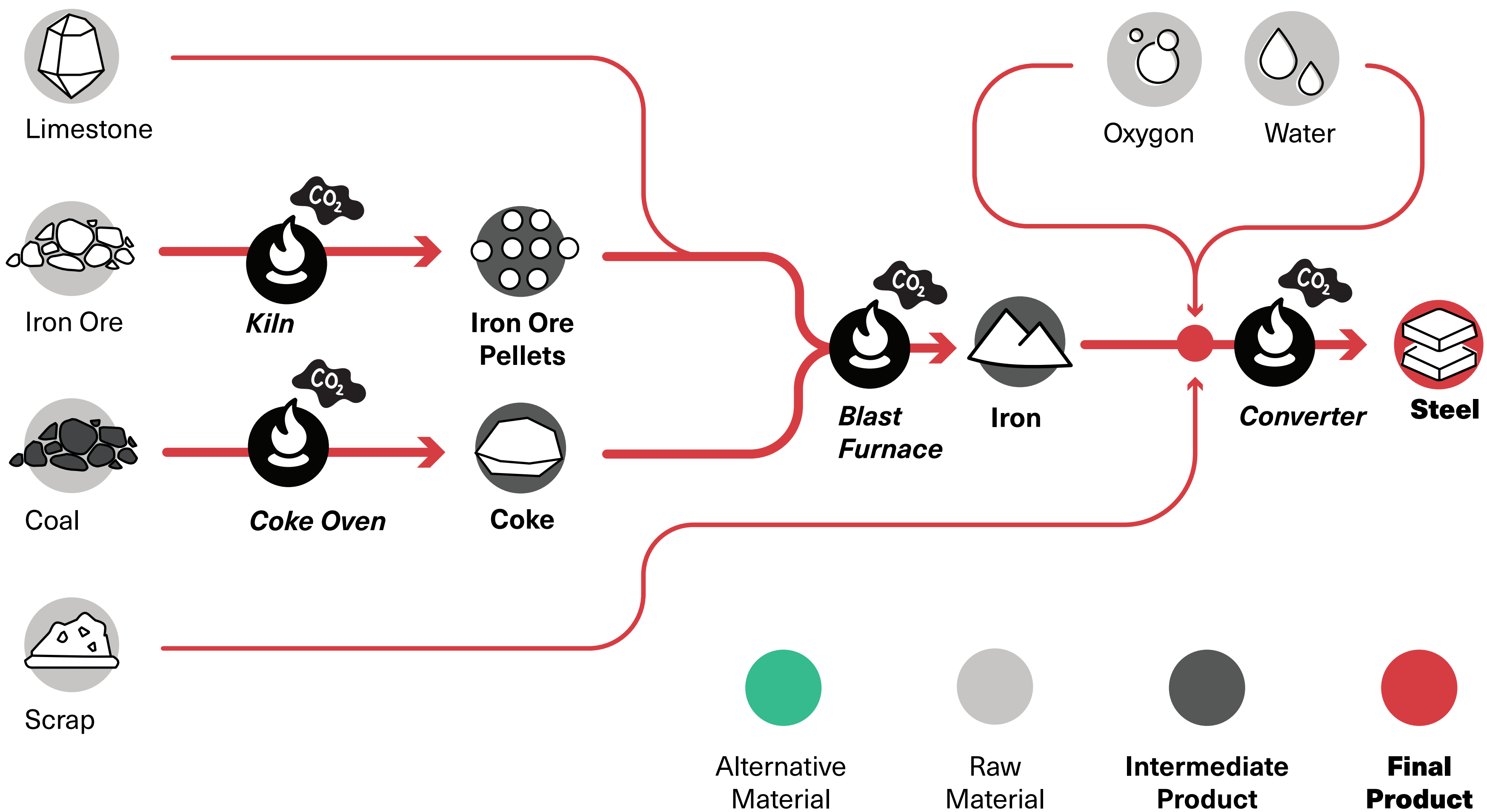


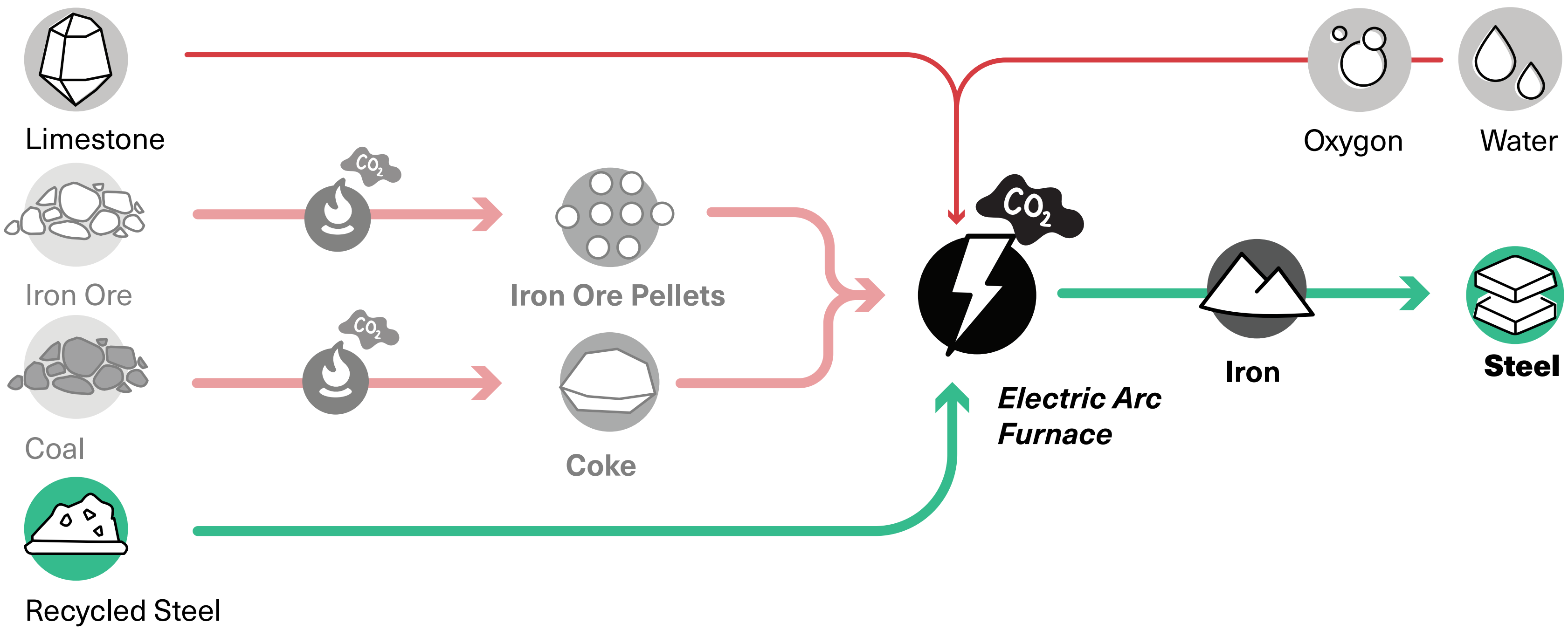
Raw Material Extraction

Mining and transporting iron ore and coal contribute about 10% of steel's total CO_2 footprint (Åhman et al. 2018).

Steel

Manufacturing Process





Recycled Steel

Recycled steel is produced by melting down scrap metal in an Electric Arc Furnace (EAF), significantly reducing energy consumption and carbon emissions compared to virgin steel production.

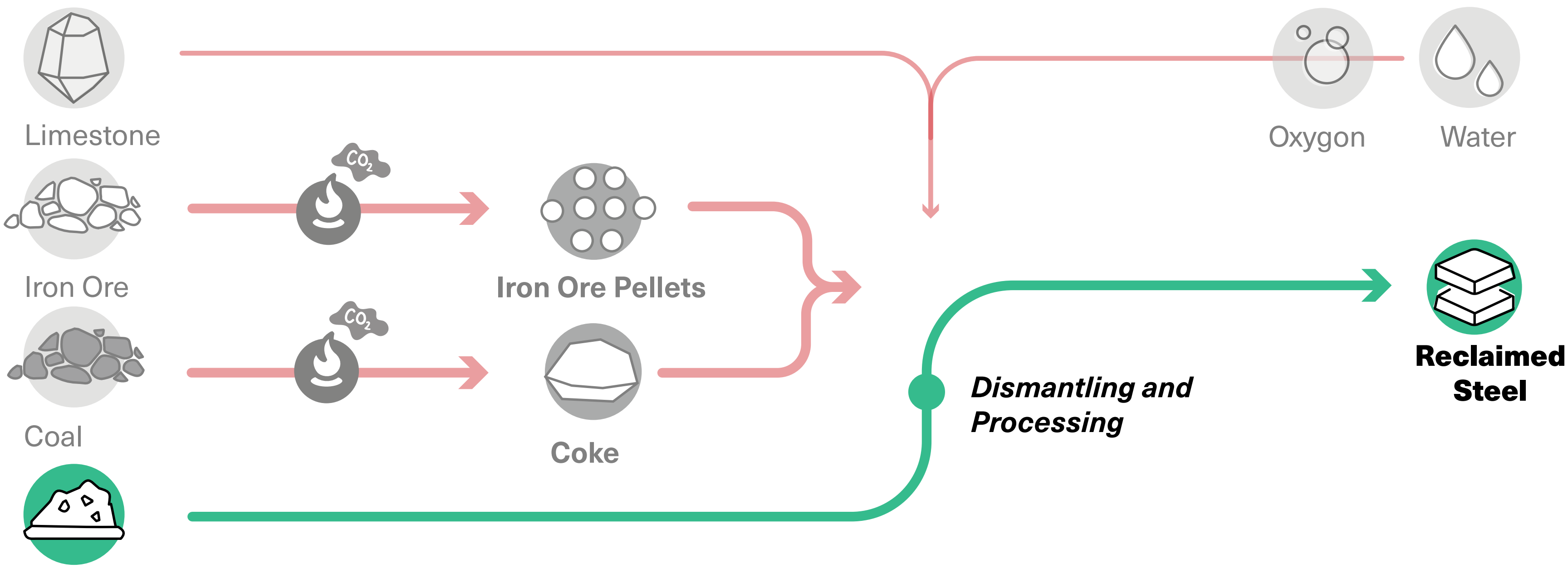
Traditional steelmaking relies on coal-based blast furnaces, which require large amounts of raw materials and generate high emissions. In contrast, recycled steel eliminates up to 70% of emissions by avoiding iron ore extraction and coal combustion (World Steel Association 2023).

While recycled steel retains the same strength and durability as virgin steel, its availability is often limited by scrap metal supply chains (Boden and Recker 2021).

Pro	Con
+ Drastically reduces emissions by eliminating coke and iron ore extraction. + Energy-efficient when using renewable-powered Electric Arc Furnaces. + Cost-effective, as it reduces reliance on mined materials.	– Availability is constrained by regional scrap metal supply. – Energy-intensive if powered by fossil fuels, reducing its benefits.

Chemin des Carrières I Strasbourg, France
Reiulf Ramstad Arkitekter and Parenthèse Paysage
A series of pathways, structures and landscape interventions that span 11 kilometers throughout rural villages and natural areas outside of Strasbourg. The path follows a former defunct railway right-of-way and leads visitors through a series of viewpoints and public spaces, ending at an abandoned quarry. The corten steel elements used in the project were made with close to 100% scrap content.

Image credit: Portes Bonheur, Le Chemin des Carrières



Reclaimed Steel

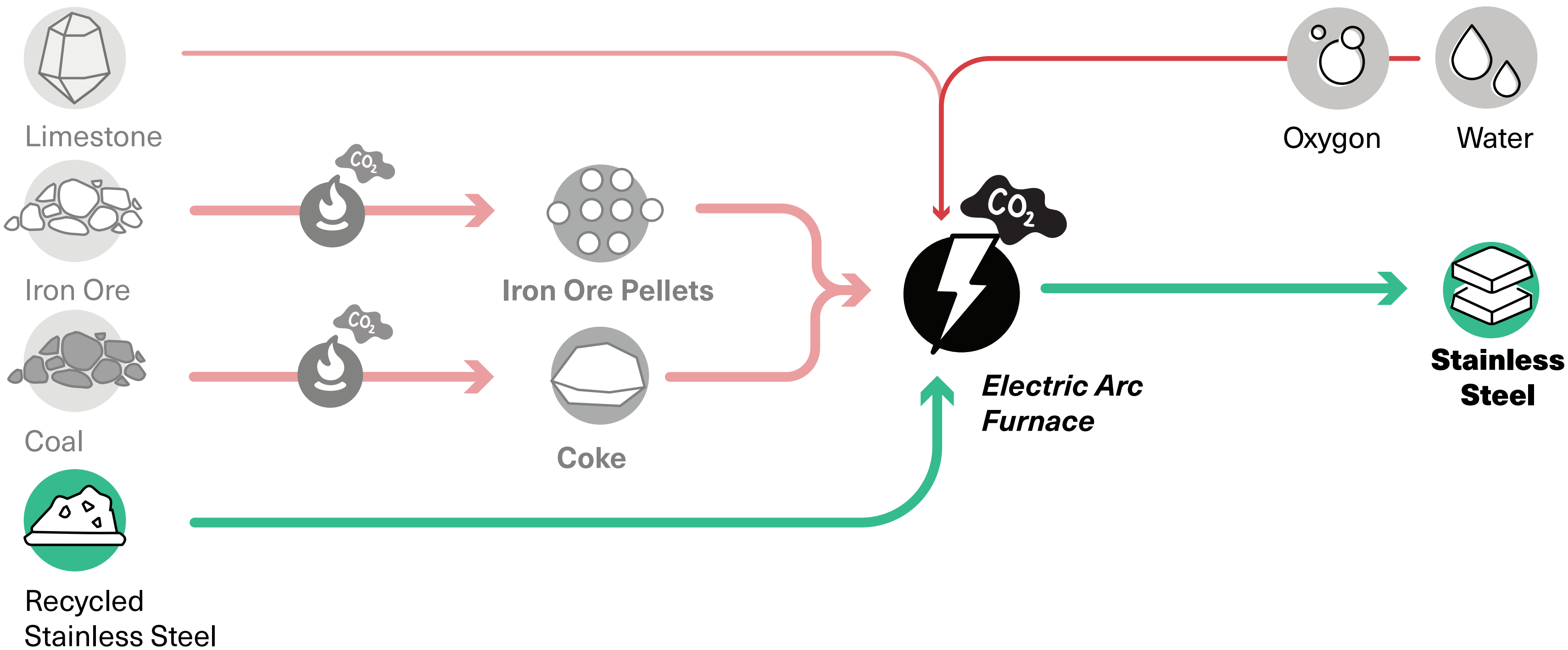
Reclaimed steel refers to salvaged structural steel components that are reused in their original form rather than melted down and remanufactured. Steel is highly durable, with a lifespan exceeding 150 years when properly maintained, making it a prime candidate for reuse in construction.

