INTESA SANPAOLO
INNOVATION CENTER

INDUSTRY TRENDS REPORT

INFRASTRUCTURE & CONSTRUCTION

SUSTAINABLE CONSTRUCTION MATERIALS

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
GRINS FOUNDATION

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EXECUTIVE SUMMARY

Globally, the construction sector represents a $8.000b market which will reach $12.000b by 2028 and continue to be a major contributor of greenhouse gases. Sustainability is therefore becoming vital across all phases of a building's lifecycle. In the ***design stage***, the focus is on the use of digital solutions to drive efficiencies. In the ***operations*** stage, effective waste and wastewater management is important. In the ***operations*** stage, effective waste and wastewater management is important. In the ***construction*** stage, prefabricated and modular construction saves resources while **sustainable construction materials** support the wellness of occupants and provide broader environmental, social and economic benefits.

This report explores the last of these areas with an exploration of the market overall and a deep dive into selected significant material and application areas.

After cement, bricks hold the largest volume share in the construction materials market followed by steel, timber, plastic, glass and insulation. Current end-of-life scenarios are inadequate across most of these categories with reuse, repurposing or recycling typically limited or low value.

For ***bricks***, sustainable innovations are focused on autoclave aerated concrete material which offer very good thermal conductive performance. For ***plastics***, market participants are notably looking to recycle. For ***glass***, the development of "smart" windows promises to protect buildings and their owners or occupiers from any excessive heat and light and for ***insulation***, bio-based binders are attracting R&D dollars.

Overall, however, the market for sustainable construction materials currently suffers from a lack of incentives whilst there are also technical challenges to recovery. Moving forwards, industry stakeholders on both the supply and demand side are all increasingly keen to be (and to be seen to be) green whilst new funding stems from public and private sources.

Digital solutions will form part of the response and are being developed by the likes of Hesus (France), EME (Germany) and Restado (Germany). Collectively, these will notably lead to the growth of the concept of Buildings as Material Banks which aims for materials to create and retain value. Here as elsewhere, greater sustainability across the construction supply chain and life cycle will be enabled by creating more and better data.

Within the ***engineered wood*** market, materials for construction notably include plywood, OSB, LVL, CLT, glulam and hardboard. Each product has its own characteristics which determines its applications with CLT the fastest growing segment in a total market valued at $200b as it proves to offer a sustainable alternative to concrete and steel.

Overall, the sector is being shaped by green regulations which will increase demand but also lead to some slight price increases. Market participants are responding by innovating with Plantd (US), for example, using environmentally friendly inputs to replace OSB, and Tomra (Norway) leveraging sensors and AI to recover wood from waste streams and feed this back into EW production. Outside of engineered wood itself, R&D efforts are focusing on bonding agents where consumers are demanding bio-based alternatives.

Current common petrochemical adhesives include UF, MUF and phenol, which are notably being replaced by ***tannins, and various approaches to leveraging linins***. Other, longer term and more sustainable alternatives which are still largely in the lab stage of development

are carbohydrates and EPI. H.B. Fuller (US) is working with Covestro (Germany) to replace fossil raw materials. More broadly, architects, engineers, developers and consumers are increasingly looking at mass timber structures, primarily due to their "green" credentials.

From an application standpoint, ***roofing materials*** are amongst the most dynamic with ***metal*** emerging as the fastest growing and most sustainable segment. Here, the market is valued at $28.600b and is expected to reach $39.400b in 2030.

Metal roofs are notably recyclable and capable of reflecting more than 70% of the sun's rays, lowering the temperature of buildings and reducing energy costs. ***Plastic*** is emerging as another alternative, with the segment growing at 3.1%. Polycarbonate, acrylic, polystyrene and polyvinyl chloride (PVC) roofs are increasingly supplied in sustainable regenerated and prefabricated sheet formats.

The future is, however, represented be eco-friendly "living" or ***green*** roofs. These are supported by the award of government incentives which encompass new builds and retrofitting but the costs of procurement and installation as well as structural reinforcements often remain prohibitive.

In the longer term, ***solar*** technologies are now advancing to the point at which building integrated photovoltaics can replace conventional construction materials. Tesla (US), for example, is one of many companies that has developed solar tiles which insulate buildings and also function and solar power generation modules.

Modular materials is another application area and is growing rapidly due to the impact of new technologies and the shift towards sustainability. The approach itself brings environmental benefits, reducing waste by 85% and cutting greenhouse gas emissions by 3%, and is increasingly being supported by the introduction of more sustainable materials particularly across the main areas of concrete and steel.

Concrete modular systems provide excellent thermal and sound insulation and are widely used in residential buildings. Here, the focus is on lightweighting and recycling.

In 2020, Holcim invested in CPC, a Swiss start-up which invented carbon-prestressed concrete which allows a 75% decrease in CO_2 emissions. BubbleDeck (Denmark) has developed a solution which reduces the concrete used in a building by 50% and replaces it with recycled plastic balls.

Steel modular systems offer strength and durability which make it the most economical choice for most high-rise buildings. Here, developments centre on improving versatility.

Tata Steel's (India) HabiNest solution is 100% recyclable and consumes 48% less fresh water than a conventional structure. Ecosteel (US) has produced a solution with a urethane core between two pre-finished steel facing which improves insulation.

Indeed, sustainability initiatives in the modular materials market more generally have targeted ***insulation*** with US-based Plant Prefab using cellulose, and Knauf Insulation's (Germany) Supafil made up of 80% recycled glass and ideally suited for prefab manufacturers as it requires no manual cutting.

INTRODUCTION

Globally, the construction sector represents a $8.000b market which will reach $12.000b by 2028 and continue to be a major contributor of greenhouse gases

According to the World Green Building Council, at present buildings are responsible for 39% of global energy-related emissions with 28% stemming from operational emissions and the energy needed for heating and cooling and the remaining 11% stemming from **construction materials** and construction activity.

Overall, the sector is driven by a combination of factors.

A post-pandemic recovery has prompted the uptake and start of new projects. Since 2021, the construction of energy and utility plants, transportation stations and healthcare institutes has increased notably. In the private sector, tourism and business travel has restarted boosting the construction of hospitality facilities. Over the next three to six years, the market will benefit from the continued refurbishment of offices and the construction of new commercial buildings due to decarbonization efforts in key economies.

Another driver is economic growth in emerging markets which has accelerated building construction. This will create demand for construction materials and services in countries such as China, India and Indonesia whilst the United Arab Emirates, Saudi Arabia, Mexico and Brazil are other rising economic powers that will see increasing activity.

Finally, the launch of green growth initiatives and the drive to use advanced technologies to reduce emissions have prompted the expansion of selected building construction segments. This comes as part of the UN's wider Sustainable Development Goals (SDGs) where climate care and environmental protection are essential. As a result, low-carbon buildings or facilities, smart homes and clean power generation plants will remain a primary focus in the building construction market moving forwards. Additionally, digital technologies such as Artificial Intelligence (AI), Machine Learning (ML) and the cloud will make inroads.

Sustainability is therefore becoming vital across all phases of a building's lifecycle

Sustainable innovation involves the use of technologies in the design, operation and construction stages. Participants in the market are adopting various solutions with Frost & Sullivan identifying selected leading sustainability measures including:

- ***Net zero energy homes*** (NZEHs) which consist of the incorporation of smart energy solutions and building design improvements for zero energy consumption. Growth opportunities here include residential solar photovoltaic (PV) systems and zero energy building (ZEB) to grid interaction
- Advanced ***heating, ventilation and air conditioning*** (HVAC) and lighting solutions which are energy efficient and include green HVAC systems, smart heat pumps and intelligent lighting systems

In the *design* stage, the focus is on the use of digital solutions to drive efficiencies

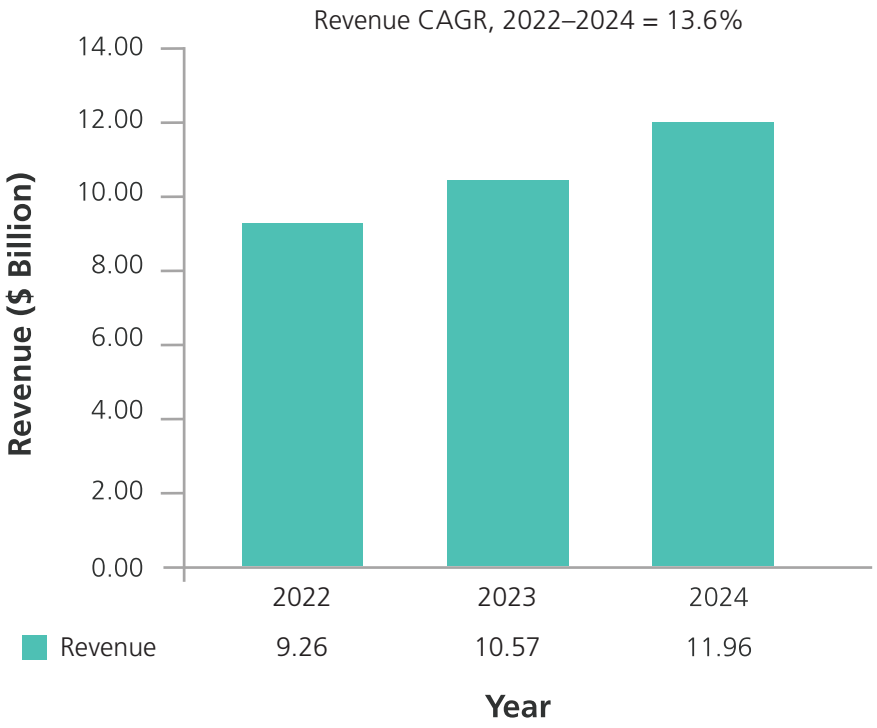
The competition between leading construction management companies and core building technology vendors will continue in 2025 and in the coming years as players jostle to capture and leverage emerging opportunities across all phases of a building's life cycle.

The former will notably look to expand their capabilities in the operations and maintenance (O&M) stage by adding digital twin capabilities while the latter will seek to consolidate and build on their leadership in the design and build stage by adding building information modelling (BIM) capabilities via partnerships or M&A.

Companies involved in architecture, engineering and construction (AEC) activities will also work to push their construction management solutions and strategies, starting with the design phase and incorporating BIM-enabled digital twins. They will look to intervene before construction to mitigate compliance issues, to reduce risks and to enable smooth project handovers to building owners or operators.

More generally, urban planners and smart city developers will increasing deploy digital solutions to assess the impact of their activities on climate change and vice versa.

Digital construction Management Solutions Revenues, Global, 2022–2024



In the *operations stage*, effective waste and wastewater management is important

Water conservation policies and the need to reduce non-revenue water (NRW) losses are driving investments in smart water metering. These can enhance the long-term sustainability of water supply infrastructure. Climate change-induced droughts and water stress caused by overexploitation have caused utilities globally to explore economical and environmentally sustainable solutions to mitigate these issues and ensure conservation. Smart water meters have become a front-line tool to ensure the e cient use of precious water resources and are now a component of smart city development.

In the *construction stage*, prefabricated and modular construction saves resources …

COVID-19 created a shift toward the use of modular buildings and construction techniques. Although the pandemic has declined, market participants should continue to develop their manufacturing capabilities to rapidly provide prefabricated buildings during crises and disasters. The next two to three years will notably see the use of modular construction to build healthcare facilities and schools in rural areas as well as temporary housing for populations that are displaced because of political conflicts and natural disasters.

The post-pandemic era has also demonstrated the need for more efficient construction methods in response to ongoing socioeconomic trends such as labour shortages. Market participants will need to promote the use of modular construction solutions to other building industry stakeholders to address the anticipated workforce challenges and should partner with property developers to design state-of-the-art buildings using environmentally friendly materials which are examined in the fourth main chapter of this report.

… while sustainable construction materials support the wellness of occupants and provide broader environmental, social, and economic benefits

Over time, the construction of new infrastructure and buildings using conventional materials will gradually decline as developed and developing markets increasingly adopt regulations requiring the use of sustainable materials in building construction.

Source: Frost & Sullivan

In parallel, more and more customers are looking for projects with green materials as their awareness of environmental matters grows. These materials will help buildings to adapt to the often-negative effects of changing climates, mitigate further environmental damage and ultimately reduce the carbon footprint from the built environment.

The main levers of growth in the sustainable construction materials market include;

- Greater environmental awareness among developers and owners
- Increased availability of biodegradable, organic and natural solutions
- Improved regulatory measures

CIRCULAR ECOCOMY APPROACH FOR SUSTAINABLE CONSTRUCTION

The circular economy offers a transformative model for the construction and infrastructure sectors, providing an alternative to the traditional linear economy, which is based on a cycle of production, consumption and disposal. In the linear economy, resources are extracted, turned into products, and, once their useful life is over, often end up in landfills. This process not only results in the waste of valuable resources but also contributes significantly to pollution and climate change. The circular economy seeks to "close the loop" of materials by promoting redesign, reuse, repair, recycling and recovery, thus reducing environmental impact and enhancing resource efficiency.