Unlike recycled steel, which requires energy-intensive reprocessing, reclaimed steel retains its original shape and strength, significantly reducing embodied carbon emissions (Geyer et al. 2022). However, size inconsistencies, rust removal, and certification requirements can pose challenges to its widespread application (Cullen et al. 2012).

Pro	Con
+ Avoids the need for melting and re-manufacturing, drastically lowering energy requirements.	– May not always match required dimensions, requiring modifications or custom design.
+ Potentially cheaper than new steel since it bypasses the manufacturing process.	– Needs thorough cleaning and surface treatment, which can add cost and labor.
+ Reduces demolition waste, supporting circular economy principles.	– Requires rigorous structural testing, adding logistical hurdles.

Cycling through the Trees I Hechtel-Eksel Belgium Image credit: Burolandschap
Burolandschap
An elevated walking path weaves through the nature park, utilizing reclaimed steel throughout its design. The pathway allows cyclists and pedestrians to enjoy sweeping views of the region.

Urban Outfitters HQ, Philadelphia, USA Image credit: ArchDaily
D.I.R.T.
The site uses a combination of reclaimed and recycled steel across the campus, including in various landscape details from insets in paths to lighting fixtures.

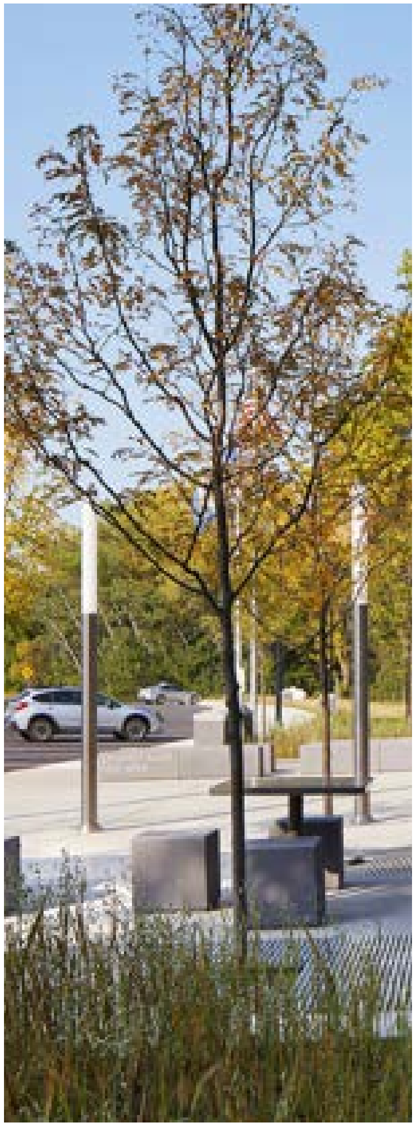


Stainless Steel

Stainless steel is an alloy of iron, chromium, nickel, and molybdenum, offering exceptional corrosion resistance and a long lifespan.

It is widely used in public infrastructure, cladding, and street furniture due to its high durability and low maintenance needs (Outokumpu 2022). However, stainless steel production is energy-intensive, and while it is 100% recyclable, its high cost and embodied carbon impact often limit its application to smaller-scale urban elements (AISI 2023).

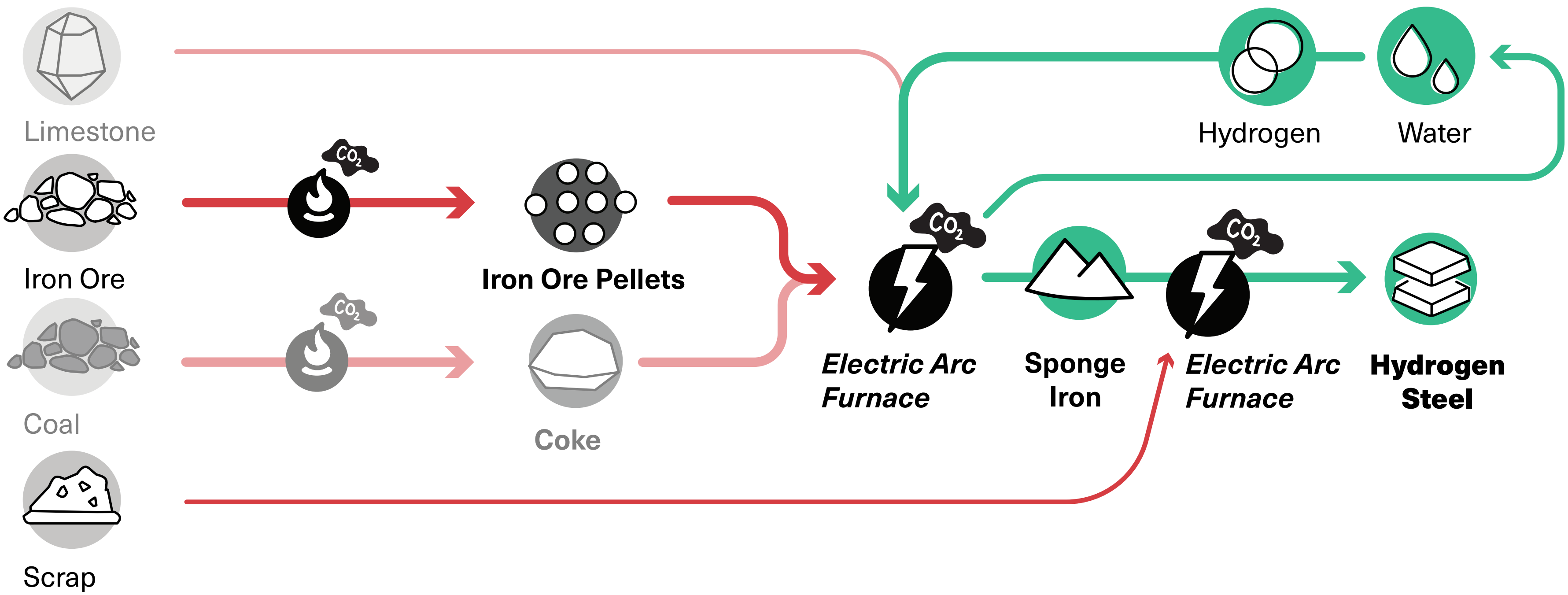
Pro	Con
+ **Extremely durable, with a long lifespan and low maintenance requirements.**	– **High embodied energy, due to the energy-intensive refining process.**
+ **Highly corrosion-resistant, reducing the need for protective coatings or treatments.**	– **Expensive compared to other steel types, limiting large-scale applications.**
+ **Fully recyclable, contributing to a more circular material economy.**	– **Nickel mining and alloying processes contribute to environmental degradation if not responsibly**

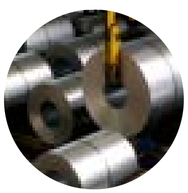


Straight River Northbound Safety Rest Area I Owatonna, USA
Snow Kreilich Architects

Image credit: Snow Kreilich Architects

Stainless steel is used in both the facade of the rest area structure and in the sites' lighting fixtures and benches. These elements are exposed to harsh weather conditions in a relatively exposed environment and the longevity of stainless steel in this application will reduce its impact over time.





Hydrogen Steel

Hydrogen steel (or green steel) replaces coal-based blast furnaces with a process called Direct Reduced Iron (DRI), where hydrogen gas removes oxygen from iron ore, eliminating CO_2 emissions (Åhman et al. 2018).

When produced using renewable energy sources, hydrogen steel can achieve zero-emissions steelmaking (Material Economics 2021). While promising, hydrogen steel production remains expensive and dependent on scalable green hydrogen availability (Vogl, Åhman, and Nilsson 2018).

Pro	Con
+ **Eliminates coal from steel production, drastically cutting CO_2 emissions.**	– **High production costs due to green hydrogen's limited availability.**
+ **Compatible with renewable energy, making it a future-proof alternative.**	– **Energy-intensive electrolysis, requiring a fully decarbonized power grid to maximize benefits.**
+ **Produces high-quality steel comparable to conventional methods.**	– **Scaling limitations, as hydrogen infrastructure is still under development.**

Green Steel Manufacturing

Boden, Sweden: The World's First Large-Scale Green Steel Plant

Image credit: MIT Technology Review

Located in Boden, Sweden, H2 Green Steel is constructing the first fully integrated fossil-free steel production plant, set to begin operations by 2025. The facility will use 100% renewable electricity sourced from hydropower and wind energy, making it the first industrial-scale example of hydrogen-based steel production. By eliminating coal and integrating circular water and material use, the plant aims to produce 5 million tons of fossil-free steel per year by 2030, demonstrating the commercial viability of large-scale hydrogen steel (H2 Green Steel 2022).

Masonry

Masonry is one of the oldest and most durable building techniques, used for centuries in everything from monuments to infrastructure. However, traditional fired masonry, particularly clay bricks, is a significant contributor to global carbon emissions, with kiln firing alone responsible for 3% of global CO_2 emissions (Gavilan and Bernold 1994).

This high-carbon impact is primarily due to the energy-intensive firing process, as well as the environmental costs of quarrying and transporting raw materials

Key Emissions

Kiln Firing

High-temperature kilns, often powered by fossil fuels, generate 50% of a brick's carbon footprint.

Raw Materials

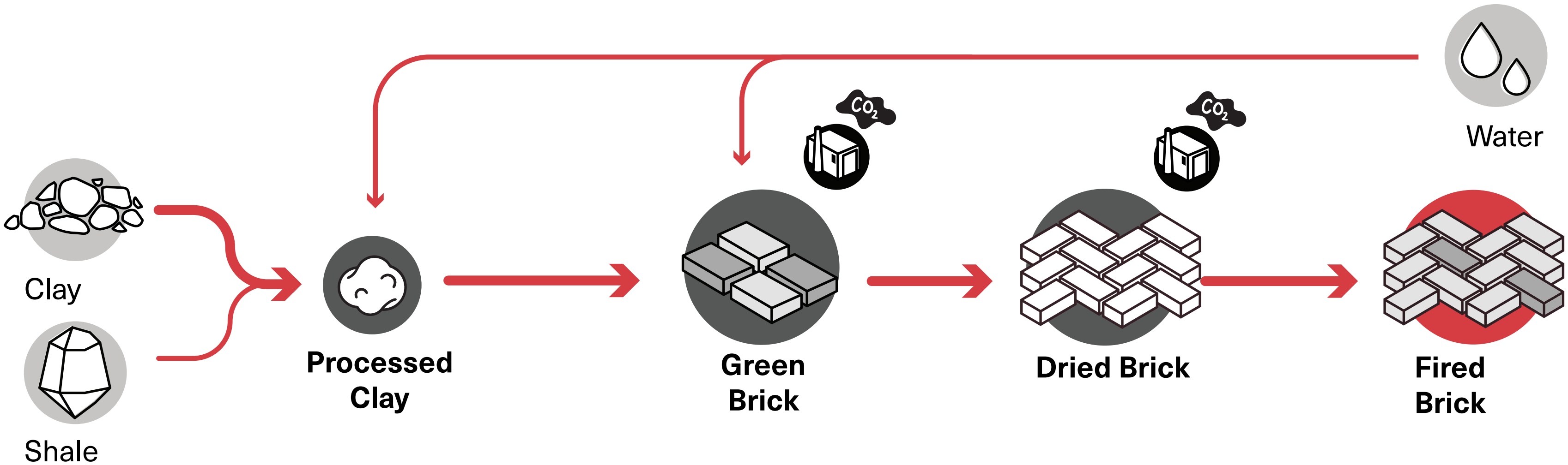
Quarrying and processing clay and other raw materials contribute 20% of a brick's total emissions.

Automated Brick Plant I Estonia
A largely automated plant producing various types of brick in Estonia. The plant is operated by Wienerberger, the world's largest brick manufacturer.

Image credit: Wienerberger

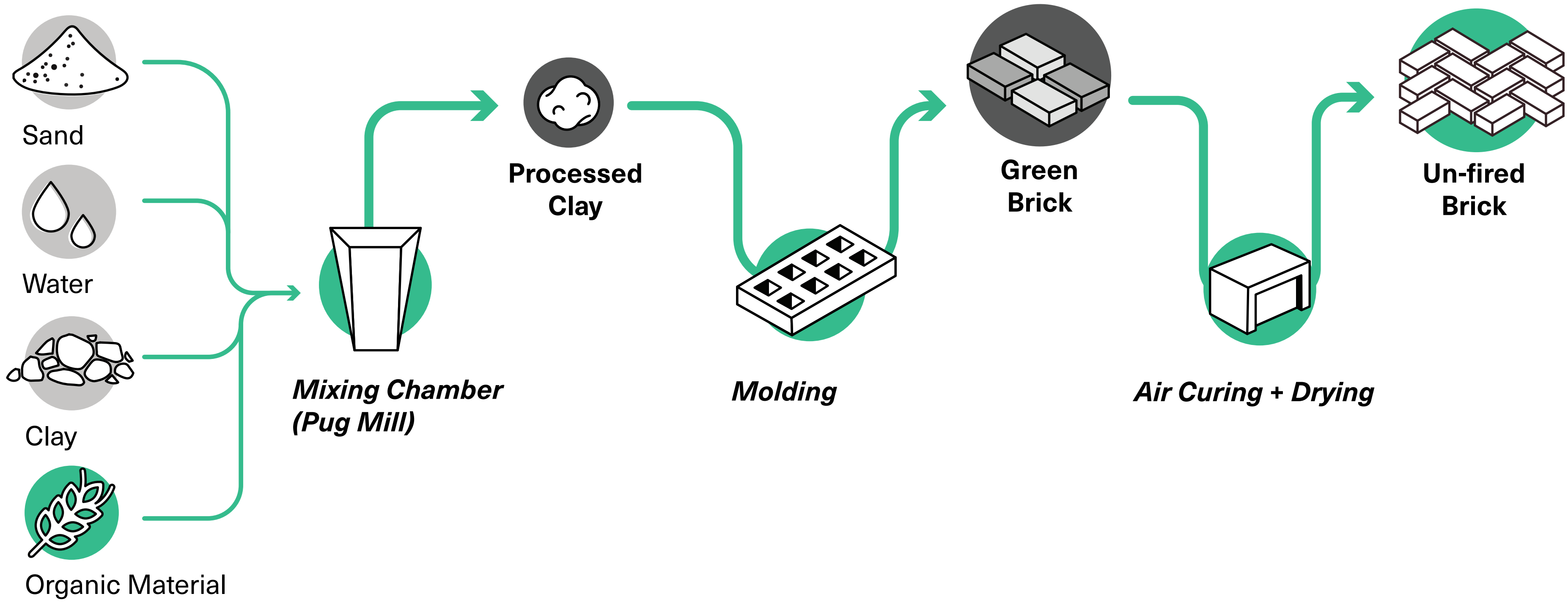
Fired Brick Production

Manufacturing Process



Ningbo History Museum, I Ningbo, China
Completed in 2008, the museum's façade is constructed entirely of recycled bricks salvaged from demolished buildings

Image credit: Architectural Review



Unfired Masonry

Unfired masonry products do not undergo high-temperature kiln firing, making them a low-carbon alternative to traditional fired bricks.