A key advantage of the circular economy in construction is the reduction in demand for virgin raw materials Materials like concrete, steel, glass, and wood, commonly used in construction, are extracted from finite natural resources. However, in a circular economy, materials from demolitions or renovations can be recycled and reused, cutting down on resource extraction and minimizing waste. Currently, the construction sector generates vast amounts of waste, much of which is discarded in landfills. In contrast, the circular model treats waste materials as valuable resources to be recovered and reused rather than disposed of.

This approach encourages more durable, modular, and flexible building designs, making structures easier to repair or modify over time as needs change. Moreover, innovative technologies and smart monitoring systems allow for better material optimization, preventive maintenance, and enhanced energy efficiency in buildings. Adopting renewable energy sources and energy-saving systems further reduces the environmental footprint of construction projects.

Collaboration between designers, businesses, and material suppliers is crucial to fostering innovation and developing circular solutions that not only improve sustainability but also create new business opportunities, reduce costs, and enhance the competitiveness of the sector.

The 2024 report by the Ellen MacArthur Foundation, "Building Prosperity: Unlocking the Potential of a Nature-Positive, Circular Economy for Europe", highlights the value of a circular economy that is regenerative by design. This study focuses on Europe's built environment and explores how a nature-positive circular economy can unlock significant economic opportunities, increasing resilience, competitiveness, and vibrancy in cities.

The construction sector is central to Europe's economic health, yet it is at a pivotal moment that requires urgent action from all stakeholders. This sector accounts for the largest share of the continent's material footprint and over 36% of its total emissions. Meanwhile, a vast number of unused buildings and brownfield sites contribute to inefficient urban sprawl that degrades natural environments. Addressing waste and inefficiency in the built environment is essential to achieving Europe's climate and biodiversity targets and securing long-term prosperity.

The Ellen MacArthur Foundation's analysis shows that the construction sector's future contributions to the European economy need not be a choice between economic growth and environmental preservation. By shifting to a nature-positive circular economy with a systemic approach, mutually reinforcing benefits can be achieved for the economy, nature, and society. Six circular economy strategies were identified in the report as mature and scalable solutions with significant potential to drive both economic and environmental benefits. When applied

as an integrated system, these strategies reinforce and multiply each other's positive impacts.

The six strategies are grouped under three overarching ambitions, aligning with the EU's vision for a modern, resource-efficient and competitive economy that operates in harmony with nature:

- **Revitalize** land and assets to reduce pressure on nature: revitalizing brownfields offers opportunities to incorporate nature-positive designs that enhance biodiversity and human health. This approach promotes compact, multi use urban centers, reducing urban sprawl and alleviating pressure on housing markets by repurposing well-located land and buildings.
- **Maximize** nature in cities to create resilient, vibrant urban spaces: increasing green spaces and tree coverage in cities has proven economic, social, and health benefits. Urban areas can also benefit from integrating water features and native vegetation suited to local conditions. Green roofs and walls, although not the primary focus of this report, are established concepts that offer additional potential for expanding green infrastructure.
- **Optimize** building design and material sourcing to capture economic value, reduce waste, and meet climate targets: enhancing material efficiency in building design can reduce both material and carbon footprints. Prefabricated and modular construction are frontrunners in these efforts. Using low-impact materials, such as recycled or regeneratively sourced bio-based alternatives, alongside materials produced using low-carbon manufacturing processes, offers further reductions in environmental impact. However, bio-based materials like timber must be carefully managed to avoid adverse effects on biodiversity and land use.

The potential benefits of these strategies are vast. By 035, more than half a trillion euros could be unlocked annually, with over €150 billion in additional economic benefits for businesses, citizens, and urban stakeholders. These strategies offer a pathway to achieving substantial economic, environmental, and social gains, transforming Europe's construction and infrastructure sectors into engines of sustainability and prosperity.

This report focus on the construction stage of a building's lifecycle with an exploration of the market for sustainable construction materials overall and a deep dive into selected material and application areas including engineered wood, roofing and modular materials

SUSTAINABLE CONSTRUCTION MATERIALS

After cement, bricks hold the largest volume share in the construction materials market followed by steel, timber, plastic, glass and insulation

Cement is used in buildings as part of concrete, mortar and stucco, for example, while **bricks** are primarily made of clay but can also consist of concrete, sand-lime, fly-ash and calcium silicate and steel includes reinforcement bars (rebars), beams, plates, **steel** framing, roofing and roof trusses.

Timber is usually implemented in buildings shaped as posts of different sizes and dimensions. It includes both **raw lumber** (hardwood and softwood) and **engineered wood.**

Plastic covers thermoplastics which are used in window and door frames, wall panels, vinyl flooring and roofing with some of the most common being polyethylene foam and PVC membranes. In addition, **glass** is mostly applied in windows, doors, walls and skylights while **insulation** materials consist primarily of mineral glass, expanded polystyrene (EPS) and cellulose solutions.

Current end-of-life (EoL) scenarios are inadequate across most of these categories with reuse, repurposing or recycling typically limited or low value

Limited or low value EoL exploitation areas include;

- **glass,** which is often coloured, treated, laminated, coated or contaminated from the demolition site, all scenarios that pose challenges to material recovery. Glass is hardly ever reused to build new windows, and, in the construction industry, most ends up in landfills. If recovered, glass is often shredded and downcycled to other glass-containing products, including painting components and countertops
- **raw lumber** (hardwood and softwood) which is usually polluted with nails, concrete, bolts and other metallic elements and may have undergone treatments that can restrict its reuse for applications related to animals such as bedding. Shredding is the most usual downcycling practice
- **engineered wood** (plywood, MDF, composite and CLT) which is itself produced by recycling pre-consumer waste from wood production. Today, structural wood, if recovered, is not reused for the same function in new constructions. This is mostly due to regulations and building standards. When separated, it is typically chipped or otherwise damaged and therefore mostly used as biomass for energy generation, animal bedding, garden landscaping or particleboard production. Engineered wood is also used in the construction phase of a building's lifecycle, notably for scaffolding and packaging, but this too is largely mixed with other waste and sent to landfills. Floorings and moldings sometimes enter the reclaimed wood business, depending on their condition and the market maturity
- **cement** which almost always contains rebars, plastics, wood, plaster and gypsum. This poses a challenge to reuse, as any contaminant might affect its mechanical properties. Shredding (for aggregates) is the most usual downcycling practice
- **bricks** which are usually shredded and/or sent to landfill, depending on local regulations. Recovered EoL bricks, even those contaminated with mortar, are typically downcycled, often with several other materials, to be used as mulch and sports court, drainage, or landscape filling

Medium value EoL exploitation areas include;

- **insulation** (EPS) which is high volume, low weight and low value. EPS recycling rates in the United States are reported to be rising but, in the EU, all expanded polystyrene from demolition sites is incinerated or sent to landfills. In some parts of the world, EPS may still contain flame retardants which restrict how the material can be downcycled

Other construction materials that no or close-to-no end-of-life exploitation value at the point of demolition include mineral glass insulation, vinyl PVC flooring, polyethylene foam, roofing PVC membrane and rubber.

It is only really steel that currently offer high value in its EoL exploitation. The industry is very mature in this respect with beams in particular benefitting from a high degree of reuse and recycling. With rebars, recovery is lower as they are often combined with concrete but some sources nonetheless claim a recycling rate of 90%.

For *bricks*, sustainable innovations are focused on autoclaved aerated concrete material which offer very good thermal conductive performance

Xella is one of the major manufacturers with its AAC products including bricks and panels. The main components of the company's solutions are water, lime, cement and sand. AAC's benefits include the fact that it insulates buildings, which therefore need less heating, and is lower in weight than traditional bricks. The material also leads to reduced emissions since it requires less mortar and therefore produces less waste during construction while its favours larger bricks which accelerate building. Another sustainable brick manufacturer is Lignacite which produces lignacite blocks composed of cement, aggregates and recycled wood.

For *plastics*, market participants are notably looking to recycle

BASF is a key player in this segment with its *Ultradur* and *Ultramid* products which form part of its low carbon portfolio and are used to improve PVC profiles in windows. **Pact Group** offers *noise walls* for exterior applications which are made with recycled plastic whilst **DSM's** *EcoPaXX PA410* aims to provide an alternative to aluminum profiles and contains nearly 70% tropical castor bean plant.

Forbo with its *vinyl flooring* aims to achieve nearly 23% recycled content on average with some of its products reaching nearly 90% whereas **Santa Luzia** claims to recycle 9,000 tons per year of EPS to manufacture *mouldings*, panels and other products.

For *glass*, the development of "smart" windows promises to protect buildings and their owners or occupiers from any excessive heat and light

Here, **View** has developed *View Smart Windows*, a proprietary solution that provides variable-tint capabilities to glass and where the final windows have a controller connected to the cloud which enables the shading levels to be adjusted automatically.

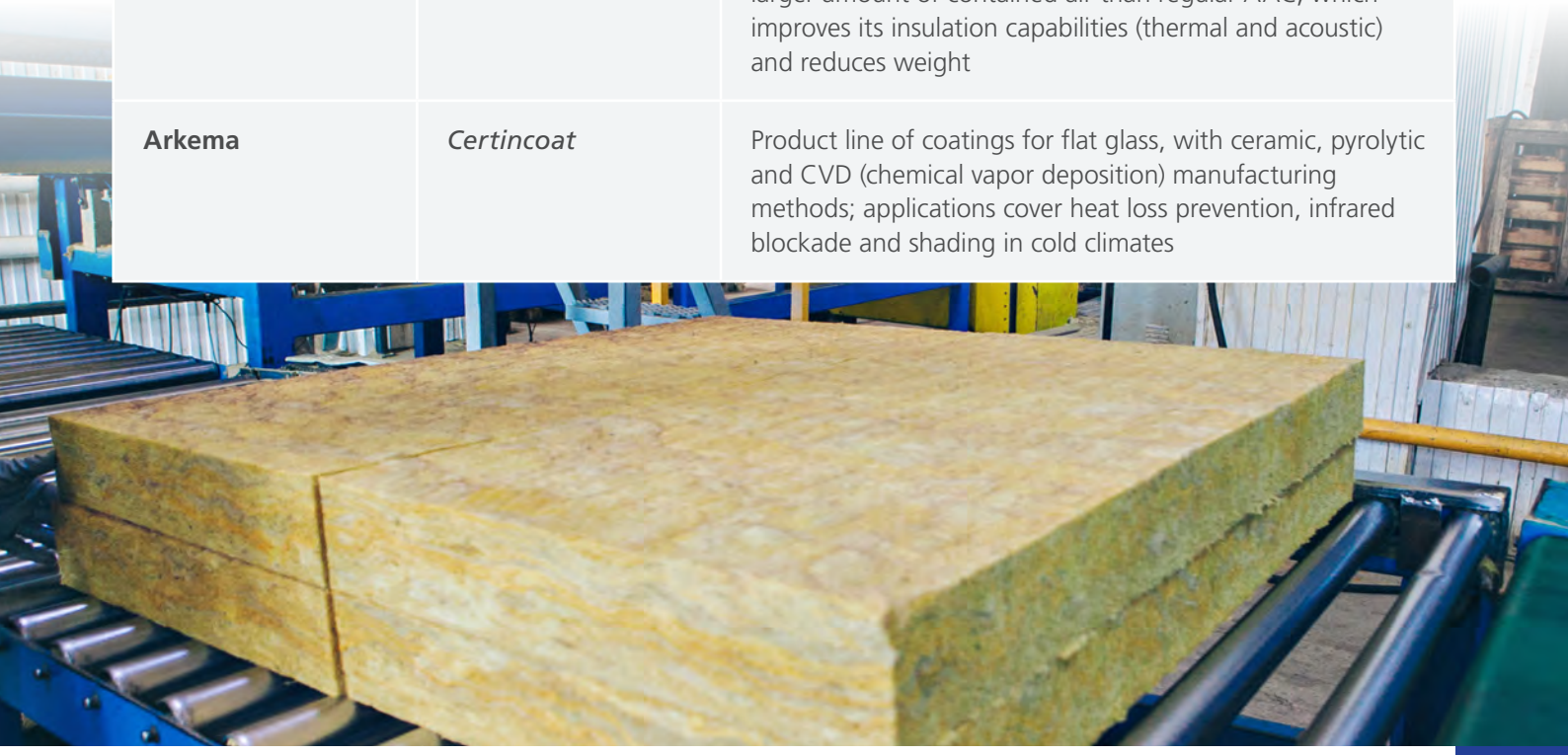
Other examples of sustainable innovations in the area include;

MANUFACTURER	PRODUCT	DESCRIPTION
AGC	*Fineo*	Double glazing w/2 sheets of glass each, 1 w/coating + vacuum gap; U = 0.7 W/m²K
Guardian Glass	*SunGuard*	Product line with single-, double-, and triple silver glass; aimed for implementations requiring solar control and/or thermal insulation. The different products achieve different performances, in terms of selectivity, U- value, solar factor, and light transmittance
Crown Electrokinetics	*DynamicTint*	Variable tint glass (ink-container film); does not require glazing replacement; can be used as retrofit. Solar energy can be used to power the unit
Saint-Gobain	*Net Zero Glass*	Achieves improved thermal insulation values using low-e coatings
Saint-Gobain	*ORAÉ*	Low carbon glass: 7 kg CO_2 eq./m2 (for a 4mm substrate) (a 40% reduction compared, as stated by the company, with Saint-Gobain Glass European baseline clear glass). This is achieved by using RE and recycled content, enabled by recovery programs
Sabic	*Lexan Thermoclear*	The company states that this 9-wall PC (polycarbonate) sheet reaches U-values below 1, like double- or triple-pane windows, thus reducing the need for house heating

Here, Knauf has developed ECOSE, a binder that is made from natural raw materials, used in all of the company's glass mineral wool products and which offers 70% energy-intensity improvements which compared to conventional alternative products.

Other examples of sustainable innovations in the area include;

MANUFACTURER	PRODUCT	DESCRIPTION
BASF	*Elastopir*	Brand for BASF's polyurethane (PU) rigid foam insulation systems, based on Polyisocyanurate (PIR); this product line is part of the company's low carbon footprint portfolio. Products in this portfolio are certified with the REDcert2 standard, using a mass balance methodology and biomethane as feedstock
CertainTeed-(Saint Gobain)	*Sustainable Insulation*	The company states in this product's EPD that it has between 25% and 50% of glass cullet and an organic binder, mainly composed of citric acid and sugars
Dupont	*Styrofoam XPS*	The company claims a 20% of pre-consumer recycled content, +30x energy savings than the embodied energy in the product, at least 28x GHG emissions prevention in relation to the product's own carbon footprint on a 50-year period, and 100% renewable energy manufacturing process
Knauf	*Glass wool insulation*	In several of its products, the company states to include up to 80% of external recycled cullet
Xella	*Multipor*	The material has all the benefits of AAC. Multipor has a larger amount of contained air than regular AAC, which improves its insulation capabilities (thermal and acoustic) and reduces weight
Arkema	*Certincoat*	Product line of coatings for flat glass, with ceramic, pyrolytic and CVD (chemical vapor deposition) manufacturing methods; applications cover heat loss prevention, infrared blockade and shading in cold climates



Source: Frost & Sullivan

Several new sustainable construction materials are emerging as alternatives to traditional materials, each offering unique environmental benefits.

the most relevant sustainable construction materials that are alternative to the traditional ones include:

Bamboo: It is a fast-growing, renewable resource that can be harvested sustainably. It has a high strength-to-weight ratio, making it suitable for various construction applications.

Cork: Harvested from the bark of cork oak trees without harming the tree, cork is a renewable material with excellent insulation properties. It is lightweight, fire-retardant, and can be used for flooring, wall coverings, and insulation.

Hempcrete: Made from hemp fibers mixed with lime, hempcrete is a carbon-negative material that provides good thermal and acoustic insulation. It is lightweight and fire-resistant, making it a viable alternative to traditional concrete.

Recycled Steel: Steel can be recycled indefinitely without losing its properties. Using recycled steel reduces the demand for new steel production, thereby lowering the carbon footprint associated with construction.

Reclaimed Wood: Sourced from old buildings and structures, reclaimed wood is a sustainable choice that adds character and warmth to new constructions. It reduces the need for new timber and minimizes waste.

Mycelium: Which is the vegetative structure of a fungus and when dried, it is highly durable and resistant to mold, water, and fire. Like bamboo, mycelium is organic and compostable, so it leaves little waste and has virtually no negative impact on the environment. When combined with materials like timber, sawdust, and demolition waste, mycelium can be molded into bricks used for constructing buildings and their parts.

Mass timber: Mass timber products are created by mechanically bonding various types of softwood to form large, prefabricated wood components. It can come in several forms, including cross-laminated timber (CLT), laminated strand lumber (LSL), laminated veneer lumber (LVL), nail-laminated timber (NLT), and glue-laminated timber (GLT).

On the sustainability side, mass timber serves as a viable substitute for traditional construction materials like steel and concrete, which have a higher carbon footprint. Using mass timber instead of conventional building materials can significantly reduce emissions.

Rammed Earth: This ancient building technique uses natural materials like soil, clay, and sand to create durable structures with excellent thermal mass, ideal for energy-efficient buildings.

Recycled Glass: Made from old glass products, recycled glass is durable and can be used in various applications such as flooring and countertops, reducing the need for new raw materials.

Straw Bale: Straw bales are used as insulation and structural components in construction. They offer high insulation values and are biodegradable, making them a sustainable choice for eco-friendly buildings.

Aerated Concrete: This lightweight material is made by introducing air into concrete, providing excellent insulation and fire resistance. It is often used in building structures.

Bendable Concrete: Also known as Engineered Cementitious Composite (ECC), bendable concrete is a type of concrete that can withstand bending. Unlike conventional concrete, which is brittle and can easily crack or break, bendable concrete is 500 times more resistant to cracking and is more effective at absorbing shock.

Precast Concrete: Many of the CO_2 emissions associated with ready-mix concrete that is poured and hardened on site are avoided when precast concrete is manufactured at a plant off-site. Manufacturers can guarantee precise specifications with pre-cast concrete, which lowers waste and the energy required to make and assemble conventional concrete. Furthermore, throughout the course of their lifetime, certain novel kinds of concrete can reabsorb up to 25% of their embodied carbon footprint.

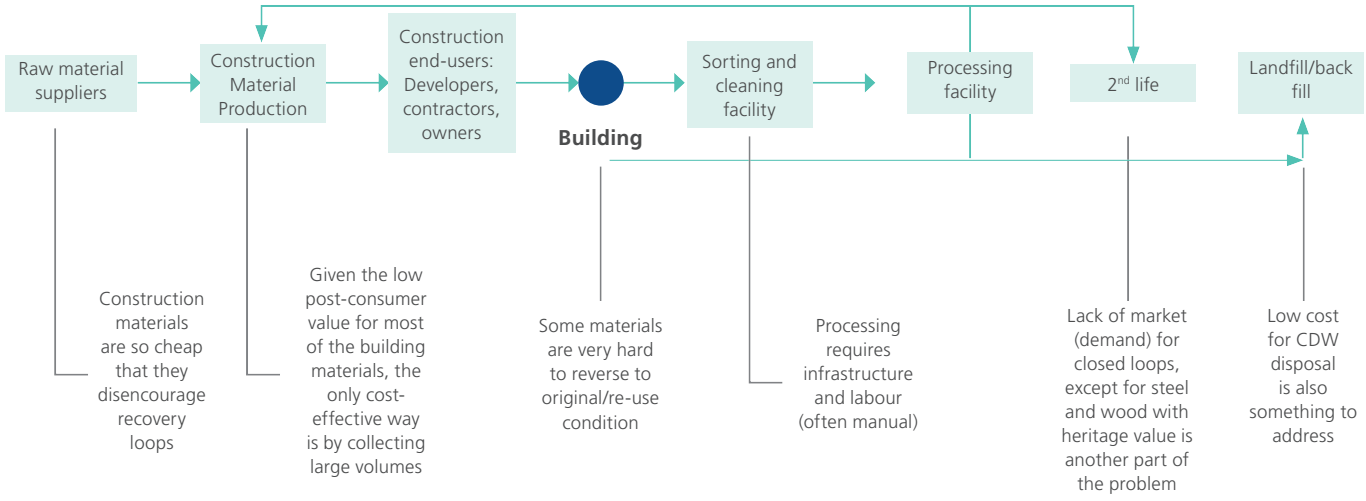
Earth Blocks: Compressed earth blocks are made from natural materials like soil and clay, offering a low-carbon footprint and excellent thermal properties.

These materials not only reduce the environmental impact of construction but also offer durability, energy efficiency, and aesthetic appeal, contributing to a more sustainable future in the building industry.

Overall, however, the market for sustainable construction materials currently suffers from a lack of incentives …

These manifest themselves at every stage of the value chain.

Sustainable Construction Material Recovery Issues



… whilst there are also technical challenges to recovery.

In general, materials stemming from demolition sites have a poor value to volume to weight ratio. Furthermore, they are often contaminated by or combined with other substances such as glues, gypsum, rubber, plasters and concrete while, for some materials, regulation and standards prevents materials from being directly reused. This means that there is limited incentive to develop collection schemes.

In fact, overall, there is limited scope for recovering good quality materials, so the industry tends to currently go for volume.

Nonetheless, the benefit of recycling does not compare favourably with the cost of a "clean" demolition nor the cost of logistics. Moreover, there is a lack of collaboration between contractors and the downstream chain while any financial support in place for material recovery is often ineffective or inexistant.

Finally, demolition sites require a project-by-project approach that complicates any attempt to improve material reuse. They occur without any fixed schedule while each site has its own requirements and thus restrictions.

Moving forwards, industry stakeholders on both the supply and demand side are all increasingly keen to be (and to be seen to be) green …

Many variables are indicating that companies have been transitioning to a sustainability "state of mind" for several years now. This has been constant over time and will

Source: Frost & Sullivan

grow amongst smaller companies moving forwards. For reporting companies this implies streamlining data and processes (both internal and external), improving governance and transparency across the organization, building a better and more sustainable approach to reducing costs and improving their reputation in respect of their stakeholders.

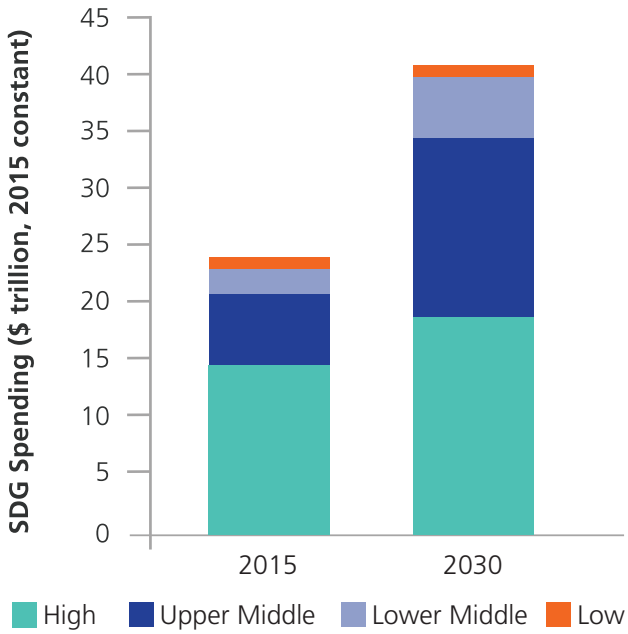
The share of the top 250 companies in the Fortune 500 ranking that report on sustainability has notably risen from 35% in 1999 to reach 96% by 2020.

… whilst new funding stems from public and private sources

As the largest countries and companies drive huge sums of money into green markets, many others are rushing to find their position as product and service providers and to leverage the emerging opportunity that this investment is generating.

Overall, public funds directed to SDG-related sectors globally stood at nearly $25 trillion in 2015 with this sum expected to reach $40 trillion in 2030.

Public Spending by Country Income Group on SDG-related Sectors, Global, 2015 and 2030



Mainly driven by regulation, spend on building efficiency in particular is expected to grow tremendously in the next few years. This will have a direct impact on construction materials such as glazing, insulation and sealants, but will also benefit systems vendors selling sensors as well as automation and electrical products.

Digital solutions will form part of the response and are being developed by the likes of Hesus (France), EME (Germany) and Restado (Germany)

Overall, these products and services aim to improve resource efficiency and circularity in the building sector. For them to work at scale, standardization across the supply chain and sustained overall market demand are critical.

Hesus focuses on waste management and covers all aspects from surveying and analyzing the soil on construction sites to on-site waste sorting and disposal, spoil and debris loading and unloading, transportation to disposal facilities and the treatment and/or recovery of waste. It notably provides digital traceability solutions.