These materials, including Compressed Earth Blocks (CEBs), Rammed Earth, Geopolymer Masonry, Adobe Bricks, and Cob Blocks, require minimal energy for production and often incorporate local, natural, or industrial waste materials (Minke 2021).

While these materials offer significant carbon reductions, they may require additional sealing and structural reinforcement in high-moisture environments (Houben and Guillaud 1994).

Pro	Con
+ Lower carbon footprint than traditional masonry due to the lack of kiln firing.	– More susceptible to water damage, requiring protective treatments.
+ Can be locally sourced, reducing transportation emissions.	– Strength and durability can vary, necessitating careful engineering.
+ Reusable and biodegradable, contributing to a circular building economy.	– Limited standardization, making widespread use more challenging.

Unfired Masonry Products

Compressed Earth Blocks (CEB's)

CEBs are high-density earthen blocks created by compacting moist soil mixed with stabilizers such as cement or lime. These blocks are highly durable and offer thermal mass benefits, reducing heating and cooling loads in buildings (Adam and Agib 2001). Unlike traditional adobe, CEBs require mechanical compaction, increasing strength while maintaining low embodied energy (Minke 2021).

Rammed Earth

Rammed earth construction involves compacting damp soil in layers within a temporary framework, creating dense, monolithic walls with excellent thermal mass (Hall and Djerbib 2004). This method eliminates the need for additional masonry units and uses locally sourced materials, reducing transport-related emissions (Norton 1997). However, proper water protection and foundation design are essential to ensure durability in wet climates (Minke 2021).

Geopolymer Masonry

Geopolymer masonry uses industrial byproducts such as fly ash or slag to create a cement-free binding system. These bricks exhibit higher strength and chemical resistance than traditional earthen blocks while significantly reducing CO_2 emissions (Davidovits 2013). As a relatively new technology, geopolymer bricks require further standardization and material testing for widespread adoption (Zhang et al. 2020).

Adobe Bricks

Adobe is a sun-dried mixture of clay, sand, straw, and water, offering a simple, low-energy masonry solution. These bricks provide excellent insulation and are highly breathable, making them suitable for hot and arid climates (Houben and Guillaud 1994). However, water sensitivity requires the use of protective coatings or stabilizers to enhance durability (Reddy and Kumar 2010).

Cob Blocks

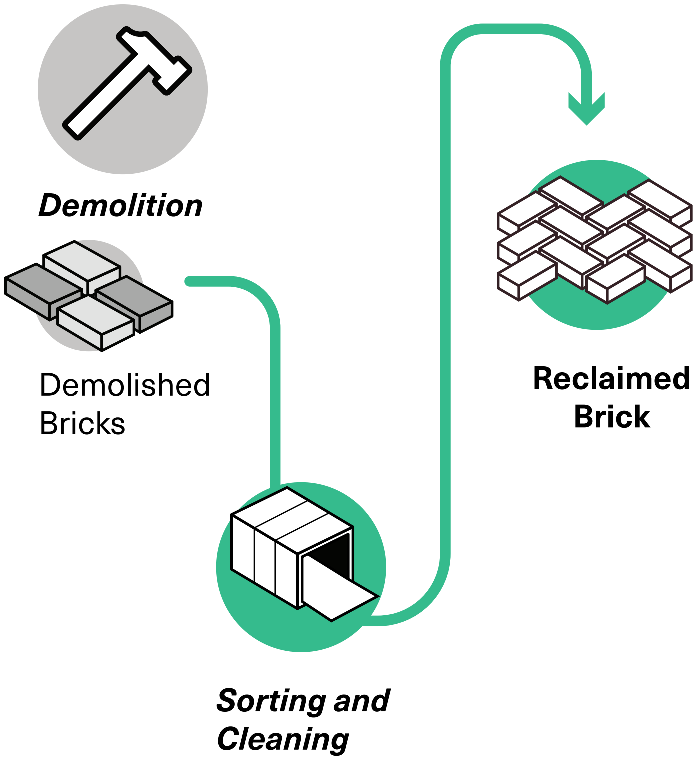
Cob is a hand-shaped mixture of clay-rich soil, sand, and straw, typically molded in place rather than cast into bricks. This material offers organic, sculptural design possibilities while maintaining high thermal performance (Smith 2002). Cob walls are self-supporting and eliminate the need for mortar, but require thicker walls and extended drying times compared to other unfired masonry techniques (Keefe 2005).

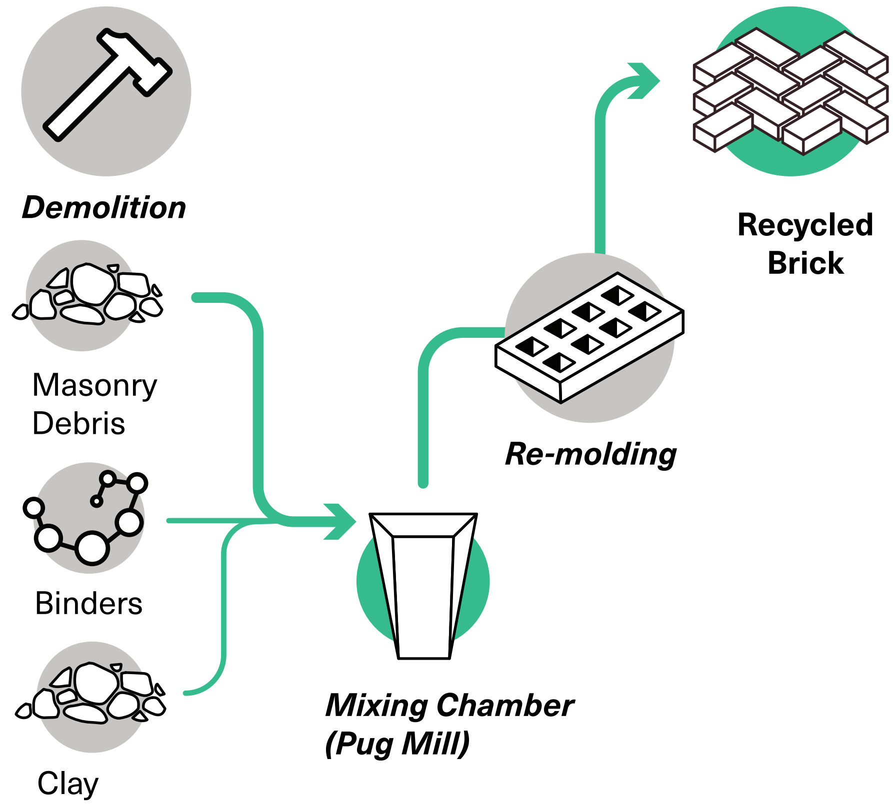
Lafayette College Arts Plaza I Easton, USA
Spillman Farmer Architects
The Arts Plaza is constructed in the shell of a former auto-body shop and utilizes recycled brick, alongside geopolymer masonry, to form a dynamic performing arts and community space.

Image credit: ArchDaily

Friendship Centre I Gaibandha, Bangladesh
Kashef Chowdhury
Constructed and finished primarily using local hand-made bricks, and compressed earth blocks, the pavilions, courtyards, pools and green corridors of the Friendship Centre show how a number of sustainable brick materials can be used to create a variety of intimate and public spaces.

Image credit: Architectural Review

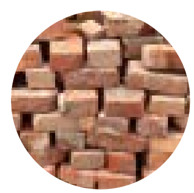




Reclaimed Brick

Reclaimed bricks are salvaged from demolition sites and repurposed for new construction, reducing waste and embodied carbon.

Unlike newly manufactured bricks, reclaimed bricks require no additional firing, making them an environmentally friendly alternative (Gavilan and Bernold 1994). However, structural integrity and uniformity must be assessed before reuse, as aging bricks may require cleaning, testing, and re-mortaring (Chusid 2017).



Recycled Brick

Recycled bricks are made by crushing and re-manufacturing waste bricks into new bricks, reducing the need for virgin clay and lowering the embodied carbon of masonry materials.

This process allows waste from construction and demolition to be reintegrated into the supply chain while maintaining the structural integrity of traditional bricks (Khatib 2005). Advances in binding agents and brick molding technologies have enabled recycled bricks to match or even exceed the durability of conventional bricks (Poon and Chan 2006).

Arkadia I Alexandria, Australia
DKO Architecture + Breathe Architecture

Image credit: DKO

The building incorporates recycled and reclaimed brick throughout its structure. It utilizes recycled brick on the rooftop garden as benches and seating elements. This application could be adopted more broadly as a means to replace concrete in public seating elements.

Canal Park I Washington DC, USA
Olin

Image credit: Olin

Diverted 1,782 tons of material from landfills by recycling 100% of bricks on site, along with concrete and asphalt, during construction and demolition.

Wood

Wood is one of the most widely used and renewable materials in landscape and urban design.

As a biogenic material, it sequesters carbon while growing, making it an environmentally beneficial alternative to high-emission materials like concrete and steel.

However, wood's sustainability is dependent on responsible harvesting practices, as poorly managed logging can lead to deforestation and biodiversity loss (FSC 2022).

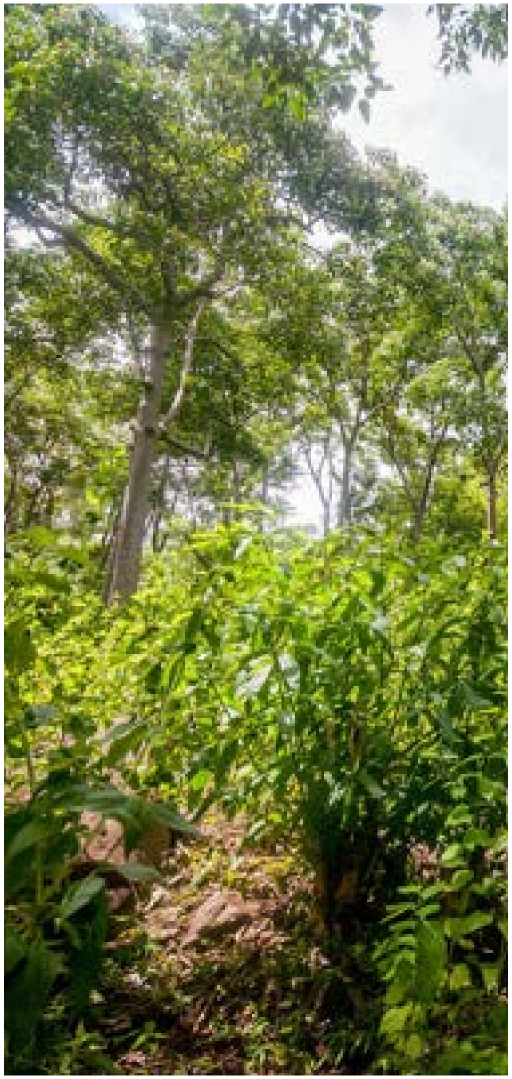
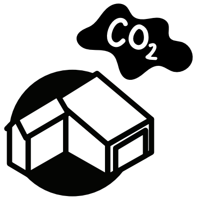


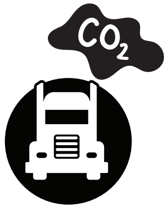
Image credit: Unsplash

Key Emissions



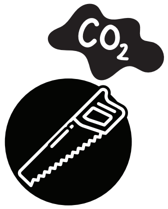
Sawmills + Drying

Energy-intensive processes that can contribute up to 40% of a wood product's carbon footprint, especially when powered by fossil fuels (Lindenmayer et al. 2019).



Transportation

Moving logs to sawmills and finished products to markets can account for 30% of total emissions, depending on distance and transport methods (PEFC 2023).



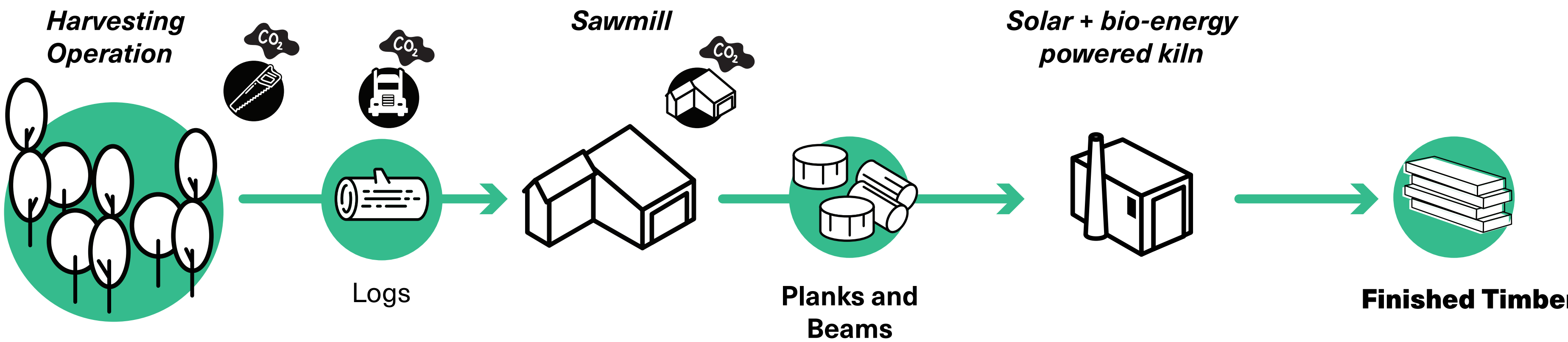
Harvesting + Forest Management

Harvesting practices, including logging machinery and land conversion, contribute another 25% of emissions, highlighting the need for sustainable sourcing (Glover et al. 2021).