EME is a start-up digital platform aiming to match waste streams with demand across any industry, including construction. It works by providing materials with a digital

Source: Frost & Sullivan

passport, containing several descriptive variables that then acts as its digital twin. Using various tracking technologies (barcodes, QR codes and chips), it follows the material across its lifecycle and uses AI supply materials where they are needed.

Restado provides an online marketplace for EoL building materials from demolition sites and for leftovers from construction activity. The company covers a wide range of products and is open to work in partnership with dismantling and demolition companies, component exchanges and trading companies to accelerate the recovery and reuse of spent construction materials. In addition, Restado participates in research initiatives and collaborates with other stakeholders to create fresh approaches to circular construction, such as the Cradle2Cradle program to encourage the digitization of raw material registers and ecological building material certification as well as urban mining and upcycling.

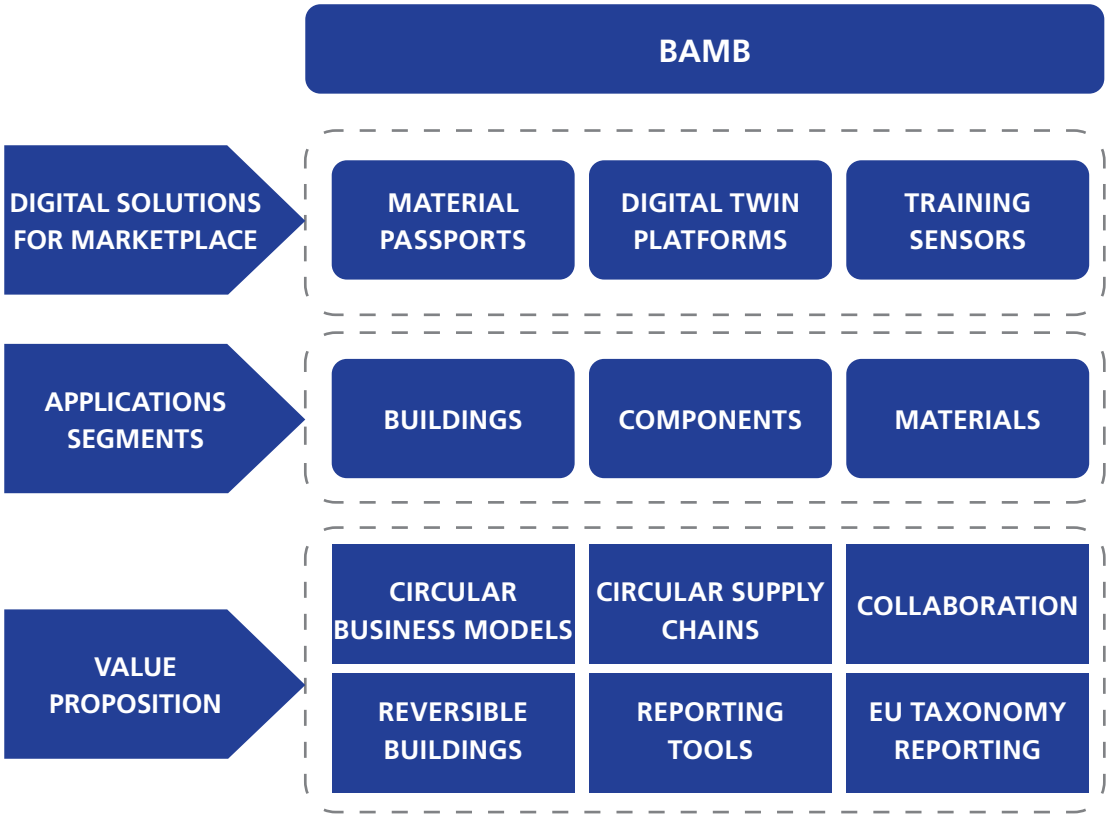
Collectively, these will notably lead to the growth of the concept of buildings as material banks which aims for materials to create and retain value

The idea of **buildings as material banks** (BAMB) sees all structures as reservoirs of valuable resources that may be recycled or reused by parties in the construction process.

This includes those involved in building design, engineering, consulting, construction and deconstruction and research and development as well as material producers and suppliers, public and private property developers and owners, technology and platform providers and rent and leasing, reuse, repair and recovery players.

At a conceptual level, BAMBs are all about enabling reversible building design and, on a practical level, rely on the development and roll-out of effective material passports.

BAMB Components



Source: Frost & Sullivan

Here as elsewhere, greater sustainability across the construction supply chain and life cycle will be enabled by creating more and better data

Data is needed along the supply chain in all industries to measure markets, adjust policies and ultimately reduce the amount of waste.

The building industry is no different.

Ideally, any product should be traceable from its production to the building site, including during its use and after demolition as it moves to a closed-loop or downcycle facility. Nevertheless, tracking materials is useless if this is not supported by;

- effective demolition and handling practices applied by contractors to ensure that materials are not harmed and can be recovered to a maximum extent
- incentives to promote collection and reuse
- efficient construction and material design standards

Construction material manufacturers should therefore fully embrace digital tools such as AI, BIM, digital twins and the IoT to not only accelerate their processes but also to generate data that can be effectively implemented, handled and shared with the rest of the downstream supply chain. This will lead to improved sustainability, via reuse, recycling and downcycling, and increased efficiency while also creating new, untapped business opportunities.

TILEGREEN

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

TileGreen has developed an industrial process to transform all forms of plastic waste into sustainable building materials.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=7dBCVqCO464

COMPANY **STRUCTURE**

FOUNDED: **2021**

COUNTRY: **EGYPT**

OF EMPLOYEES: **10 – 20**

Website: https://tilegreen.org/

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- TileGreen has developed an industrial process to transform plastic waste into sustainable construction elements such as paving tiles. The company produces a material called polymer aggregate composite in which plastic waste is mixed with natural aggregates, such as sand and gravel, to create a substitute for concrete.
- The semi-finished product consists of small plastic shards mixed with sand to form a substance that is molded into highperformance interlocking paving tiles. This composite can be used to produce sustainable alternatives to traditional building materials.
- TileGreen utilizes unwanted plastic waste, such as single-use plastic bags and food containers that cannot be safely recycled.

Main competitive advantage

TileGreen has developed a process to create high-performance and durable interlocking paving tiles by processing recycled plastic. The patented thermomechanical technology transforms low-value and mechanically non-recyclable plastic waste, combined with mineral aggregates and plastic additives, into sustainable building materials. This material can be used in construction to produce materials such as paving tiles, bricks, beams, and urban furniture. Compared to traditional technologies to produce cement-based products, TileGreen's process allows for up to 62% of energy savings and up to 35% of water savings, enabling a sustainable and cost-effective manufacturing.

Value Proposition

- TileGreen is committed to reducing the environmental impact of plastic waste through the recycling and reuse of all types of plastics, utilizing them to produce building products alternative to cement.
- The company aims to reduce CO_2 emissions resulting from cement production, thereby minimizing the environmental impact generated by the construction industry.

RECOMA

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

RECOMA has developed sustainable construction panels starting from recycled materials.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=TJ6Fao-etCg

COMPANY **STRUCTURE**

FOUNDED: **2021**

COUNTRY: **SWEDEN**

OF EMPLOYEES: **11 – 50**

Website: https://www.recoma.com

TOTAL FUNDING: **SEK 15M**

PRODUCT **OVERVIEW**

Technology Focus

- RECOMA has developed sustainable construction panels obtained using waste as input material. The company has implemented a recycling process in which packaging waste, such as food cartons and beverage containers, is first sterilized and shredded, before being pressed into panels at high temperatures.
- These semi-finished products are then transformed into durable components. The process emits significantly less carbon than the production of traditional wood-based or gypsum construction panels.
- The material produced from the recycling process is formed into construction panels for both external and internal use. The 12mm panels, when combined with an additional 12mm layer of gypsum board, can achieve a 60-minute fire resistance rating.

Main competitive advantage

RECOMA develops construction panels from waste materials such as cardboard and other packaging materials. The company creates sustainable and versatile construction panels capable of replacing traditional building materials in a variety of applications: interior walls, exterior walls, ceilings, floors, and furniture. The RECOMA construction panel can replace all types of wooden boards and two-layer construction elements. The patented manufacturing process by employing waste materials addresses the issues of deforestation and extraction of natural materials, it does not require additives or chemicals and it generates no waste, reducing CO_2 emissions. This solution also helps to lower costs for the construction sector by reducing both water and energy consumption.

Value Proposition

- RECOMA is committed to providing a sustainable solution for the construction sector by producing construction panels from waste materials, reducing waste levels and emissions. The process recycles waste with minimal environmental impact and produces products that can replace other materials with up to 90% CO_2 savings.
- The company aims to reduce the use of valuable natural raw materials in the production of building elements. Moreover, the company seeks to utilize materials that would otherwise be destined for incineration.

Source: Crunchbase, RECOMA

GREENFUL GROUP

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

Greenful Group is developing sustainable construction materials starting from recycled textile and plastic waste.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=w_wP2pGRVJE

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **ESTONIA**

OF EMPLOYEES: **2 – 10**

Website: https://greenful.com/

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Greenful develops construction materials made from recycled waste. Greenful's sustainable construction products outperform existing materials in terms of strength, durability, and CO_2 footprint.
- The company offers three main products. Panel is a robust load-bearing panel made from textile fibers and a unique composite material. Greenful Panel has a wide variety of sizes and has built-in fire-resistant shielding. Structural Insulated Panel provides a foam insulating layer made from textile fibers for enhanced insulation, making it particularly suitable for colder climates.
- Greenful also provides Ecotile, a thick and sustainable tile created from a conglomerate of textile fibers, tire rubber, and plastic that are shredded and mixed with glue. This solution replaces concrete, asphalt and bricks, and can be used for paving sidewalks and park grounds.

Main competitive advantage

Greenful develops eco-friendly, durable, and sustainable construction materials made entirely from recycled waste. These materials are highly versatile and can be used for both the interior and exterior of buildings, including flooring, roofing, furniture, and many other applications. Up to 70% of a house can be built entirely with Greenful panels. The production process for these panels is sustainable, involving no toxic chemicals or water use. The process relies solely on electricity from renewable sources, avoiding energy from fossil fuels.

Value Proposition

- Greenful aims to reducing the level of textile waste, which often goes in landfills or is incinerated, by recycling into sustainable construction materials. The company is on a mission to provide sustainable construction materials that outperform traditional ones, starting from 100% recycled raw materials and offering fully recyclable products.
- The company is committed to producing sustainable materials to reduce CO_2 emissions in the construction industry and promote circular economy practices.

CARBON INSTEAD

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

Carbon Instead is developing a process to produce sustainable biochar for buildings.

Maturity:

Under development

Multimedia:

N.A.

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **GERMANY**

OF EMPLOYEES: **2 - 10**

Website: http://carboninstead.de

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- The company develops a technology to convert biomass into biochar through a thermal process. This biomass enables the replacement of carbon-intensive materials, such as cement and sand, with sustainable biochar.
- Biochar is obtained through a pyrolysis process. During this process, biomass is modified to isolate the carbon contained in organic waste, creating a raw material that captures CO_2. This material can then be integrated into products with a long lifespan, making them suitable for both residential and commercial buildings.
- The result of pyrolysis is a porous material with high strength, as well as excellent thermal and acoustic insulation properties.

Main competitive advantage

The company develops a technology to produce biomass through a thermal process. This biomass enables the replacement of carbon-intensive materials, such as cement and sand, with sustainable biochar. The technology developed by Carbon Instead reduces CO_2 emissions of the construction industry, while also providing a highly sustainable method for managing organic waste. The resulting material demonstrates high performance in terms of strength, as well as acoustic and thermal insulation. The company biochar can be used for the construction of both commercial and residential buildings.

Value Proposition

- Carbon Instead aims at reducing the carbon footprint of industrial materials in several domains. The company removes more carbon from the carbon cycle than it brings into it.
- The company is on a mission to transform biogenic waste streams into valuable raw materials that can be used as additives or replacements for conventional industrial materials.
- The company aims to address the issue of mineral resources scarcity and the challenges of long-distance transportation by promoting local and sustainable production of materials.

Source: Crunchbase, CARBON INSTEAD

STRAWCTURE ECO

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

Strawcture Eco is developing a sustainable building material based on compressed agricultural fibers.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=5IxFceVUKPA

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **INDIA**

OF EMPLOYEES: **2 - 10**

Website: https://strawcture.com

TOTAL FUNDING: **$0,375M**

PRODUCT **OVERVIEW**

Technology Focus

- Strawcture Eco is creating a solution called AgriBioPanels, construction panels made by compressing agricultural fibers such as straw. Straw is a natural residue left over when a crop like sugarcane, coconut, or wheat is harvested.
- AgriBioPanels are compressed agri-fiber panels made of over 90% straw, compressed at high temperature and pressure. The panels are available in three different quality grades and can range in thickness from 8mm to 35mm.
- The panels are composed of straw and a binding adhesive, supported internally by a galvanized iron grid.

Main competitive advantage

Strawcture Eco develops construction panels by compressing agricultural fibers like straw. The straw-based AgriBioPanels provide high thermal insulation and high fire resistance due to the high content of straw and silica. The panels are lightweight, durable and do not require water during the production process, reducing manufacturing costs. Panels can be used both externally and internally. The AgriBioPanels are easy to install, enabling fast construction.

Value Proposition

- Strawcture Eco aims to develop sustainable building materials that can reduce the extraction of natural resources. Thecompany lev erages materials that would otherwise be destined for incineration, enabling a circular economy model.
- The company produces bio-based panels to reduce carbon footprint within the construction industry.

NATURLOOP

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

NaturLoop is developing building materials based on coconut husks and bio-based resin wastes from agriculture.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=GrBVlv5l_DI

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **SWITZERLAND**

OF EMPLOYEES: **2 - 10**

Website: https://naturloop.com

TOTAL FUNDING: **$0,33M**

PRODUCT **OVERVIEW**

Technology Focus

- NaturLoop is developing sustainable construction materials using agricultural waste. The company is creating Cocoboard, a fully natural fiberboard made from coconut husks and natural tannin.
- Cocoboard is composed of 90% coconut husk fibers and 10% bio-based resin. To produce Cocoboard, the raw material undergoes a process in which coconut fibers are extracted from the husks and processed to achieve the desired quality. These natural fibers are then combined with a bio-based resin.
- Cocoboard features a fine surface texture that can be treated with any coating system. It is durable and robust.

Main competitive advantage

Cocoboard is a natural panel made from coconut husk fibers and bio-based resin. The panel is durable and sturdy, suitable for both internal and external applications. The production process of Cocoboard is non-toxic, using resin derived from tannin, a plant-based compound found in nature. This solution functions as a sustainable alternative to Medium Density Fibreboard - MDF.

Value Proposition

- The company aims to reduce the environmental impact of the construction industry by providing a sustainable and lowimpact building panel.
- The company aims to increase the availability of sustainable, waste-based building materials by using coconut husks instead of wood thus addressing the issue of deforestation.

Source: Crunchbase, NATURLOOP

BIOBUILDINGBLOCK

COMPANY **OVERVIEW**

Industry Segment:

Sustainable construction materials

Brief Description:

BioBuildingBlock is developing a construction system of wooden bricks and steel bars for building structures with reinforced walls.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=vXyR0HJvomY

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **ITALY**

OF EMPLOYEES: **2 - 10**

Website: https://biobuildingblock.com

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- BioBuildingBlock is developing a sustainable construction system based on wooden bricks and steel bars. The wooden brick consists of a load-bearing block with flat faces that have complementary shapes for connecting with other similar modules placed side by side. It also has features that allow it to be anchored to the load-bearing blocks of nearby modules to form the building structure.
- The anchoring means also include reinforcing bars designed to be inserted into a pair of adjacent modules to form a meshed reinforcement structure. Each bar has ends associated with connecting elements for coupling with the opposing ends of contiguous bars belonging to an adjacent module.
- The bio-brick is composed of wood or other natural composites such as wood chips, cellulose, rock wool, or sheep's wool.

Main competitive advantage

BioBuildingBlock is developing a construction system composed of wooden bricks and steel bars for building green structures with reinforced wooden walls. The bricks provide high thermal insulation performance, ensured by natural materials contained within the modules. The BioBuildingBlock system is modular and adaptable to different needs; the bio-bricks can be customized with channels to accommodate electrical, plumbing, or heating systems, as well as openings for electrical outlets and light switches. The construction system is also designed to withstand natural disasters, such as tornadoes or hurricanes. The company's system allows for the precise determination of the number and position of each brick during the design phase, facilitating the subsequent assembly process and reducing waste materials on-site.

Value Proposition

- The company is on a mission to provide a sustainable construction material, in order to reduce the environmental impact of buildings.
- • BioBuildingBlock is committed to enhancing the safety of inhabitants by improving the static and dynamic properties of buildings, enabling them to withstand various natural disasters.

ENGINEERED WOOD

Within the engineered wood market, materials for construction notably include plywood, OSB, LVL, CLT, glulam and hardboard

Plywood is used for sheathing, flooring, roofing, panelling and concrete moulds while OSB (oriented strand board) is deployed for sheathing, subflooring, panelling and LVL (laminated veneer lumber) for beams, headers and studs. CLT (cross laminated timber) finds its application in panels (walls, floors and roofs) whereas glulam (glued laminated wood) is key for structural elements and hardboard for sheathing, subflooring and panelling.

Each product has its own characteristics which determines its applications …

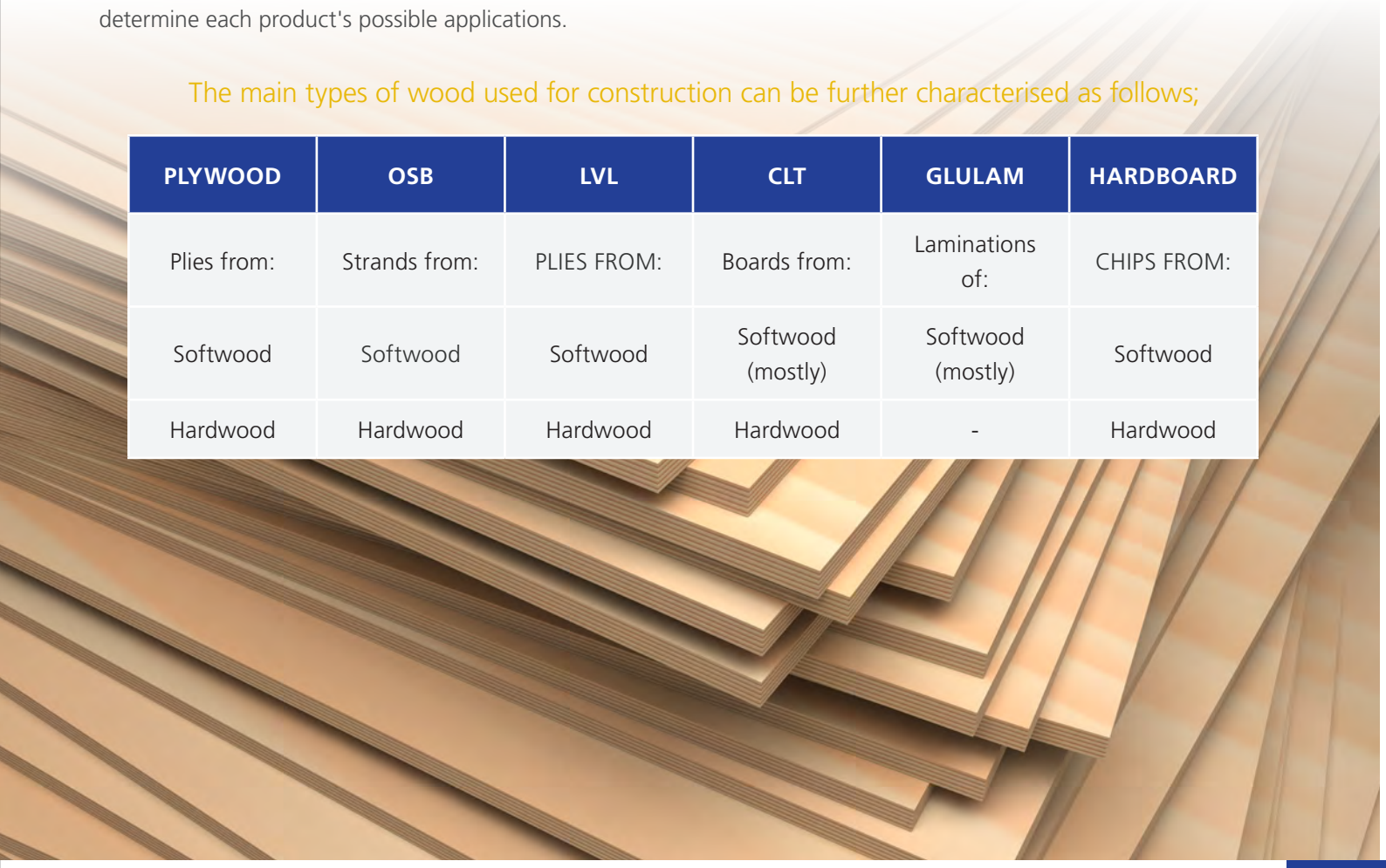
Engineered wood (EW) products have some common and some different characteristics. Each has its own malleability, mechanical properties (including its internal bond and modulus of rupture and elasticity) and behavior as a substrate for coatings and finishes. These factors determine each product's possible applications.

In broad terms;

- **OSB** and **hardboard** use strands, chips or wood dust for production, undergoing compression through different processes and using bonding agents. These products consist of wood particles, making it easy to minimize manufacturing waste and incorporate recycled wood from other sources
- **Plywood** and **LVL** have veneers, requiring compression and gluing. Plywood sees wide use across the construction, joinery, packaging and other sectors (although it is not used for structural purposes) while LVL mostly caters to construction because it is a suitable structural component of buildings
- **CLT** and **glulam** involve gluing timber beams and panels together and primarily find their use as structural elements in construction

The main types of wood used for construction can be further characterised as follows;

PLYWOOD	OSB	LVL	CLT	GLULAM	HARDBOARD
Plies from:	Strands from:	PLIES FROM:	Boards from:	Laminations of:	CHIPS FROM:
Softwood	Softwood	Softwood	Softwood (mostly)	Softwood (mostly)	Softwood
Hardwood	Hardwood	Hardwood	Hardwood	-	Hardwood

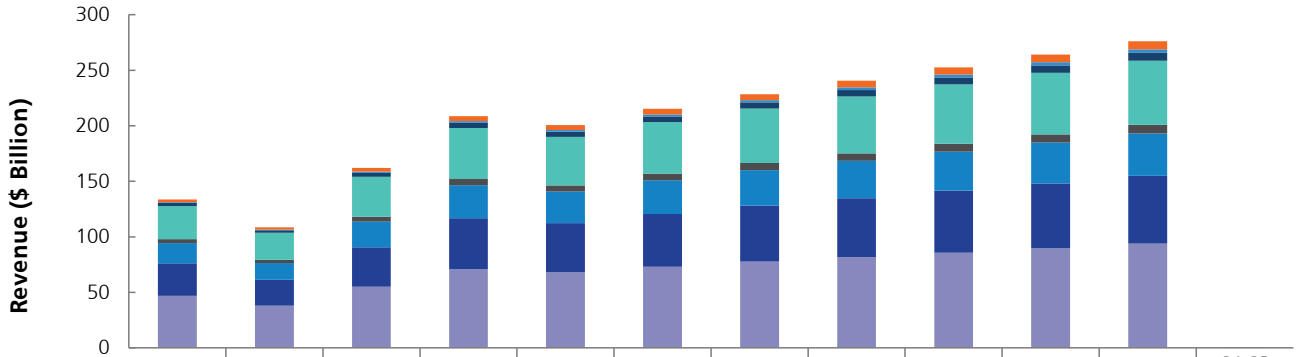


Source: Frost & Sullivan

… with CLT the fastest growing segment in a total market valued at $200b as it proves to offer a sustainable alternative to concrete and steel

The global market for CLT is growing at 12.2% on average as compared to 4.1% for plywood, 3.7% for OSB, 5.8% for LVL, 7.3% for glulam and 4.5% for hardboard.

Engineered Wood, Revenues by Product Type, Global, 2019-2029



	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	CAGR (22-29)
Glulam	2.42	2.17	3.36	4.51	4.52	5.02	5.50	5.97	6.44	6.91	7.40	7.3%
CLT	0.63	0.64	0.95	1.39	1.50	1.76	2.03	2.29	2.56	2.84	3.12	12.2%
LVL	2.81	2.20	3.58	4.71	4.62	5.05	5.46	5.84	6.23	6.61	7.00	5.8%
MDF/HDF	29.70	24.24	35.92	45.84	43.73	46.53	49.01	51.21	53.39	55.47	57.62	3.3%
Hardboard	3.67	3.00	4.43	5.74	5.54	5.97	6.37	6.73	7.09	7.44	7.80	4.5%
OSB	18.17	15.13	23.10	29.62	28.38	30.34	32.09	33.67	35.24	36.75	38.31	3.7%
Particle board	29.29	23.25	35.59	45.87	44.16	47.41	50.36	53.05	55.73	58.33	61.01	4.2%
Plywood	46.89	38.03	55.10	70.94	68.24	73.19	77.69	81.77	85.84	89.79	93.86	4.1%

Year

Overall, the sector is being shaped by green regulations which will increase demand but also lead to some slight price increases

Sustainability is as a mega trend with legislation amongst a number of factors shaping manufacturing practices and consumption patterns with a view to minimizing environmental and social impacts. In this context, the demand for wood (in any form and across use cases, including construction) will increase moving forwards, as it offers physical and chemical qualities that allow it to compete against other materials in a more sustainable fashion. Nonetheless, green regulations, such as EU laws limiting the import and export of products associated with deforestation and forest degradation, will impact wood production (locally and overseas) and have a slight inflationary effect.