Agroforestry Farm I Tenggara, Indonesia
This sustainable hardwood forestry project in Indonesia implements selective harvesting and multi-species replanting, ensuring continuous biodiversity and carbon sequestration. By prioritizing non-clearcut methods, the farm provides sustainably sourced hardwood for construction.

Sustainable Wood Certifications

Certification	Description
FSC (Forest Stewardship Council)	Global certification ensuring responsible forest management, balancing environmental, social, and economic factors.
PEFC (Program for the Endorsement of Forest Certification)	Internationally recognized certification promoting sustainable forest management, widely used in Europe and beyond.
SFI (Sustainable Forestry Initiative)	North American certification ensuring responsible forestry practices and conservation efforts.
Rainforest Alliance Certified	Ensures forests are managed sustainably, benefiting biodiversity, workers, and local communities.
MTCS (Malaysian Timber Certification Scheme)	Malaysia's certification standard for legal and sustainable timber production, endorsed by PEFC.
ATFS (American Tree Farm System)	Certification program for small, family-owned forests in the U.S., promoting responsible forestry.
CSA (Canadian Standards Association)	Canada's sustainable forest management standard, ensuring ecological and economic balance.
TLTV (Timber Legality & Traceability Verification)	Verification system ensuring timber legality and traceability, often used in high-risk areas.
SVLK (Indonesia's Timber Legality Assurance System)	Indonesia's mandatory certification verifying the legality of timber products for export and domestic use.



Sustainable Hardwood & Softwood Timber

Sustainable hardwood and softwood timber are sourced from responsibly managed forests that follow certification programs such as the Forest Stewardship Council (FSC) and Program for the Endorsement of Forest Certification (PEFC).

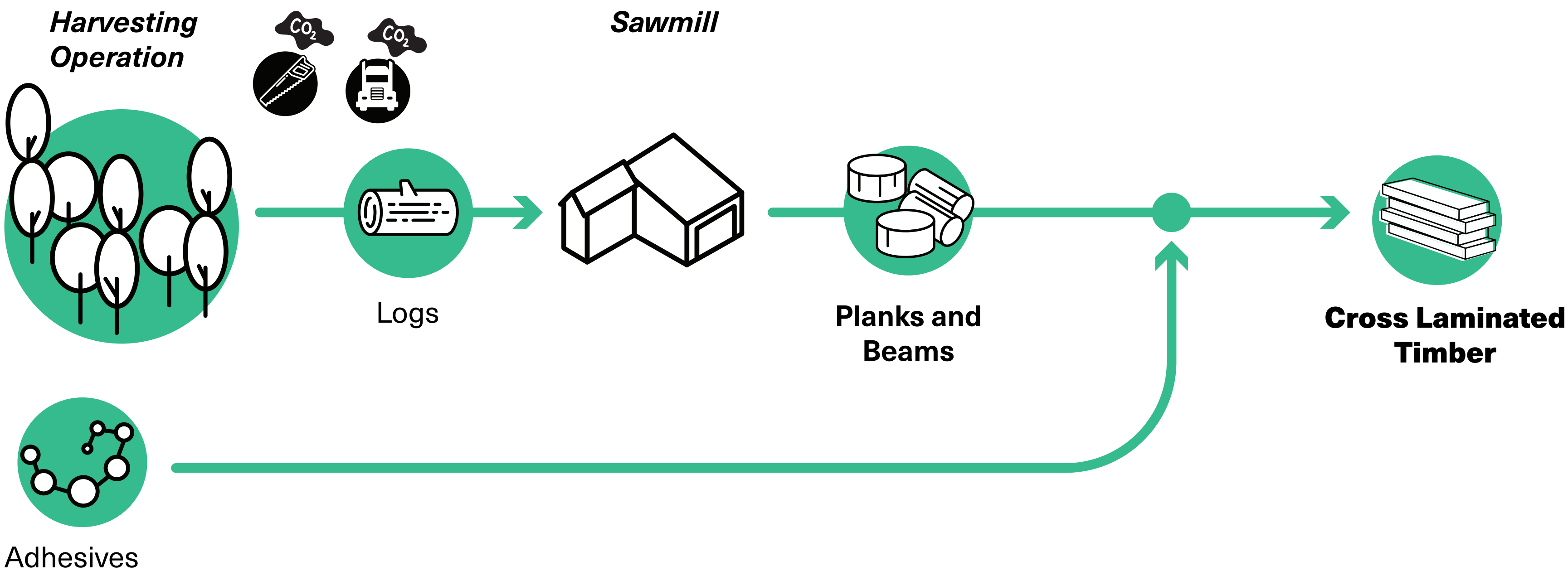
These materials are renewable, biodegradable, and capable of long-term carbon sequestration, making them a viable alternative to carbon-intensive materials like concrete and steel (FSC 2022).

While hardwoods like oak, maple, and teak offer high durability, softwoods like pine, spruce, and fir grow faster, providing a more renewable and widely available option (PEFC 2023).

Pro	Con
+ Trees absorb CO_2 as they grow, locking carbon into the material even after harvesting.	– Unsustainable logging can lead to habitat destruction and biodiversity loss, making certification essential.
+ When responsibly sourced, timber provides a continuous, sustainable resource.	– Some wood species require treatment or protective finishes to enhance durability.
+ Hardwoods excel in high-wear applications, while softwoods offer lightweight and cost-effective alternatives.	– Softwoods can be more flammable, necessitating fire-resistant treatments for specific applications.
+ Compared to steel or concrete, timber requires significantly less energy to process and manufacture (Lindenmayer et al. 2019).	

21st Serpentine Pavilion I London, United Kingdom
Theaster Gates
This pavilion is largely comprised of a lightweight stained black wood. The artist responsible for the design collaborated with various non-profits and architecture firms to select a wood product that was both substantially and ethically harvested.

Image credit: Archello



Cross Laminated Timber

Cross-Laminated Timber (CLT) is an engineered wood product made by layering solid-sawn timber in alternating grain directions, creating strong, stable, and durable panels.

Originally developed in Europe in the 1990s, CLT is now widely used in mass timber construction, offering a low-carbon alternative to concrete and steel (Glover et al. 2021).

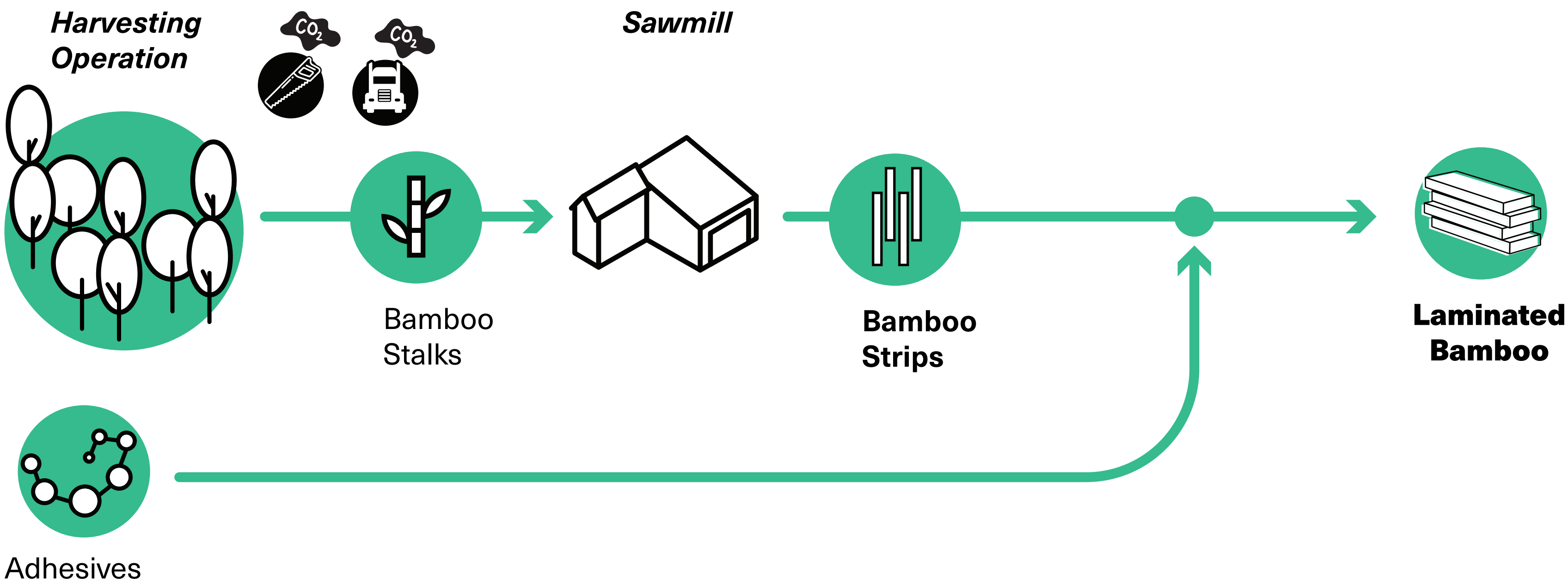
Its structural integrity, fire resistance, and speed of installation make it ideal for mid- and high-rise buildings, public infrastructure, and prefabricated designs (Smith and Thomas 2020).

Pro	Con
+ Significantly reduces embodied carbon, sequestering CO_2 throughout its lifespan.	– Higher upfront costs than conventional wood framing.
+ Lightweight yet structurally strong, reducing foundation requirements and material use.	– Requires certified sustainable sourcing to prevent deforestation risks.
+ Prefabrication streamlines construction, minimizing waste and improving efficiency.	– Limited availability in some markets, depending on manufacturing capacity.
+ Excellent thermal performance, enhancing building energy efficiency.	– Moisture sensitivity, requiring protective treatments in exterior applications.

Engels Plein (English Square) I Leuven Belgium
West 8

Image credit: West 8

This plaza, partially inhabiting a leftover space below a highway, underwent a significant redesign into a new revitalized streetscape and urban plaza. Cross Laminated Timber was used as decking in the plaza in certain areas, to reduce the reliance on traditional stone and concrete pavers.



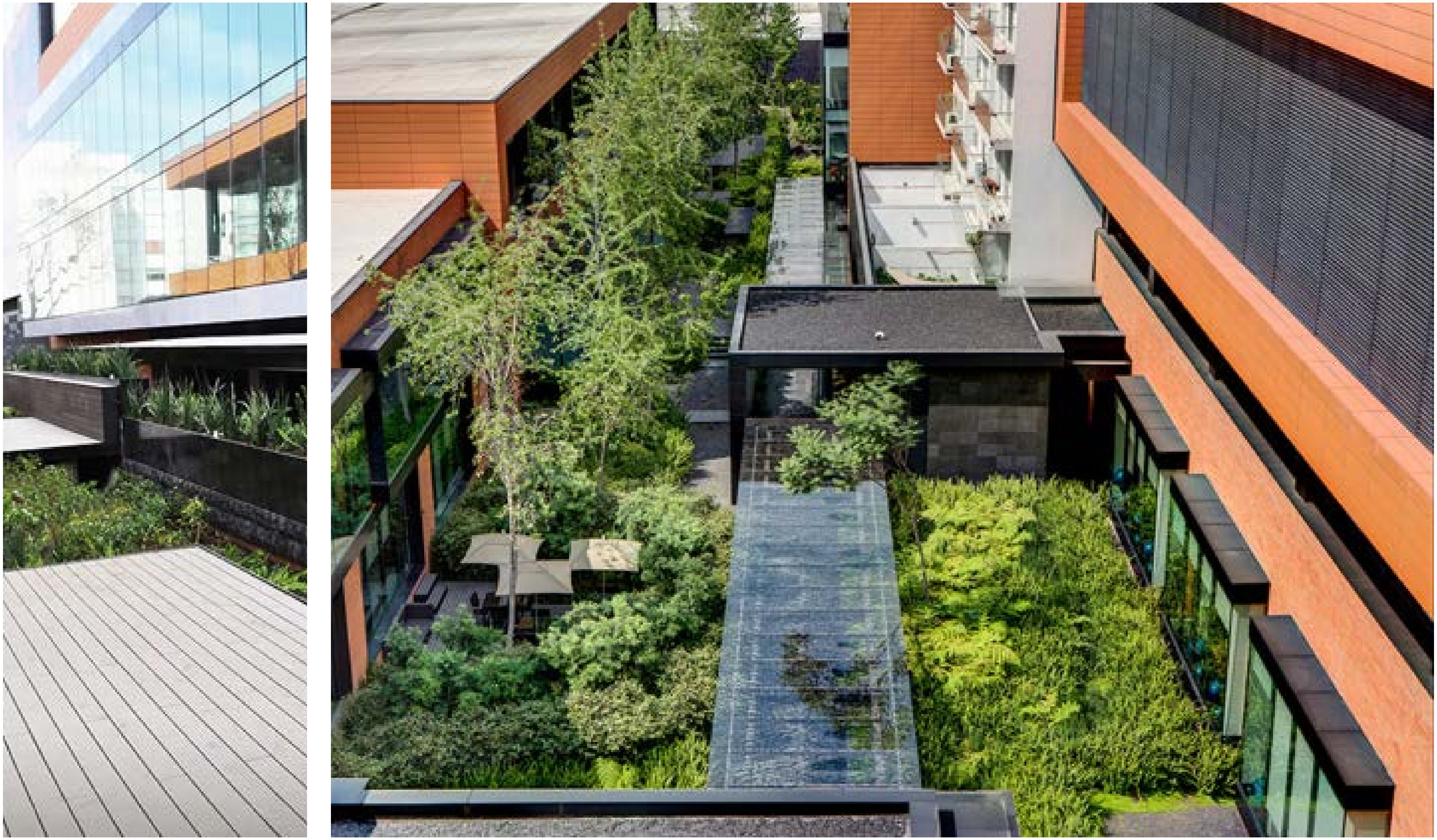
Bamboo

Bamboo is a rapidly renewable material that grows significantly faster than hardwood trees, with some species maturing in 3-5 years.

It offers high tensile strength, making it a viable alternative to concrete and steel in structural applications.

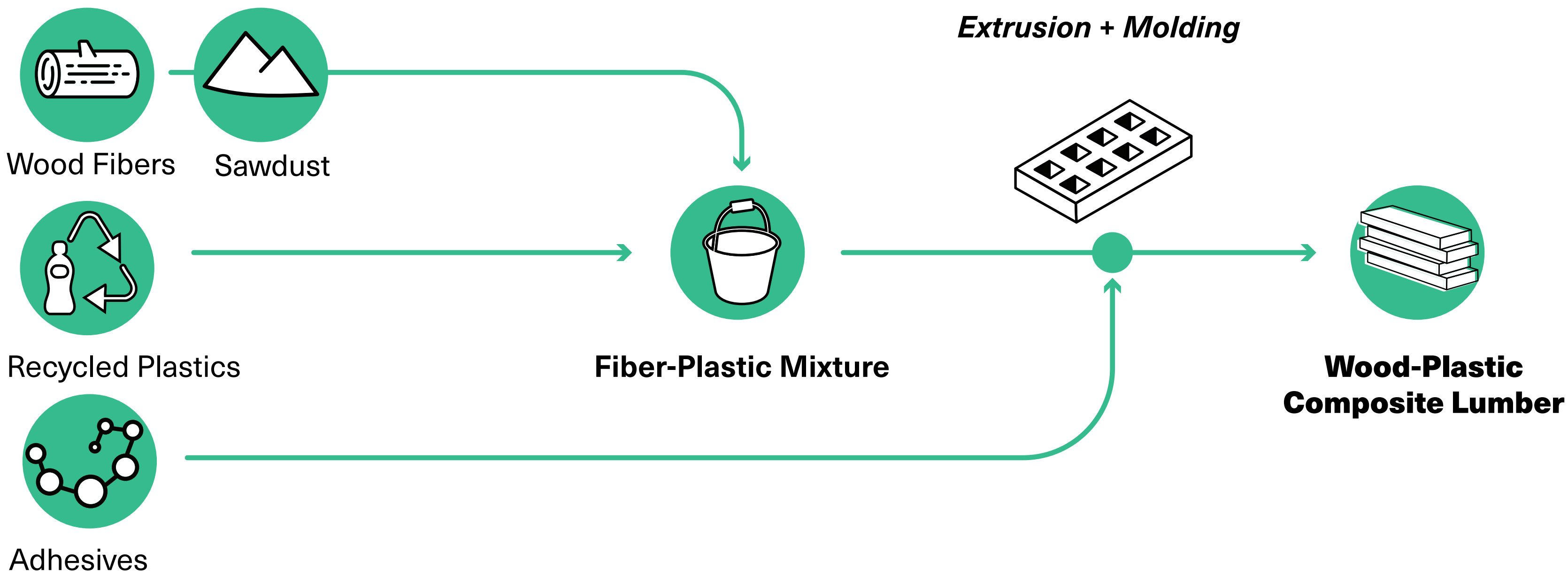
Bamboo's natural flexibility and durability make it well-suited for urban infrastructure, pavilions, and lightweight construction (van der Lugt 2017). However, proper treatment is required to enhance durability and prevent decay (Zhang et al. 2022).

Pro	Con
+ Fast-growing and renewable, making it one of the most sustainable building materials.	– Susceptible to pests and moisture, requiring chemical or thermal treatment.
+ Sequesters carbon at a high rate, helping to offset construction emissions.	– Standardization issues, as growth conditions affect material quality.
+ High strength-to-weight ratio, providing structural resilience.	– Limited large-scale applications, due to regulatory constraints in some regions.
+ Naturally regenerates, without the need for replanting	



Coyoacán Corporate Campus I Mexico City, Mexico
DLC Architects
This landscape ties together a corporate headquarters in the context of a dense urban fabric of a historic neighborhood in Mexico City. The plaza surface is partially volcanic granite and partially a wood composite that is 60 percent bamboo and 40 percent non-toxic resin.

Image credit: Landezine



Wood Plastic Composite Lumber (WPC)

Wood Plastic Composite (WPC) is a hybrid material made from wood fibers and recycled plastics, offering a low-maintenance and durable alternative to traditional lumber.

Commonly used in decking, cladding, fencing, and urban furniture, WPC combines the natural aesthetics of wood with the weather resistance of plastic (Clemons 2002).

Its moisture resistance and reduced maintenance needs make it particularly suited for high-exposure outdoor applications (Stark and Berger 2020).

Pro	Con
+ Incorporates recycled materials, reducing plastic waste.	– Higher embodied energy than natural wood due to plastic content.
+ Requires less maintenance than traditional wood, extending product lifespan.	– Not biodegradable, making end-of-life disposal a concern.
+ Resistant to moisture, rot, and insects, making it ideal for outdoor use.	– Limited load-bearing capacity, restricting structural applications.
+ Eliminates the need for toxic wood treatments, reducing environmental impact.	

Other Wood Products

Reclaimed Wood

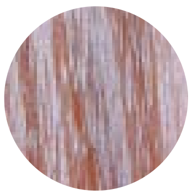
Reclaimed wood is salvaged from deconstructed buildings, old barns, and industrial sites, giving it a second life in furniture, flooring, and architectural elements. This practice reduces deforestation and landfill waste. However, nails, adhesives, and potential contaminants require careful processing before reuse (Chusid 2017)

Accoya Wood

Accoya is a modified softwood created through an acetylation process, which alters wood's cellular structure to improve durability, stability, and resistance to decay. It is widely used for cladding, decking, and window frames and has a longer lifespan than traditional treated wood. Accoya is sourced from sustainably managed forests, making it a low-maintenance and eco-friendly alternative (Rowell 2012).

Thermally Modified Wood

This process enhances wood's moisture resistance, dimensional stability, and fungal resistance by heating it in an oxygen-free environment. Thermally modified wood is ideal for outdoor applications like cladding and decking, as it maintains reduced swelling and warping over time. However, the modification process can reduce wood's mechanical strength, requiring proper engineering considerations (COST FP1407 2019).



Black Locust Wood

Black locust is a naturally rot-resistant hardwood, often used in outdoor infrastructure, decking, and urban landscaping. It requires no chemical treatment and is a viable alternative to tropical hardwoods like ipe. Due to its fast growth rate and durability, black locust is gaining popularity as a sustainable timber source for climate-resilient projects (Lindenmayer et al. 2019).

Bamboo-Laminated Timber

Bamboo laminated timber is created by bonding layers of bamboo strips under pressure, forming a strong and flexible engineered wood alternative. It has a high strength-to-weight ratio, making it suitable for structural elements, flooring, and furniture. Bamboo's rapid renewability and carbon sequestration potential make it a leading choice for low-impact construction (van der Lugt 2017).

Wood Alternatives in Landscape Design

Image credit: Accoya

Image credit: Black Locust Lumber

Image credit: Archiproducts

Accoya Wood Bridges

Accoya wood is increasingly used for pedestrian and vehicular bridges, thanks to its dimensional stability, rot resistance, and extended lifespan. Through its acetylation process, Accoya achieves superior durability and resistance to moisture, outperforming traditional hardwoods in bridge decking and support structures.

As a certified sustainably sourced material, Accoya bridges offer a low-maintenance, eco-friendly alternative to tropical hardwoods and chemically treated lumber (Rowell 2012).

Wood Block Paving

Wood block paving is a historic and durable alternative to stone and concrete, traditionally used in urban streetscapes.

Made from hardwoods like black locust and oak, modern wood block paving provides shock absorption, noise reduction, and a permeable surface that supports stormwater management. Advances in thermal modification and preservative treatments have further improved wood block durability, making it a viable option for low-traffic pedestrian zones and public plazas (Forest Stewardship Council 2023).

Street Furnishings

Sustainably sourced wood is commonly used for benches, bollards, planters, and wayfinding elements in public spaces. Engineered wood products such as Accoya, thermally modified wood, and bamboo laminated timber can withstand public use and offer an alternative to conventional steel or cement. Wood's biophilic qualities also contribute to comfort and well-being in urban environments (Van der Lugt 2017).

Mission Boulevard Linear Park I Hayward, USA
Surfacedesign
The design team re-purposed fallen trees collected from tree-cutting crews around Hayward to create the park's seating areas. Concrete slabs sourced from work sites were sliced and transformed into pavers, while old benches from various parts of the town were refreshed with a coat of paint and up-cycled.

Image credit: Turf Magazine

Soils

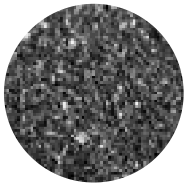
Soils are made in part of broken-down plant matter. This means they contain a lot of carbon that those plants took in from the atmosphere while they were alive. Especially in colder climates where decomposition is slow, soils can store, or “sequester”, this carbon for a very long time.

Urban parks and green spaces throughout the world have a similar amount of carbon stored in their soils as in natural regions close to cities, which means urban green spaces can be important to global carbon sequestration and mitigating the potential effects of climate change.

Stockholm Biochar Project I Stockholm, Sweden Image credit: Unsplash

Initiated by the City of Stockholm, this project transforms urban green waste into biochar through pyrolysis. The produced biochar is then utilized in public green spaces to enhance soil quality and sequester carbon. Additionally, the pyrolysis process generates renewable energy, contributing to the city’s district heating system (C40 Cities 2015).

Soil Amendments



Biochar

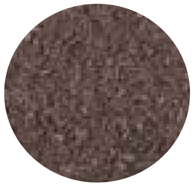
Biochar is a carbon-rich material produced by pyrolyzing organic biomass in a low-oxygen environment. It is used to improve soil health, enhance carbon sequestration, and increase water retention, making it a key tool in climate-resilient landscape design. Biochar can reduce soil acidity, enhance microbial activity, and store atmospheric CO_2 for centuries (Lehmann and Joseph 2015).

Pro

+ Resists decomposition, storing carbon for potentially thousands of years
+ Promotes soil health and facilitates the retention of organic carbon

Con

- Can contribute to eutrophication
- Pyrolysis (the process of heating biomass in a low-oxygen environment) requires specialized equipment and can be energy-intensive



Compost

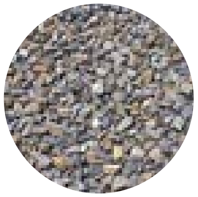
Compost is decomposed organic matter that improves soil fertility, increases microbial diversity, and enhances carbon sequestration. By recycling food scraps, yard waste, and agricultural residues, compost reduces methane emissions from landfills and supports closed-loop material cycles in urban landscapes (US EPA 2022).

Pro

+ Reduces landfill waste
+ Introduces microbes that break down organic matter, suppress soilborne diseases, and facilitate nutrient cycling

Con

- Can contribute to eutrophication
- Local availability varies with waste generation and infrastructure



Pulverized Rock

Pulverized rock, also known as rock dust or enhanced rock weathering (ERW) material, is crushed basalt, limestone, or silicate minerals applied to soils to capture atmospheric CO_2, remineralize degraded land, and improve soil structure. The chemical reaction between rock dust and CO_2 leads to long-term carbon storage while enriching soils with essential minerals such as calcium, magnesium, and silica (Beerling et al. 2018).

Pro

+ Enhances soil fertility and structure, promoting plant growth
+ Concrete can be used as pulverized rock, creating circularity and reducing waste

Con

- Extraction and grinding of rock are energy-intensive processes, potentially offsetting carbon gains from enhanced weathering.
- Depending on source rock, rock dust can contain heavy metals or other contaminants (e.g., arsenic, cadmium).

Biochar Resource

Metabolic Matters

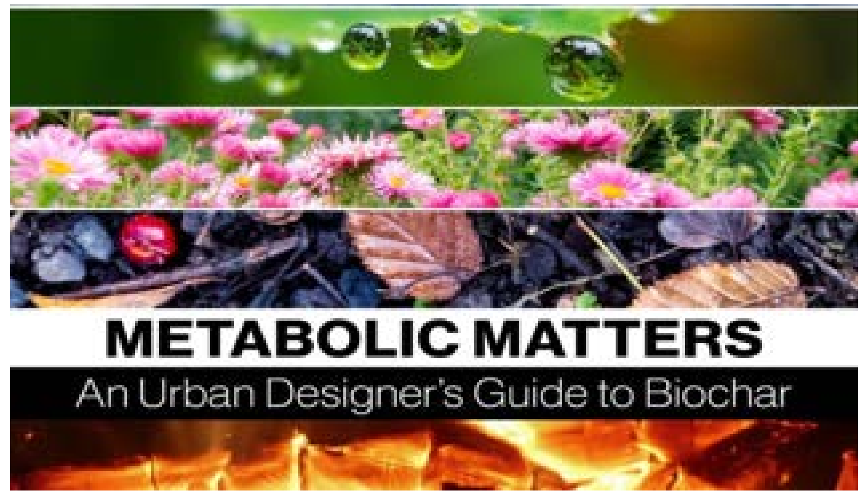
Justin Roberts

How can biochar help designers tackle urban challenges, biodiversity loss, and climate change? How can a metabolic approach foster resilient, climate-stable systems?

This guide explores biochar's origins, applications, and potential as a soil amendment and climate tool, offering designers a practical framework to integrate it into their work. Rooted in a three-month independent study in Sweden and Finland, funded by the Valle Scholarship, the research highlights real-world innovations from the Rest till Bäst project. Published with support from the Green Futures Lab and the Scan Design Foundation, this guide aims to ignite creative exploration of biochar's role in sustainable design.

Metabolic Matters can be downloaded from the UW Green Futures Lab website at:

https://greenfutures.be.uw.edu/publications/



Additional Soil Amendments

Algae and Seaweed-Based Amendments

Algae and seaweed-based soil amendments contain bioactive compounds that enhance microbial activity, plant growth, and soil structure. These materials stimulate root development and increase organic matter, potentially enhancing carbon storage and nutrient cycling in soils (Craigie 2011).

Mycorrhizal Fungi Inoculants

Mycorrhizal fungi form symbiotic relationships with plant roots, improving nutrient uptake, soil aggregation, and carbon storage. These fungi increase soil organic matter by promoting plant biomass growth, stabilizing soil structure and reducing nutrient leaching (Smith and Read 2010).

Bio-stimulants

Bio-stimulants, including humic acids, fulvic acids, and amino acids, improve soil microbial diversity, nutrient availability, and root architecture. These compounds enhance plant resilience to stress, leading to increased soil organic carbon storage and improved soil fertility (du Jardin 2015).

Wood Chips and Mulch

Applying wood chips and organic mulches to soil surfaces reduces erosion, improves moisture retention, and enhances organic matter levels. As they decompose, wood-based mulches increase soil microbial activity and contribute to long-term carbon storage (Tammeorg et al. 2014).