Forests cover a whopping 42% of the EU's land surface and how to account for the carbon dioxide absorbed by trees when calculating climate emissions has long been a tricky task. Experts describe this as 'LULUCF', shorthand for the impact land use, land use change and forestry have on the climate.

The ability of trees to store carbon dioxide and stop it being released into the atmosphere is arguably one of the planet's greatest weapons against global warming. Changing patterns of land use can therefore be disastrous for the climate.

in April 2024, the European Parliament signed off on new climate rules, which experts at the NGO FERN (a non-governmental organisation set up in 1995 to monitor the European Union's involvement in forests and to coordinate the activities of NGOs at European level), say will allow for greenhouse gases emitted because of global transport and huge levels of meat consumption, for example, to be effectively 'hidden' by the carbon absorbed by forests in some cases.

Even though negotiations on LULUCF are done and dusted, FERN says that there are other ways to protect forests, including an ambitious **2050 Decarbonisation Strategy.** They also call for forested countries such as Estonia, Finland, Sweden and France to **overhaul their forest policies and protect them against destruction** to meet the growing demand of the bioeconomy.

While the growth in wood use is expected, it's crucial to address the ecological issues associated with deforestation. This will likely involve a combination of stricter regulations, improved forest management practices, and increased use of plantation forests to meet demand while preserving natural forests.

Market participants are responding by innovating with Plantd (US), for example, using environmentally friendly inputs to replace OSB …

Plantd is developing carbon-negative building panels which are similar in looks to OSB but use processed grass as a raw material to cater to applications such as sheathing, roof decking and subflooring. The company provides the machinery to build the panels. By using grass, Plantd claims it requires nine times less plantation area than timber whilst also offering reduced costs and higher carbon capture. The company operates out of North Carolina.

XTB, a brand of **Renew Materials**, based in China and Singapore, similarly provides panels composed of agricultural straw which resemble OSB.

Its products cater to flooring, furniture and packaging use cases.

…. and Tomra (Norway) leveraging sensors and AI to recover wood from waste streams and feed this back into EW production

Established in 1972, Tomra is a leading company that specializes in collection and sorting systems that cover a wide array of materials and products, including food waste, some mining materials, aluminum, e-scrap and textiles.

The firm offers solutions that leverage artificial intelligence and automated sensor technologies to sort wood from other waste and wood itself into two different streams including unprocessed wood and processed wood composites. Furthermore, Tomra's technology allows the recovery of valuable materials from waste streams and returns them to the manufacturing process. Indeed, most wood waste, both pure and engineered, across construction, packaging and joinery applications currently undergoes downcycling, landfilling or incineration with only small amounts seeing recycling or reuse.

The EW industry regularly uses wood waste from other streams, including sawmill residues and recycled wood, to manufacture its products, meaning that the company's solutions represent a good fit for existing processes.

Outside of engineered wood itself, R&D efforts are focusing on bonding agents where consumers are demanding bio-based alternatives

Bonding agents allow the creation of new and innovative products such as CLT, which can replace solid wood, and enable the reuse of discarded wood by products.

The main issue with bonding agents has been the use of formaldehyde which is a known carcinogen. Its use in adhesives is increasingly being regulated but alternatives typically alter the behaviour of the resin, with impacts on its reactivity and ability to cross link.

Bio-based adhesives represent apt substitutes for businesses that must adhere to the new rules and address the concerns of consumers about safety and sustainability.

Researchers in laboratories globally are innovating and producing bio-based products that function like conventional petrochemical adhesives. Indeed, some companies already offer bio-based options commercially and research indicates that some protein-based resins have already reached market maturity.

Chemical companies should continue to invest heavily in this area and also look closely at start-ups that are innovating in the field for inspiration and potentially acquisition. As the new generation of resins taps into non-petrochemical markets, conventional market participants might find themselves dealing with supply chains outside of their comfort zones. Partnerships with the correct participants could therefore help ease the transition to bio-based.

The total potential addressable market for bio-based adhesives is significant, reaching players directly involved in producing EW for construction, joinery and packaging purposes and dozens of other seeking alternatives to fossil-based resins across other segments.

Current common petrochemical adhesives include UF, MUF and PF …

The advantages and disadvantages of and synthetic alternatives to urea-formaldehyde (UF), melamine-urea formaldehyde (MUF) and phenol (PF) are;

	GRADE	PROS	CONS	SYNTHETIC ALTERNATIVES
UF	Interior	• Low cost • Good performance • Ease of use • Clear color	• Formaldehyde emissions • Non-resistant to water	• R&D on glyoxal, 5-hydroxymethylfurfural, glutaraldehyde, furfural, and dimethoxyethanal, as alternatives to formaldehyde • MDI • For particleboard and plywood, thermoplastics (polyethylene, polypropylene, poly vinyl chloride) and their copolymers • R&D on ethylene vinyl acetate (EVA) films for plywood
MUF	Interior and semi exterior	Reduced formaldehyde emissions according to melamine content but not completely absent	Cost increases with melamine content	Melamine for formaldehyde-based adhesives
PF	Exterior	Lower emissions than UF but not completely absent	Some organizations list phenol as hazardous	N/A

Source: Frost & Sullivan

… which are notably being replaced by *tannins* …

There are several variations in approach to using **tannins** as a formaldehyde scavenger.

These include deploying non-fortified or chemically modified thermosetting tannins in particleboard, plywood and other particle products; tannin-urea-formaldehyde for plywood and tannin-resorcinol-formaldehyde or tannin-bonded for glulam and finger joints.

Other options cover using isocyanate/tannin copolymers, hardeners (non-formaldehyde) for thermosetting tannin adhesive and self-condensation of tannin.

Overall, the industry is seeking to increase supply through the expansion of production infrastructure and the addition of lignin, protein, soy flour and/or furfuryl alcohol to tannins. It also seeks to reduce or eliminate formaldehyde emissions using glyoxal, glutaraldehyde or vanillin; non-aldehyde hardeners; hexamine and poly (vinyl alcohol); the hardening of the tannins by self-condensation and self-condensation through wood substrate catalyzation or the addition of silica, silicate or other accelerators.

… and various approaches to leveraging *lignins*

These include the networking of **lignin** in presence of hydrogen peroxide; self-coagulation and cross-linking of lignin by a strong mineral acid in the presence of aluminium salt catalysts; the addition of laccase enzyme-activated lignin to the fibers, or activating the lignin, in situ, in the fibers, by enzyme treatment with the addition of polymeric isocyanate for MDF and methylolated lignin or lignosulphonates in PF resins.

Other approaches cover copolymerized lignin–phenol–formaldehyde (LPF) resins (an LPF resin for plywood contains up to 50% lignin) for plywood; pre-methylolated lignin with small amounts of synthetic PF resin and isocyanates (PMDIs); a mixture of tannin/hexamine with pre-glyoxalated lignin for particle board, thin hardboard and other agglomerate panels and corn stover biorefinery lignin and glyoxal for Plywood.

Other, longer term and more sustainable alternatives which are still largely in the lab stage of development are carbohydrates and EPI

For **carbohydrates**, variations in approach include its use as modifiers of existing PF and UF adhesives; forming degradation compounds for use as adhesives in building blocks (furanic resins); directly as wood adhesives (liquefied products from cellulosic materials); glucose- and sucrose-based non-isocyanate PUs; glucose with maleic anhydride and a diamine forming polyamide binders; citric acid (from fruits such as lemons and oranges) and sucrose, citric acid as part of the ongoing research into carboxylic acids and sugar-based binder from surplus and other sustainable feedstock.

For **EPI**, options cover isocyanates from vegetable oil which are used in glulam end products and leverage water-based emulsion with bio-based isocyanate as a cross-linker.

Overall, bio-based adhesive substitutes can achieve comparable or better performance than their synthetic counterparts according to laboratory experiments.

Indeed, for instance, H.B. Fuller (US) is working with Covestro (Germany) to replace fossil raw materials

The company claims to be partially replacing fossil-based raw materials by applying a mass balance approach to bio-sourced isocyanates from Covestro. H.B. Fuller states that its *Rakoll ECO 3 ZF* product does not use formaldehyde during formulation or release formaldehyde emissions during setting.

More broadly, architects, engineers, developers and consumers are increasingly looking at mass timber structures, primarily due to their "green" credentials

Wooden structures of all types are gaining momentum. Indeed, the most visible and striking case studies are high-rises using mass timber (glulam, CLT and LVL) but other types of residential and commercial buildings are also adopting these materials.

Mass timber structures are seeing greater traction in regions that already have a tradition in this respect such as North America and northern Europe. Other markets, such as Japan, are also showing high growth potential because of their long track record of using wood widely in the building environment.

Moving forwards, the entire building industry should increasingly consider mass timber as a sustainable building material.

Market participants that rapidly build their supply chains to address this opportunity will have a competitive advantage as demand takes off while the entrance of a new set of materials into the market will opens new opportunities for EW manufacturers and chemical companies producing (bio-based) adhesives as well as other stakeholders including building information modeling software developers, testing laboratories and contractors with strengths in wood building. Building codes must quickly adapt to include mass timber, particularly in countries with a significant wood stock.

Source: Frost & Sullivan

URBAN MACHINE

COMPANY **OVERVIEW**

Industry Segment:

Engineered wood

Brief Description:

Urban Machine leverages robotics and Artificial Intelligence - AI to reclaim lumber for reuse in several domains.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=0lGW0EMTaIc

COMPANY **STRUCTURE**

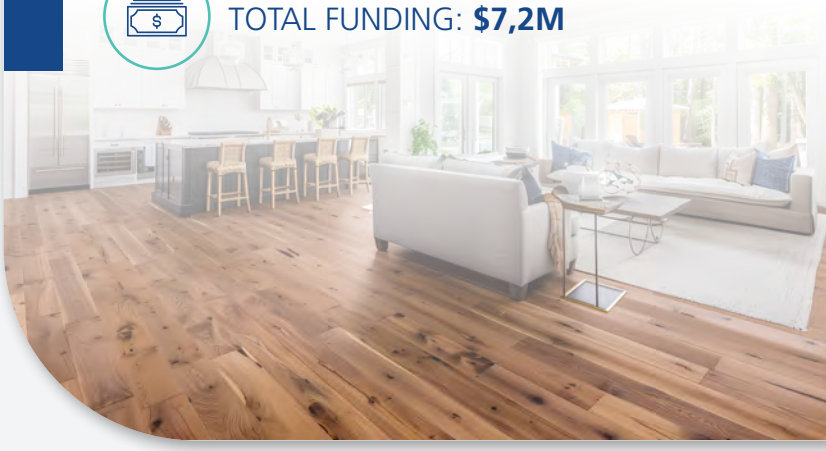
FOUNDED: **2021**

COUNTRY: **USA**

OF EMPLOYEES: **20 – 50**

Website: http://urbanmachine.build

TOTAL FUNDING: **$7,2M**



PRODUCT **OVERVIEW**

Technology Focus

- Urban Machine develops a robotic solution to remove metal fasteners from construction wood waste, reclaiming it for the production of high-quality wood products. The machine is a robotic system that employs Artificial Intelligence - AI to remove fasteners from lumber.
- AI-based vision systems detect metal fasteners in wood, such as nails, screws, and staples on all four faces, while high-speed precision end-effectors remove them. The machine includes wood cleaning capabilities via brushes to obtain a finished building material.

Main competitive advantage

Urban Machine's robots can handle large volumes of locally sourced reclaimed materials, thereby lowering transportation costs and reducing the carbon footprint. The wood processed by Urban Machine is durable and of higher quality than virgin lumber. Artificial Intelligence - AI enables the planning of the wood recovery process, calculating the quantity and quality of the lumber, and reducing production time. Moreover, the solution reduces costs associated with reclaimed lumber processing.

Value Proposition

- The company aims to repurposing wood waste by avoiding the extraction of natural resources and combating deforestation.
- The company seeks to reduce CO_2 emissions from the construction and industrial sectors by providing a sustainable and low environmental impact solution.
- The solution aims to reduce industrial waste by transforming wood scrap into high-quality, locally sourced products.