Bio-based Polymers

Bio-based polymers, derived from starch, cellulose, and chitosan, improve soil structure and water retention while reducing reliance on synthetic amendments. These materials degrade naturally, enriching soil organic matter and supporting carbon sequestration (Gutiérrez et al. 2019).

Trees and Vegetation

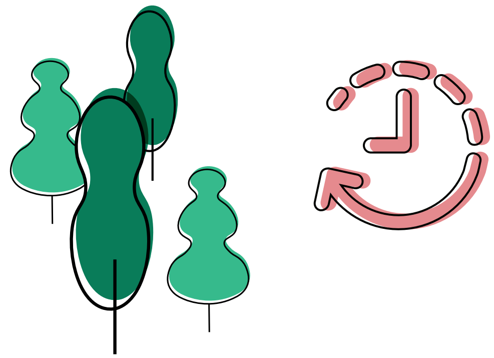
Principles for tree selection

Tree selection plays a pivotal role in urban design, offering an avenue for carbon sequestration.

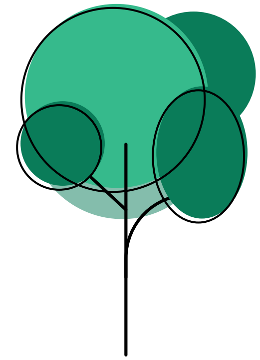
Fast-growing trees efficiently absorb carbon dioxide from the atmosphere during photosynthesis, kickstarting the carbon sequestration process. Additionally, long-living species ensure sustained carbon storage over extended periods, contributing to the longevity of carbon sequestration efforts.

Large-leafed trees, with their expansive foliage, boast higher rates of photosynthesis, enabling them to capture more carbon dioxide. Moreover, selecting native species adapted to local climatic conditions fosters resilience and ecosystem stability, optimizing carbon sequestration potential while minimizing resource inputs for maintenance.

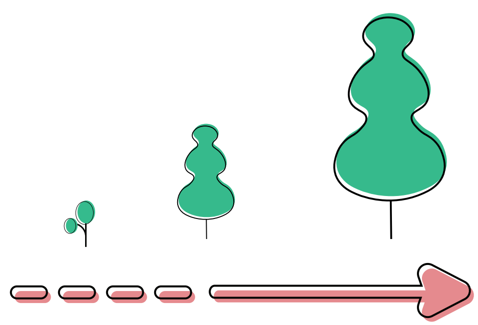
By prioritizing low-maintenance tree species, designers can ensure the continued health and vitality of urban green spaces, reducing the need for intensive care and resource consumption.



LONG LIVING



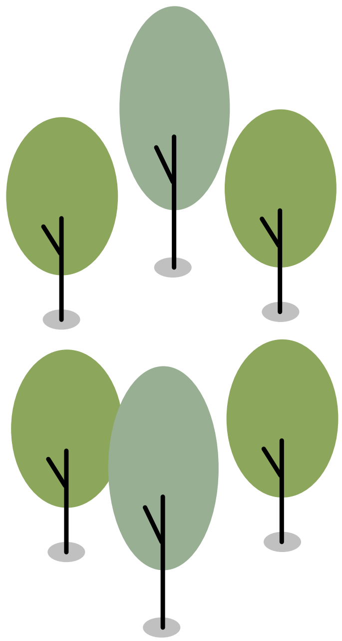
LARGE LEAF

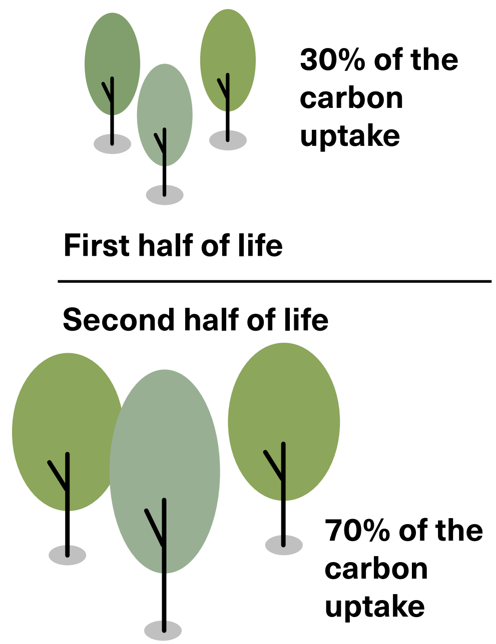


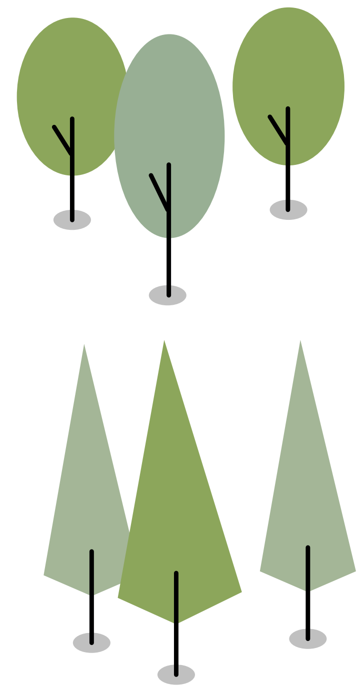
FAST-GROWING TREES

NATIVE SPECIES

Planting for Carbon Sequestration







Multi-layered planting

Multistory planting increases carbon storage by layering vegetation at different heights.

Tall trees capture carbon through photosynthesis in their trunks and leaves, while understory plants and ground cover contribute via their roots and organic matter.

Keep Existing Trees

Preserving existing large trees is crucial for maximizing carbon storage in urban landscapes.

Larger trees inherently store more carbon than smaller ones due to their greater biomass and longer lifespans.

Prioritizing the preservation of mature trees whenever feasible helps maintain and enhance the carbon sequestration capacity of the environment.

Consider Tree Species

Different types of vegetation and soils sequester carbon at varying rates.

Evergreen trees absorb carbon quickly due to their year-round photosynthesis.

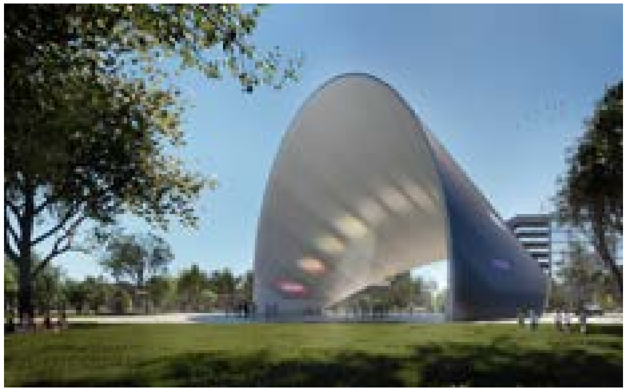
Deciduous trees store more carbon overall, despite their slower absorption rate compared to evergreens.

Emerging Energy Producing Public Spaces

Emerging energy-producing materials and landscapes represent a paradigm shift in thinking for urban designers, to actively pursue aggressive strategies to not only sequester carbon, but to reduce emissions from energy use.

These approaches present opportunities to actively integrate greenhouse gas reduction efforts in urban spaces. With the potential to generate renewable energy, these innovations can serve as another needed tool to combat climate change, ushering in a future where urban and infrastructure design can contribute significantly to a climate-positive built environment.

Land Art Generator Initiative (LAGI)
The goal of the Land Art Generator Initiative is to invite land artists and designers to promote solutions to a clean energy future by providing models of renewable energy art and infrastructure that add value to public space, inspire, and educate. LAGI has sponsored over a dozen competitions and projects since 2010, and their website hosts several useful resources.



Arch of Time
Houston, USA

Image credit: Land Art Generator

Functioning as both a timekeeping device and a community solar installation, the design includes a light display every hour in a shaded outdoor setting. Annually, it will produce 400,000 kWh of solar energy, enough to power 40 Texan homes.

Windnest
Pittsburgh USA

Image credit: Land Art Generator

Two “wind nests” rotated through wind and solar, generating energy for the 2022 SEE MONSTER exhibition, of which it was an integral component.

Image credit: Architectural Record

Freshkills North Park I Staten Island, New York
Field Operations
North Park is a part of the broader Freshkills Park, a sprawling landscape restoration project that sit on top of a former landfill. Opened in 2023, North Park incorporates numerous energy producing elements to its design, including a fully composting public restroom and parking lot powered by a micro solar grid.

How Can Landscapes be Energy Positive?

Solar-Powered Pathway Lighting

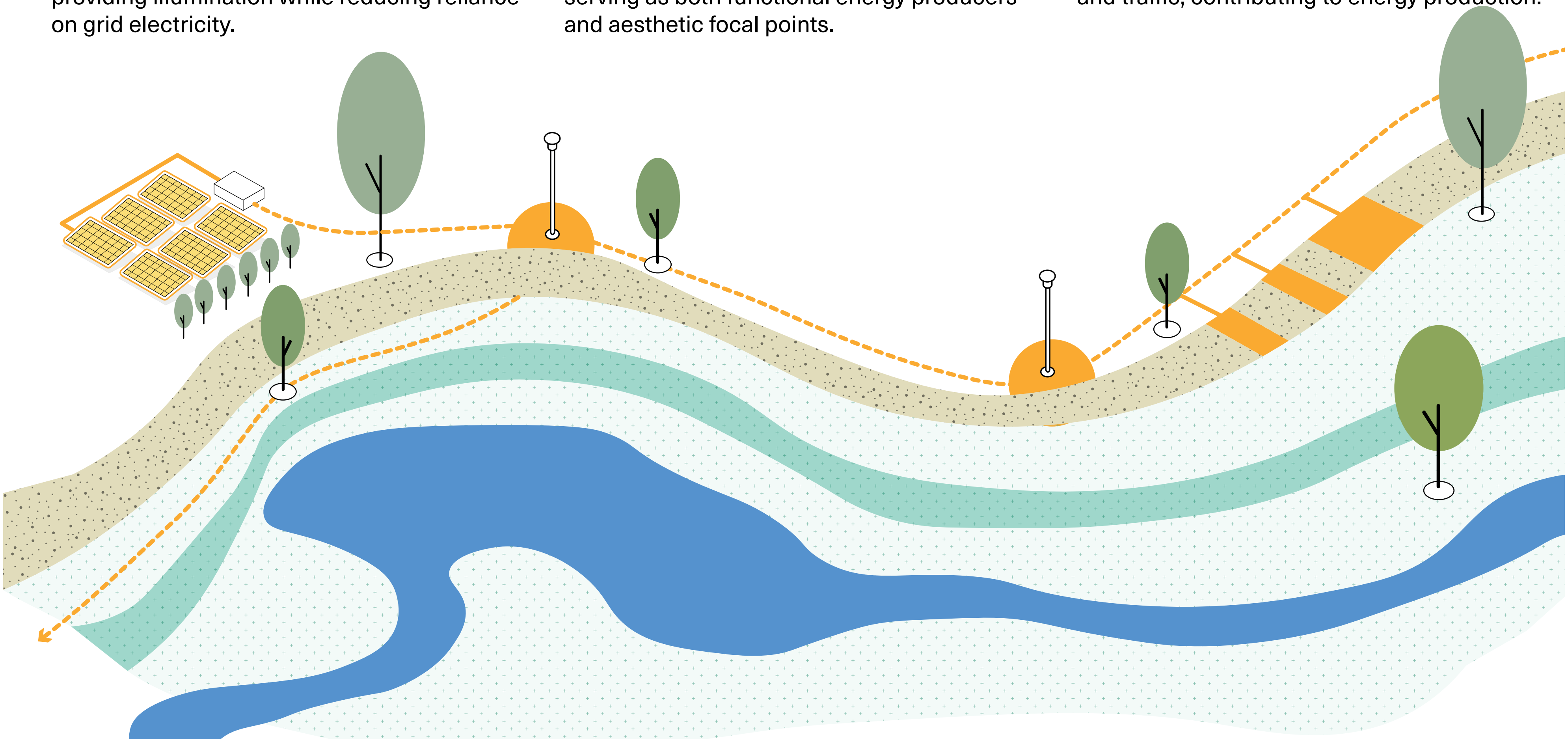
Integrated solar panels in pathway surfaces or nearby structures to power LED lighting, providing illumination while reducing reliance on grid electricity.

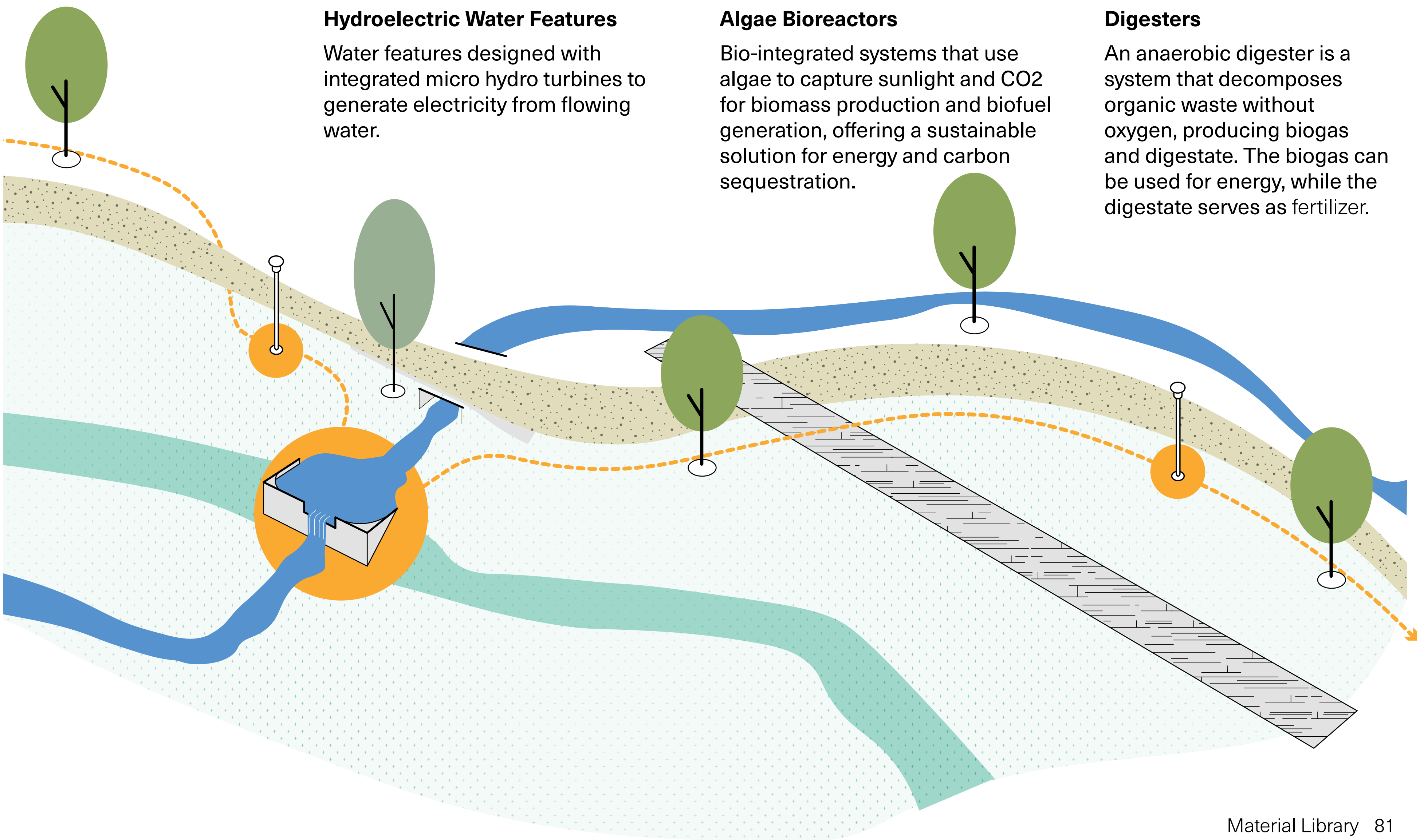
Wind-Powered Sculptures

Artistic wind turbines or kinetic sculptures that harness wind energy to generate electricity, serving as both functional energy producers and aesthetic focal points.

Piezoelectric Pathways

Pathways constructed with piezoelectric materials generate electricity from footsteps and traffic, contributing to energy production.





Hydroelectric Water Features

Water features designed with integrated micro hydro turbines to generate electricity from flowing water.

Algae Bioreactors

Bio-integrated systems that use algae to capture sunlight and CO_2 for biomass production and biofuel generation, offering a sustainable solution for energy and carbon sequestration.

Digesters

An anaerobic digester is a system that decomposes organic waste without oxygen, producing biogas and digestate. The biogas can be used for energy, while the digestate serves as fertilizer.

Climate Responsible

Case Studies

Precedents

Exemplary Case Studies

The following case studies highlight innovative, climate-responsible material strategies, demonstrating how the built environment can actively contribute to carbon sequestration, circular economic principles, and even ecosystem regeneration.

These projects not only prioritize climate-responsible material selection but also integrate other regenerative design strategies, showcasing the synthesis of materials and other carbon mitigative systems working together.

Each case study is categorized using various tags, identifying key strategies such as energy generation, carbon-sequestering materials, active transportation infrastructure, regenerative soil practices, circular design, material reuse, trees and vegetation, and wetland restoration.

By examining these projects through a material-focused lens, this section seeks to highlight how urban and landscape designs can emphatically foreground carbon sequestration and climate mitigation strategies.

Ellinikon Park in Athens Greece
Image credit: Sasaki

Energy Generation	Designs that incorporate renewable energy systems (e.g., solar panels, wind turbines, kinetic energy) to provide on-site, low-carbon power while reducing dependence on fossil fuels (IEA 2023).
Active Transportation	Prioritizes pedestrian, cycling, and public transit infrastructure to minimize vehicular emissions, improve public health, and enhance urban mobility (Gehl 2010).
Carbon Sequestering Materials	Utilizes low-carbon and carbon-negative materials that actively capture and store atmospheric CO_2, including bio-based materials (e.g., hempcrete, timber, biochar-enhanced concrete), recycled aggregates, and enhanced weathering techniques (Lehmann and Joseph 2015).
Regenerative Soil Practices	Focuses on enhancing soil health and biodiversity through compost integration, biochar application, mycorrhizal fungi inoculation, and cover cropping. These practices increase carbon sequestration and nutrient cycling in urban landscapes (Brown and White 2021).
Circular Design	Embraces design for disassembly, reuse, and recycling to minimize waste and embodied carbon. This includes modular construction, adaptive reuse, and cradle-to-cradle material strategies (Ellen MacArthur Foundation 2022).
Material Reuse	Prioritizes reclaiming and repurposing existing materials from demolition, industrial waste, or local surplus to reduce extraction impacts and extend the material lifecycle (Chusid 2017).
Trees and Vegetation	Integrates tree plantings, green roofs, and biodiverse landscapes to sequester carbon, improve air quality, and mitigate urban heat island effects. Strategic vegetation placement also enhances stormwater retention and urban cooling (Nowak et al. 2013).
Wetlands & Riparian Habitats	Restores and preserves wetlands, floodplains, and river corridors to enhance carbon storage, water filtration, and biodiversity. Wetlands store up to 30% of global soil carbon despite covering only 3% of land area, making them crucial for climate adaptation (Mitsch and Gosselink 2015).

Bridgefoot Street Park

Location: Dublin, Ireland

Design Firm: DFLA

Typology: Park

Project Summary:

Bridgefoot Street Park, designed by Dermot Foley Landscape Architects (DFLA), is a 2.5 acre public space located in Dublin's city center.

Formerly a vacant lot, the site was transformed into a public park through a collaborative design process that prioritized community needs, and climate resilience (Dublin City Council 2019). Opened in 2022, the park provides green space in a historically industrial and densely populated district, offering a mix of play areas, walking paths, and gathering spaces.

Image credit: Landezine

Image credit: Dublin City Film Office

Recycled glass, brick seconds, and calp stone were integrated into paving, retaining elements, and in-situ concrete. (Landezine 2022).

Integrates landscape elements crafted from reclaimed materials, aligning with circular economy principles to extend the lifespan of urban materials (IFLA Europe 2022). This approach influenced local policy discussions, encouraging further adoption of circular construction practices in Ireland (The Green Cities Europe Award 2023).

Over 180 trees and extensive wildflower areas were planted, enhancing urban biodiversity and improving carbon sequestration (Dublin City Council 2019). The park's Taplin's Field Community Garden supports urban greening efforts (Urban Nature Atlas 2022).

DFLA developed specialized soil substrates by blending crushed secondary raw materials with subsoils and topsoils (Landezine 2022). The soil mix fosters "natural vegetation colonization", reducing the need for chemical fertilizers and artificial soil amendments (IFLA Europe 2022).

The park is designed to integrate with Dublin's expanding cycling network, with planned adjacent two-way cycle lanes to encourage low-carbon urban mobility (Dublin City Council 2019).

Floriade Pavilion - The Voice of Urban Nature

Location: Amsterdam, Netherlands
Design Firm: Overtreders W
Typology: Pavilion

Image credit: ArchDaily

Project Summary:

Designed by Overtreders W, the pavilion was commissioned by the municipalities of Almere and Amsterdam for the Floriade Expo 2022, an international horticulture exhibition (ArchDaily 2022). The pavilion serves as an interactive space that explores the relationship between urban environments and nature, featuring themed gardens and exhibitions on sustainable urban living and biodiversity. It was constructed entirely from locally sourced, biobased materials and designed for full disassembly and reuse (Overtreders W 2022).

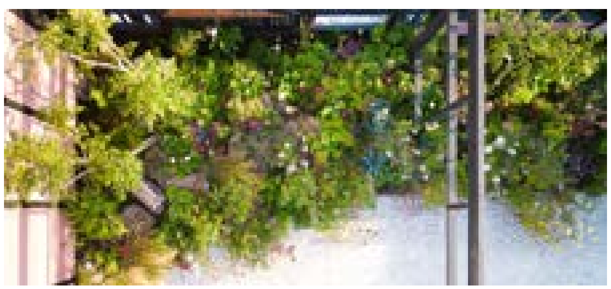


Image credit: ArchDaily

The pavilion's structure incorporates reclaimed timber sourced from demolished buildings in Amsterdam, Almere, and Zwolle (Overtreders W 2022). A modular design approach ensures all components can be disassembled and reused in future projects, preventing construction waste (ArchDaily 2022).

The pavilion was built using prefabricated wooden modules filled with hemp-lime insulation, allowing for easy relocation (Overtreders W 2022). After Floriade Expo 2022, the structure was relocated for continued use. This demonstrates a circular approach to building design (Landscape First 2022)

The hemp-lime (hempcrete) walls provide carbon sequestration benefits, as hemp absorbs CO_2 during growth, locking carbon into the material (Overtreders W 2022). Locally sourced timber harvested from managed forests ensures minimal environmental impact and promotes sustainable forest management (The Voice of Urban Nature 2022).

Includes six distinct themed gardens, acting as microhabitats that enhance urban biodiversity (Landscape First 2022). A rooftop nectar garden featuring yellow mustard and incarnate clover provides habitat for pollinators such as bees and butterflies (ArchDaily 2022).

Daramou Biodiversity Roof

Location: Sydney, Australia
Design Firm: Junglefy
Typology: Solar green roof

Image credit: Living Architecture Monitor

Project Summary:

The Daramou Biodiversity Roof is an innovative, multi-functional rooftop that combines a lush green roof with integrated photovoltaic panels to create a symbiotic, carbon-efficient system. The diverse plantings cool the roof by up to 20°C, lessening urban heat island effects, while enhancing solar performance by reducing ambient temperatures. In turn, the solar arrays provide essential shading that benefits the rooftop greenery, resulting in a cohesive design that maximizes energy efficiency and ecological resilience.

Image credit: Sempergreen

Solar panels generate renewable electricity on the roof, reducing the building's reliance on grid-based energy and lowering operational carbon emissions (Irga et al. 2021).

The green roof hosts a diverse selection of native plant species, providing food and shelter for pollinators and urban wildlife (Vanstockem et al. 2018). The vegetation also helps regulate rooftop temperatures, reducing the heat island effect and lowering cooling demands for the building (Irga et al. 2021).

The building uses cross-laminated timber (CLT) and glulam, both of which sequester carbon and reduce the building's embodied emissions (Irga et al. 2021). The timber used in construction was harvested from certified sustainable forests (Minnesota Pollution Control Agency 2021).

The building was designed using modular components, allowing for future disassembly and reuse of materials (Vanstockem et al. 2018). The interior layout was also designed to be reconfigurable, allowing for flexible space use over time and minimizing the need for material-intensive renovations (Minnesota Pollution Control Agency 2021).

Dutch Kills Green

Location: New York City, USA

Design Firm: WRT Design + Margie Ruddick Landscape

Typology: Public Space

Image credit: Landscape Performance Series

Project Summary:

In what was once an impermeably paved parking lot, Dutch Kill Greens creates a pedestrian and climate forward space. The design of the site reclaims the concrete from its previous form, reducing the energy required for material production and the amount of fossil fuels used to transports demolition waste. The abundant plantings of the site also sequesters carbon. Dutch Kill's Green transformed a vehicular dominated hardscape that was dangerous for active transport into a public amenity in a bustling neighborhood.

Image credit: Langan

803 tons of recycled concrete were used to create median barriers, reducing CO_2 emissions from new concrete production and saving an estimated $500,000–$630,000 in material costs (Landscape Architecture Foundation 2012).

174 new trees sequester 4,698 pounds of carbon and absorb 1,079 pounds of CO_2 annually, improving air quality (Landscape Architecture Foundation 2012). Native plantings used also provide habitat for urban wildlife (Inhabitat 2011). Native and drought-tolerant plantings also reduced irrigation needs by 786,500 gallons per year, saving approximately $3,500 annually (Landscape Architecture Foundation 2012).

12% increase in bicycle traffic since project completion, with an average of 3,416 cyclists per day (Landscape Architecture Foundation 2012).Safety improvements, including new pedestrian signals, contributed to a decline in fatalities on Queens Boulevard, once known as the "Boulevard of Death" (Urban Omnibus 2012).

Constructed wetlands filter stormwater pollutants, enhance urban water quality and provide habitat for native species (Inhabitat 2011). The park prevents 20.2 million gallons of stormwater from entering New York City's combined sewer system annually, reducing flood risks (Landscape Architecture Foundation 2012).

Passieg De Saint Joan Boulevard

Location: Barcelona, Spain
Design Firm: Lola Domenech
Typology: Streetscape

Project Summary:

Originally laid out by Ildefons Cerdà in 1859, Passeig de Sant Joan is a historic 50-meter-wide boulevard in Barcelona. Redesigned by Lola Domènech, the project aimed to transform an urban corridor into a vibrant, carbon-mitigative green zone. By reducing vehicular lanes, the project creates interconnected spaces for walking, biking, and outdoor leisure, all while enhancing urban cooling and carbon capture. The design carefully preserves century-old trees and introduces new rows of trees, creating a resilient, symmetrical streetscape that honors the boulevard's historic form and prioritizes pedestrian activity and ecological health.

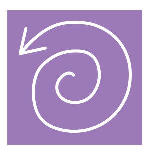
Image credit: Landscape Performance Series

Image credit: Langan

A 4-meter-wide dedicated bike lane along the boulevard improves cycling safety and offers an alternative to car travel (Urbanitarian n.d.)

The redesign expanded pedestrian areas, allowing for the addition of two rows of new trees (Domènech n.d.). The preservation of century-old trees provides natural shade, and contributes to air quality improvements (Urbanitarian n.d.)

A phreatic water irrigation system utilizes naturally occurring groundwater to sustain vegetation. This system reduces reliance on potable water, lowers irrigation costs, and maintains soil moisture levels for long-term plant health (Urbanitarian n.d.).



The boulevard incorporates modular street furniture, adaptable seating, and multi-use public spaces designed for easy reconfiguration or relocation based on community needs. This ensures that materials can be re-purposed rather than discarded (Domènech n.d.). The project also uses durable, low-maintenance materials, reducing the need for frequent replacements or upgrades (Urbanitarian n.d.).

Corniche des Forts Park

Location: Paris, France
Design Firm: Ilex landscape architecture
Typology: Park

Project Summary:

Corniche des Forts Park transforms a former gypsum quarry into a dynamic, multi-use landscape. Once an active quarry, the site was abandoned and gradually reclaimed by nature, evolving into an overgrown forest. Today, the park integrates a protected sanctuary with a public promenade that invites visitors to experience the forest ecosystem as its central feature. Thoughtful design strategies, such as circular material reuse through backfilling and innovative rainwater management, ensure that both the historic character and environmental integrity of the site are preserved. By maintaining non-accessible areas as living carbon sinks and incorporating features like gabion retaining walls that encourage further vegetation growth, the park is a benchmark for sustainable urban regeneration.