MERCER MASS TIMBER

COMPANY **OVERVIEW**

Industry Segment:

Engineered wood

Brief Description:

Mercer Mass Timber is a manufacturer of bio-based building materials for the construction of zero-carbon timber buildings.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=OFmsxeWNyp4

COMPANY **STRUCTURE**

FOUNDED: **2021**

COUNTRY: **CANADA**

OF EMPLOYEES: **50 – 100**

Website: https://mercermasstimber.com

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Mercer Mass Timber has developed a sustainable building material obtained by gluing and pressing wood into massive building components.
- The resulting mass timber is sourced from sustainable sources and designed to offer high fire resistance, as well as superior performance in terms of acoustic properties and architectural versatility.
- The company develops panels with maximum dimensions of 3.66 metres wide, 18.28 metres long and a range of thicknesses comprised between 82.5 mm and 315 mm.

Main competitive advantage

The company manufactures wood sourced from sustainable origins, designed to provide high fire resistance, superior acoustic properties, and great architectural versatility. Mercer Mass Timber products can adapt to diverse architectural solutions, for both residential and commercial buildings. The wood used is produced with a focus on conserving raw materials and resources, allowing for a reduction in production costs. Mercer Mass Timber wood reduces the carbon footprint per square meter of new buildings compared to structural concrete.

Value Proposition

- Mercer Mass Timber is on a mission to spread low carbon buildings around the globe, reducing carbon footprint from the construction sector.
- The company is committed to provide cost-effective building materials, reducing costs related to raw materials and logistics.

AISTI

COMPANY **OVERVIEW**

Industry Segment:

Engineered wood

Brief Description:

Aisti develops a foam forming process with wood fiber to create acoustic tiles and other building materials intended for industrial applications.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=MlowMpZnD48

COMPANY **STRUCTURE**

FOUNDED: **2019**

COUNTRY: **FINLAND**

OF EMPLOYEES: **10 – 20**

Website: https://aisti.com

TOTAL FUNDING: **€1,6M**

PRODUCT **OVERVIEW**

Technology Focus

- Aisti is developing Teno, a sustainable acoustic tile made from natural fibers and employing a foam forming technology that makes the final product free from plastics, synthetic binders and irritating mineral fibers.
- Teno tiles are made from wood fiber, making them fully recyclable, and and meet fire safety standards.
- Teno tiles have the highest acoustic adsorption class (class A) and are suitable for suspended ceilings applications. They are available in multiple configurations: 20 and 40 mm thickness and two sizes, 600x600 mm and 600x1200 mm.

Main competitive advantage

Aisti has developed a patented solution using wood fiber and foam forming technology to reduce the carbon footprint of suspended ceiling acoustic solutions by at least 60% compared to currently available solutions on the market. The acoustic tiles are made from wood fiber and meet both fire safety standards and acoustic standards. The tiles are plastic-free and made from fully recyclable material. The production technology is cost-effective and sustainable, allowing for lower energy consumption during production and reduced associated costs.

Value Proposition

- The company aims to reduce the environmental impact associated with the production of building materials through a sustainable and bio-based production process.
- Aisti is committed to reducing production costs by promoting the use of sustainable and reliable acoustic panels.
- The company seeks to enhance people's well-being and health in indoor spaces by promoting solutions with high acoustic insulation.

CAMBIUM CARBON

COMPANY **OVERVIEW**

Industry Segment:

Engineered wood

Brief Description:

Cambium Carbon has developed a supply chain solution targeting underutilized wood to be upcycled into carbonnegative products.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=BRwu1iJIYI0

COMPANY **STRUCTURE**

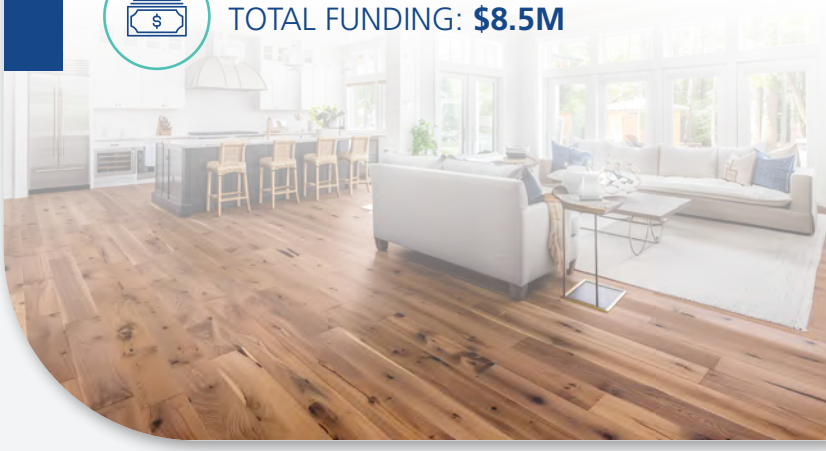
FOUNDED: **2019**

COUNTRY: **USA**

OF EMPLOYEES: **11 – 50**

Website:https://cambiumcarbon.com

TOTAL FUNDING: **$8.5M**



PRODUCT **OVERVIEW**

Technology Focus

- Cambium Carbon has developed a supply chain operating system that enables the exploitation of trees that are not suitable to be exploited in the conventional wood industry. The company works with trees that are decaying, fallen or affected by diseases making them exploitable for traditional lumber uses.
- The company works with city administrations and local arborists to collect these trees and to boost demand from users and manufacturers. Part of the profits is subsequently employed to fund planting projects.
- The supply chain output can be directed to different segments including decking, fencing and lumber made from different species. Cambium Carbon developed an application to track the supply chain and ensure transparency.

Main competitive advantage

Cambium Carbon has developed a wood supply chain solution that enables value-added exploitation of trees that are usually chipped, landfilled or burned. The supply chain is made efficient and transparent via the use of the company application. The solution enables manufacturing, sale and purchase of wood that is carbon negative and is associated with CO_2 emission levels seven times lower than wood-plastic composites.

Value Proposition

- Cambium Carbon is committed to enable underutilized wood upcycling through a solution making the related supply-chain efficient, transparent and connected.
- The company intends to contrast climate change enabling more efficient and sustainable supply chains.

STRONG BY FORM

COMPANY **OVERVIEW**

Industry Segment:

Engineered wood

Brief Description:

Strong by Form is developing timber-based composites materials for light-weight structural parts manufacturing.

Maturity:

Under development

Multimedia:

https://www.youtube.com/watch?v=VGeWP2A4SiI

COMPANY **STRUCTURE**

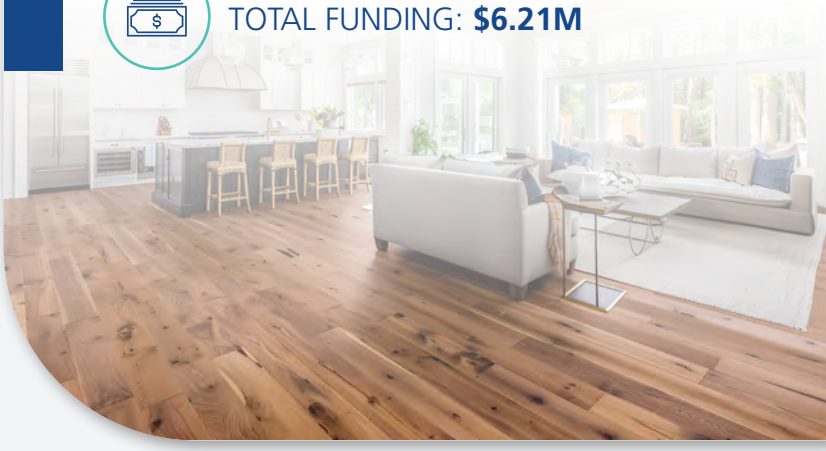
FOUNDED: **2018**

COUNTRY: **CHILE**

OF EMPLOYEES: **11-50**

Website:https://strongbyform.com

TOTAL FUNDING: **$6.21M**



PRODUCT **OVERVIEW**

Technology Focus

- Strong by Form is developing timber-based biocomposites for lightweight high-performance structural parts that is obtained via additive manufacturing processes that employs a computational platform.
- The digitalization of the production process enables controlling form, fiber orientation, density and thickness to minimize waste and optimize manufactured parts performance that is comparable to the ones of aluminium and reinforced plastic parts.
- Strong by Form biocomposite has freeform capabilities which enable manufacturing parts in complex geometries. The company technology allows to replicate trees structures natural characteristics into engineered wood parts.

Main competitive advantage

Strong by Form is developing high performance sustainable biocomposites that aim to replicate wood natural intelligence in engineered wood structures. Since the manufacturing employs wood strands, it makes efficient use of forestry resources. The company technology enables to bring waste from manufacturing process to a minimum and to reduce assembly time. While the resulting engineered wood parts have comparable performance to aluminium and reinforced plastic structures, CO_2 emissions from production are significantly reduced.

Value Proposition

- Strong by Form is committed to provide alternative materials to the construction industry that combine natural wood performance with the properties of innovative composites materials.
- The company intends to enhance sustainability of light-weight structural parts production, reducing manufacturing carbon footprint.

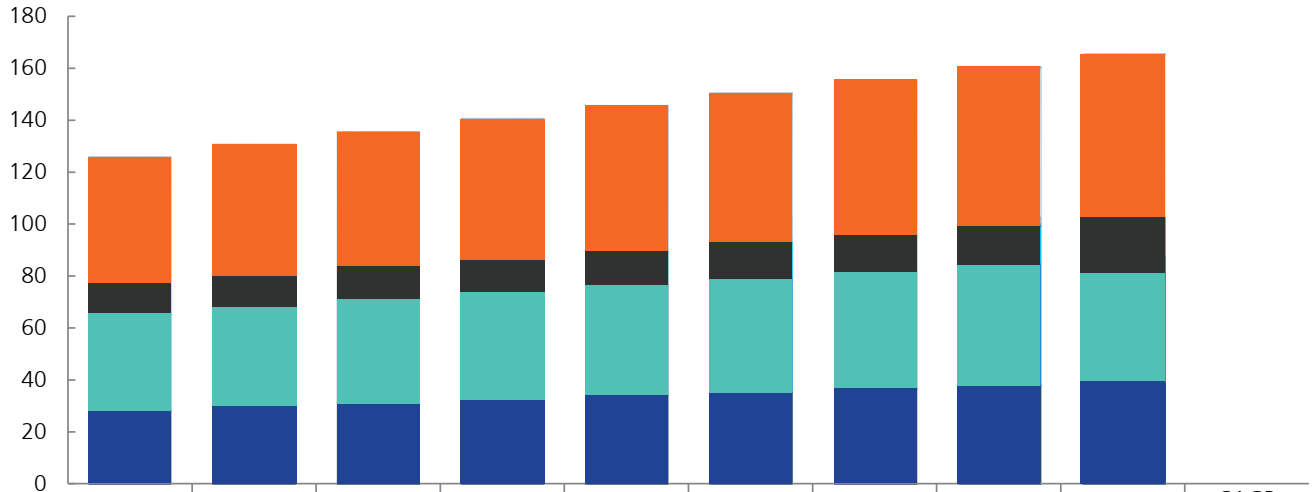
ROOFING MATERIALS

From an application standpoint, roofing materials are amongst the most dynamic with metal emerging as the fastest growing and most sustainable segment

Alternatives include **asphalt** in the form of asphalt shingles, a petroleum product that can be organic or fiberglass, the price of which depends on oil prices. Overall, it has low capital costs and offers easy installation whilst typically also guaranteeing a 20- to 50-year lifespan. Asphalt is also waterproof and attractive, especially for residential roofs, and provides adequate protection from the elements. Fiberglass shingles are thinner and lighter with a better fire rating than organic shingles which, in turn, are durable and cheaper but more flammable. However, asphalt has the potential to cause environmental problems.

Other materials that are used for roofing purposes include clay, concrete, paper-based films, slate and Tyvek, an alternative underlayment. **Concrete** and **clay** tiles offer durability, superior aesthetics, recyclability, versatility and reduced energy consumption, with a lifespan of more than 50 years. The quality of tiles is however variable and based on their soil composition. **Slate** offers users a unique texture, fire resistance, high durability, and an extended 75- to 150-year lifespan while reducing energy demand. **Wood** provides a natural aesthetic but is expensive, prone to mold/algae and requires maintenance.