Image credit: Landscape Performance Series

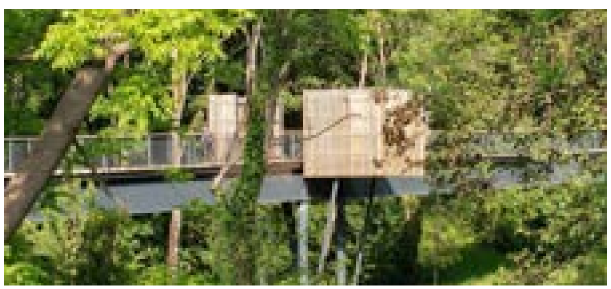


Image credit: Langan

The project prioritized conservation of century-old trees and native plant species on-site (Landezine n.d.). The 20-hectare central forest sanctuary remains off-limits to visitors, allowing natural ecological processes to continue undisturbed (Landezine Award n.d.).

Plant selection was guided by soil adaptability and water retention needs, reducing reliance on irrigation and promoting self-sustaining ecosystems (Landezine Award n.d.).

New riparian corridors on-site connect formerly fragmented green spaces, improving species migration and habitat resilience (Landezine Award n.d.).

Wetland restoration efforts across the former quarry improve stormwater retention and filtration, reducing the risk of urban flooding, and enhance water quality (Landezine n.d.).

The site includes a network of multi-use paths, facilitating walking, cycling, and running and connecting surrounding neighborhoods (Landezine n.d.). A 124.7-meter-long elevated footbridge, provides an accessible route across the park's forest sanctuary, providing sweeping views and facilitating active transportation across the project (Landezine Award n.d.).

The site underwent extensive soil remediation efforts, restoring fertility in previously degraded quarry land (Landezine n.d.). The park's extensive undisturbed sanctuary prevents soil compaction and supports root growth (Landezine n.d.).

Social Spine

Location: Copenhagen, Denmark
Design Firm: SLA
Typology: Green roof

Project Summary:

This project retrofits what was an empty, concrete roof into a social space for the students of Øresundkollegiet. The Social Spine offers a string of living rooms for student life, offering places for connection, relaxation, and study. The extensive new plantings create new habitat for insects and birds. The presence of soil and vegetation sequesters carbon, adding climate mitigation benefits to the retrofitted roof passage.

Image credit: SLA

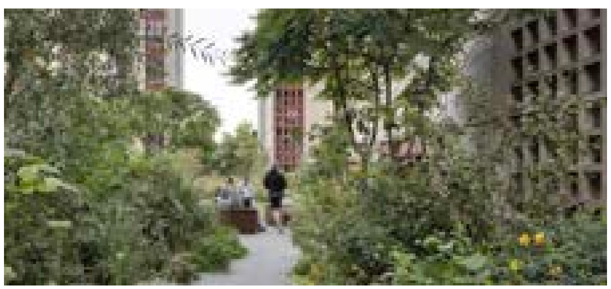


Image credit: SLA

The project introduced 350 trees, shrubs, and plants, creating a diverse ecosystem that supports pollinators, birds, and urban biodiversity (SLA n.d.). The planting strategy focused on mitigating urban heat island effects, reducing rooftop temperatures and improving microclimatic conditions (State of Green n.d.).

The original concrete terrace materials were re-purposed into paving, seating, and structural elements

Roof terrace materials were re-used and upcycled as the pavers for the new roof design.

The rooftop was adaptively reused to extend the lifecycle of existing infrastructure, integrating modular elements that can be rearranged and re-purposed to meet future needs (Arkitektforeningen n.d.).

Durable, low-maintenance materials were selected to reduce resource consumption and long-term maintenance needs (State of Green n.d.).

The redesigned rooftop serves as a pedestrian-friendly social hub, encouraging students to walk and engage with outdoor communal spaces rather than relying on indoor facilities (SLA n.d.).

Banegaarden

Location: Copenhagen, Denmark
Design Firm: Rønnow Arkitekter + Shiso
Landscape Typology: Public Space

Image credit: Banegaarden

Project Summary:

In what were the storage barns for the national railway, DSB, Banegaarden creates a space for sustainable food connection from existing structures and material found in Copenhagen. With active preservation of existing wood structures and redesign of the courtyard space, using informal materials, the complex supports culinary entrepreneurship in the midst of the city. It functions as an informal community space, creating room for connection in the midst of a regenerating industrial site.

Image credit: Visit Copenhagen

The project prioritized maintaining the original timber structures and minimizing new construction materials (Banegaarden n.d.). Natural building materials, such as wood and reclaimed bricks, were used instead of synthetic alternatives (Danish Architecture Center n.d.).

Reconfigured 100-year-old propagation greenhouses from the Botanical Gardens into a Green Growth Academy. Interior spaces were designed with modular elements, allowing for flexible programming and future repurposing (Danish Architecture Center n.d.).

Preserved existing vegetation, including blackberry brambles and willow trees, continue to thrive among the barns, maintaining an ongoing carbon sink.

The site includes over 3 acres of urban green space, featuring native trees and plants (Banegaarden n.d.).

Banegaarden is accessible by bicycle and public transportation, reducing the carbon footprint of visitor travel (Banegaarden n.d.). The site features active transportation corridors, connecting different areas and minimizing vehicular access at key spots (Danish Architecture Center n.d.).

Wood chips are used as ground cover, serving as a carbon sink and improving soil health. On-site composting of organic waste is utilized to reduce reliance on chemical fertilizers (Danish Architecture Center n.d.).

The Metro Forest Park

Location: Bangkok, Thailand

Design Firm: Tk Studios

Typology: Park

Image credit: Landezine

Project Summary:

What once was nearly five acres of abandoned suburban sprawl was regenerated to be an urban demonstration forest to educate the community about forest ecology. Visitors can observe the city from distinct vantage points, ground-level, along the skywalk, and within the observation tower, immersing themselves in the diverse levels of the canopy.

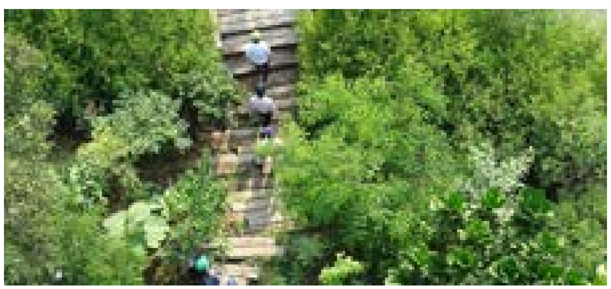


Image credit: Revista Landuum

60,000 saplings planted, representing 279 native species, significantly enhancing urban biodiversity (SUGi Project n.d.). The dense urban forest reduces ambient temperatures, counteracting Bangkok's extreme urban heat island effect (Landezine n.d.). The urban forest sequesters approximately 240,000 lbs of carbon annually (SUGi Project).

The project rehabilitated degraded land by introducing 37,000 cubic meters of earthwork and adding 6,000 cubic meters of planting soil, improving soil structure and fertility (Landezine n.d.).

Engineered berms and grading practices on-site focused on creating diverse micro-ecologies that support different plant and animal species while improving flood resilience (Landezine n.d.).

An integrated network of elevated walkways and observation towers connect the site and encourage visitors to explore the urban forest and engage with its biodiversity (Landezine n.d.).

The reclamation of the abandoned, degraded site, demonstrates how urban reforestation can transform neglected land into an ecological and civic asset.

Minghu Wetland Park

Location: Liupanshui, China

Design Firm: Turnscape

Typology: Park

Project Summary:

The Schuicheng River historically meandered through the city of Liupanshui until the industrial age when the river was channelized and became highly polluted. Through the application of landscape approaches at varying scales, the designers rejuvenated and enhanced the ecological, recreational, and social value of the landscape. The ecological restoration was accompanied by continuous pedestrian and bicycle paths creating a low-carbon urban recreation space in the city.

Image credit: Landezine

Image credit: ArchDaily

Embraced a design that prioritizes wild, low-maintenance native species, allowing natural vegetation to flourish (Landezine n.d.).

Organic soil amendments were incorporated throughout the site to improve soil structure and fertility (Inhabitat n.d.). Natural floodplain restoration techniques reduced soil erosion and increased groundwater infiltration (Landezine n.d.).

The project restored natural riverbanks, peatland wetlands, and constructed terraced wetlands. (ArchDaily n.d.).Peatland wetlands are a unique ecosystem that, despite covering only 3% of global land, stores 30% of the world's carbon. The wetlands filter stormwater runoff, removing pollutants and enhancing water quality in the Shuicheng River (Landezine n.d.).

A network of pedestrian pathways and cycling routes tie together the site and the surrounding city. Site pathways utilized locally sourced, permeable, recycled materials (ArchDaily n.d.).

The project re-purposed abandoned fish ponds and mismanaged agricultural fields (ArchDaily n.d.). By restoring natural hydrological functions, the park has reduced reliance on artificial flood control infrastructure (Landezine n.d.).

The Ellinikon Park

Location: Athens, Greece

Design Firm: Sasaki

Typology: Park

Project Summary:

The Ellinikon Park, spanning 600 acres (243 hectares), is a large-scale redevelopment project transforming the former Ellinikon International Airport into Europe's largest coastal park (Sasaki n.d.).

Designed by Sasaki, the project integrates carbon sequestration, ecological restoration, and active transportation to create a sustainable urban landscape (Green 2023)

Scheduled for completion by 2030, the park will provide Athenians with expansive green spaces, revitalized wetland habitats, and adaptive reuse of airport infrastructure (ASCE 2023).

Image credit: Sasaki

Image credit: The Ellinikon

Sourced all plant materials from within Greece, focusing on native species well-adapted to local climatic conditions. 30,000 trees were planted including 86 different species. Through strategic reforestation and planting, the park is projected to sequester significant carbon, supporting its goal of achieving carbon neutrality within 35 years (Green 2023).

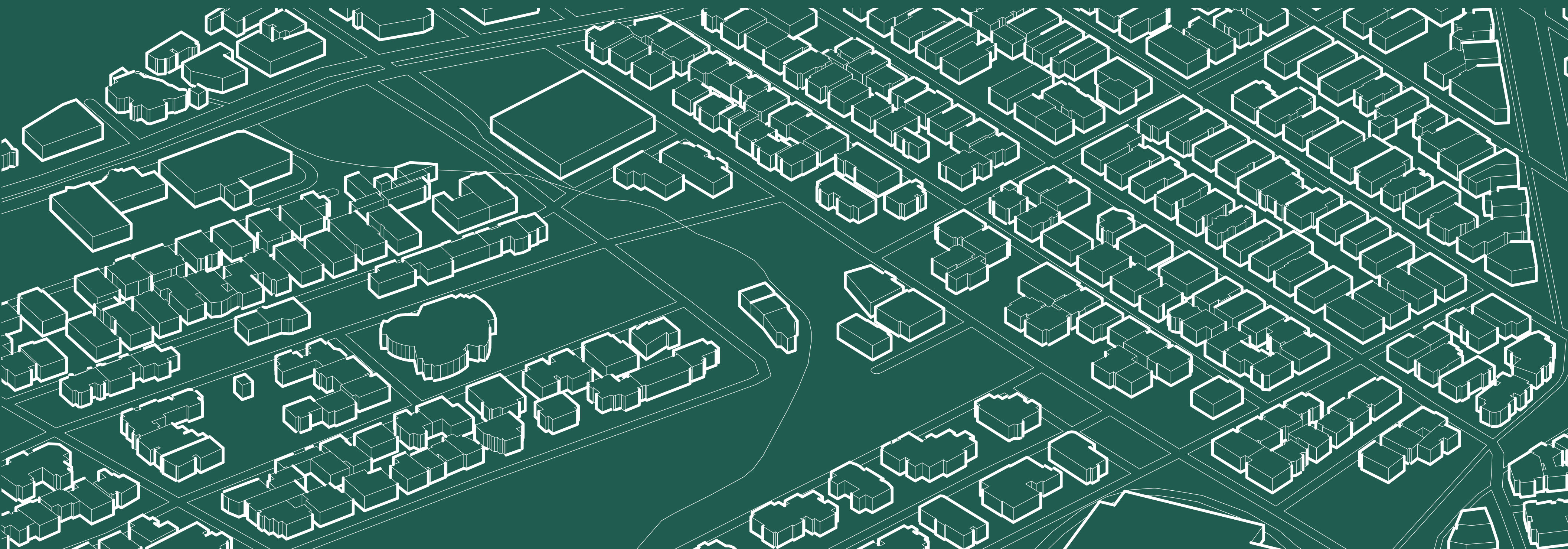
The site, previously covered in compacted and degraded soils due to decades of airport use, is undergoing soil remediation and enrichment to restore its fertility and support plant growth (Sasaki n.d.).

The former Olympic kayak center is being transformed into a seasonal lake, creating a dynamic wetland ecosystem that enhances biodiversity and stormwater retention (ASCE 2023).

A network of pedestrian pathways, cycling routes, and an extension of the city's tram network promotes non-motorized transportation (Sasaki n.d.).

Reused 309,140 sq. ft. of concrete from former runways and tarmac to create various design features from pathways to seating elements.

Resources + References



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02 Material Library

Concrete & Cement-Based Materials

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04 Additional Resources

Embodied Carbon & Life Cycle Assessment Tools

1. EC3 Tool (Embodied Carbon in Construction Calculator) - Helps designers evaluate the carbon footprint of materials and compare low-carbon options. https://www.buildingtransparency.org
2. ATHENA Impact Estimator – A life-cycle assessment (LCA) tool for analyzing the environmental impact of different materials in building design. https://calculatelca.com
3. Tally LCA – A Revit-integrated tool that provides real-time embodied carbon analysis for different materials. https://www.kieran timberlake.com/pages/view/101/tally
4. Sasaki. "Introducing the Carbon Conscience App." - Quantifies early-phase embodied and operational carbon impacts of site and building design. https://www.sasaki.com/voices/introducing-the-carbon-conscience-app/.

Material Databases & Certifications

5. Material ConneXion – A global materials database with innovative and sustainable material options. https://materialconnexion.com
6. Declare Labels & Red List Free Materials – Identifies products free of hazardous chemicals and materials. https://www.living-future.org/declare
7. Cradle to Cradle Certified™ – Evaluates the circularity, health, and sustainability of building materials. https://www.c2ccertified.org

Reports & Guidelines

8. World Green Building Council Reports – Research on embodied carbon reduction strategies in construction. https://www.worldgbc.org
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