Roofing Materials, Revenues by Product Type, Global, 2022-2030



	2022	2023	2024	2025	2026	2027	2028	2029	2030	CAGR (2022–2030)
Other	48.70	50.49	52.29	54.08	55.87	57.67	59.46	61.25	63.05	3.3%
Plastic	11.59	11.99	12.39	12.79	13.19	13.58	13.98	14.38	14.78	3.1%
Asphalt	37.12	38.52	39.92	41.32	42.71	44.11	45.51	46.91	48.31	3.3%
Metal	28.61	29.97	31.32	32.67	34.03	35.38	36.73	38.09	39.44	4.1%
Total	126.03	130.97	135.91	140.86	145.80	150.74	155.69	160.63	165.57	3.5%

Source: Frost & Sullivan

Here, the market is valued at $28.6b and is expected to reach $39.4b in 2030.

Metal Roofing Growth Metrics, Global, 2022–2030

Life Cycle Stage	Revenue for 2020	Units/ Volume	Average Price Per Unit	Revenue for 2030
Mature	$28.61 B (2022)	3.47 B sq ft (2022)	$8.17/sq ft (2022)	$39.44 B (2030)

Compound Annual Growth Rate	Number of Competitors	Degree of Technical Change	Concentration
4.1% (2022–2030)	200+ (active competitors in 2022)	5 (scale:1 [low] to 10 [high])	5.3% (Revenue share held by top 6 companies)

Metal roofs are notably recyclable and capable of reflecting more than 70% of the sun's rays, lowering the temperature of buildings and reducing energy costs.

Metal roofing typically uses steel, aluminum, copper, zinc, titanium and stainless steel. It is popular because of its visual appeal, versatile design, high utility, structural protection and long lifespan. Metal reflects more than 70% of the sun's rays, lowering buildings' temperature and reducing the energy and related costs that are needed for air conditioning. Roofs constructed of this material are also eco-friendly as they are recyclable while their low weight, weather-resistance, durability and ease of installation drive demand. However, metal can be expensive depending on the type, quality and quantity of the material needed.

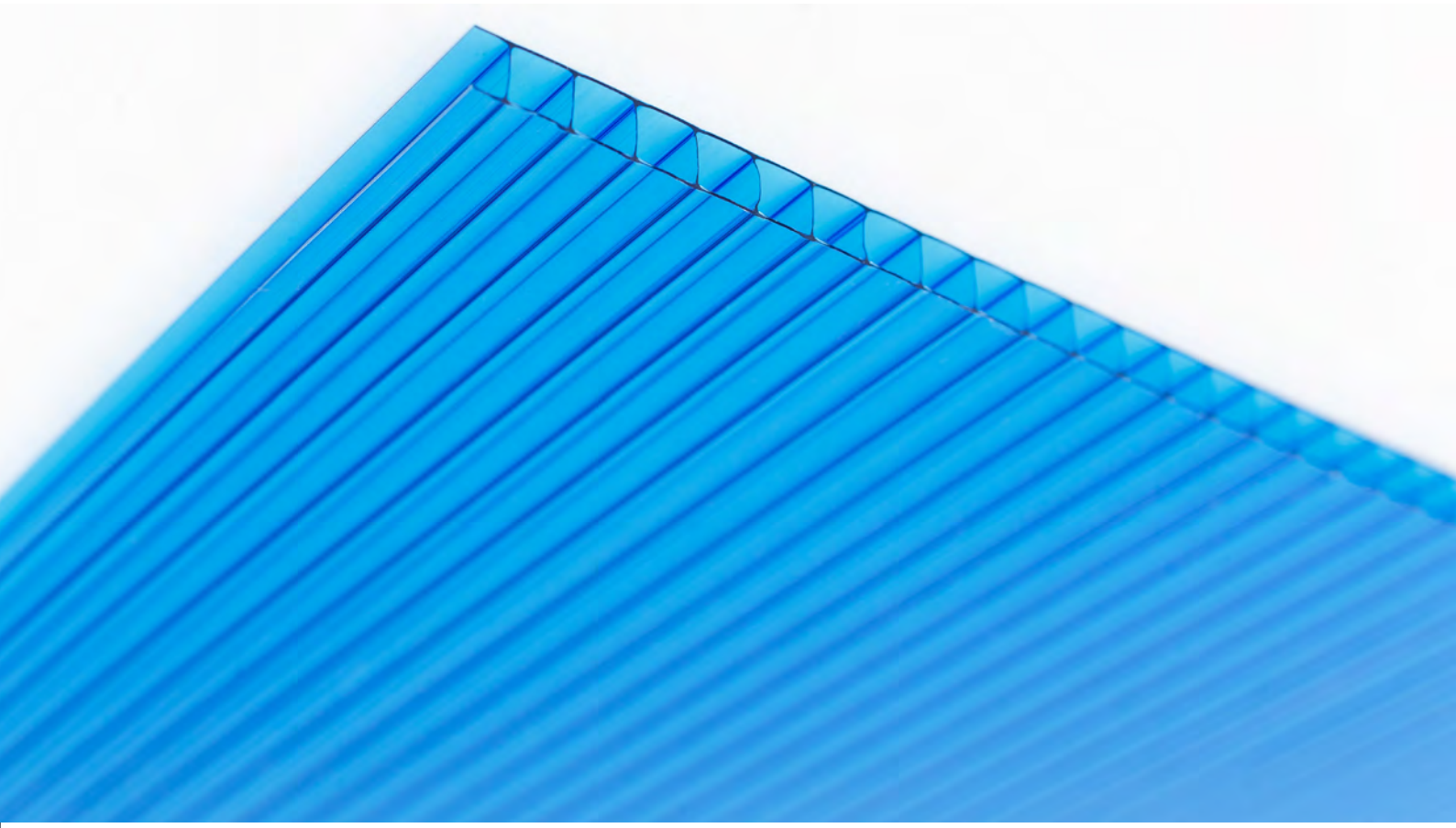
The **top competitors** in *metal roofing* market globally include BMI Group, Carlisle Construction, CertainTeed, Dow Chemical, Firestone/Holcim Building Envelope and Tata Steel/Blue Scope Joint Venture.

***Plastic* is emerging as another alternative, with the segment growing at 3.1%**

Plastic Roofing Growth Metrics, Global, 2022–2030

Life Cycle Stage	Revenue for 2020	Units/ Volume	Average Price Per Unit	Revenue for 2030
Mature	$11.59 B (2022)	2.73 B sq ft (2022)	$4.29/sq ft (2022)	$14.78 B (2030)

Compound Annual Growth Rate	Number of Competitors	Degree of Technical Change	Concentration
3.1% (2022–2030)	200+ (active competitors in 2022)	5 (scale:1 [low] to 10 [high])	6.9% (Revenue share held by top 11 companies)



Source: Frost & Sullivan

Polycarbonate, acrylic, polystyrene, and polyvinyl chloride (PVC) roofs are increasingly supplied in sustainable regenerated and prefabricated sheet formats.

Plastic roofing includes polymer composite products, such as polymer-modified synthetic, and rubber. For construction applications, hot air welding technology creates seams and fuses polyvinyl chloride (PVC), thermoplastic polyolefin (TPO), ethylene propylene diene terpolymer (EPDM) and other plastics. These are typically resistant to heat, fire, temperature changes, wind, water and hail and offer low costs, weather resistance, ultraviolet (UV) ray protection, sound and heat insulation and low maintenance. Additional plastic roofing sub-categories include polycarbonate, acrylic, polystyrene and, increasingly, recycled plastics.

The **top competitors** in plastic roofing market globally include BMI Group, Boral, Carlisle Construction, Certainteed, Dow Chemical, Firestone/Holcim Building Envelope, GAF, IKO Industries, Johns Manville, Paul Baiter and Sika.

The future is, however, represented by eco-friendly "living" or *green* roofs.

Eco-friendly roofing, such as living or green roofs, will be a significant driver of growth in the overall roofing market moving forwards.

Indeed, green roofs, also known as grass, vegetative, living or sedum roofs, are extensions of a building's existing roof which an installer has either partially or completely covered with a membrane from which to grow plants. Though easy to maintain, green roofs require, robust waterproofing, a filter cloth and the desired greenery.

In 2022, the global ecofriendly roof market was valued at more than $1 billion with building innovators becoming more aware of and adopting the concept.

Green roofs maximise the space available, offering superior aesthetics and sustainability, and are suitable for private, commercial and municipal buildings in urban, suburban and rural locations and are applicable for all settings, from living quarters to industrial facilities.

Europe holds the largest share of the total green roof market thanks to the implementation of regulations to combat climate change and extreme weather. The European Commission has notably introduced **the Green Infrastructure Strategy** to formulate a distinct plan of action to mitigate the impacts of global warming.

Green infrastructure has been defined as "A strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity." Such services include, for example, water purification, improving air quality, providing space for recreation, increase the use of green materials as well as helping with climate mitigation and adaptation. This network of green (land) and blue (water) spaces improves the quality of the environment, the condition and connectivity of natural areas, as well as improving citizens' health and quality of life.

Furthermore, The Green Infrastructure Strategy promotes nature-based solutions that help mitigate climate change such as: Protection and restoration of ecosystems like forests and wetlands, which act as carbon sinks, creation of green spaces in urban areas to reduce the urban heat island effect and promotion of green roofs and walls to improve building energy efficiency.

Regarding EU regulations to combat climate change and extreme weather, key regulations to reduce emissions include energy efficiency target of 32.5% by 2030, renewable energy target of 32% by 2030 and CO_2 emissions standards for new vehicles, requiring a 30% reduction between 2021-2030. The EU is also working to phase out coal power plants, which account for 18% of greenhouse gas emissions.

The **top competitors** in green roofing market globally include Axter, Bauder, Green Roof Blocks, Optigrun International, Soprema, Sempergreen Group, American Hydrotech, Barrett Company, ArchiGreen Roof, Onduline Group and XeroFlor.

These are supported by the award of government incentives which encompass new builds and retrofitting …

Recently, governments globally have been offering tax breaks to public and private organizations that utilize green roofs. They are implementing new regulations for the installation of living roof systems and solar photovoltaic systems. Preexisting and planned buildings both in and out of the cities are undergoing extensive green roof repairs and additions which are often supported by government incentives.

Other market drivers include the role of green roofs in managing the ambient temperature of the buildings themselves and more generally reducing the impact of urban heat accumulation. In addition, their emergence is creating employment opportunities for trained and qualified installers as well as maintenance providers who often use technologies such as drones in order to check on the status of living roofs and provide services.

… but the costs of procurement and installation as well as structural reinforcements often remain prohibitive

Green roof technology can be expensive. Within the United States, the price typically ranges between $161 and $538 per square meter but this varies according to the type of building, the type of system and the intricacy of the design.

When it comes to capital expenditure, the installation of a green roof typically costs two to three times more than that of a conventional roof. The high initial price acts as a hindrance to market growth with successful set-up requiring experience and training and, for the more extravagant projects, the intervention of a planner and/or designer.

Another factor adding to the cost is the concept of "system layering". This refers to the frequent need to reinforce existing structures to support the additional weight that plants, a growing medium and membranes add to buildings.

This general perception of high costs together with a mismatch between the short hold periods of real estate assets in investors' portfolios and the need to allow a green roof to develop over time impede the development of the market.

In the longer term, solar technologies are now advancing to the point at which building integrated photovoltaics can replace conventional construction materials

Solar skins are essentially a layer of film laden with graphics and designs that can be applied over solar panels. This film ensures that panels can be customized to align with the aesthetics of a building. They can be used to cover solar panels and are suitable for roofs on both buildings and automobiles, either as camouflage or as space for advertising which can earn the owner or operator revenues.

Sistine Solar (US) enables residential and commercial customers to enhance the aesthetic appeal of solar panels and to monetize them. Its solutions are 100% customizable with minimal power generation loss.

Building-integrated PV (BIPV) similarly offers energy savings and, in an increasing number of cases, material savings as it can replace conventional construction materials.

Ubiquitous Energy (US) supplies transparent solar glasses and has completed a handful of installations globally. The company has partnered with Andersen Corporation to offer windows and doors which it claims to be 10% more efficient that conventional solar panels.

Tesla (US), for example, is one of many companies that has developed solar tiles which insulate buildings and function as solar power generation modules.

The company's solar roof system includes steel roofing tiles and solar glass tiles. These weatherproof and durable solutions are visually appealing and come with an optional Powerwall, Tesla's energy storage module. Furthermore, the solar tiles have a 25-year warranty and enable 24/7 protection from power outages while each solar tile has a power rating of 72W. Tesla also offers an app that allows owners to map power production in real time. While implementing all these technologies in their value proposition, Tesla has installed its solar tiles on more than 480,000 roofs globally.

Source: Frost & Sullivan

ECO BLOCKS AND TILES

COMPANY **OVERVIEW**

Industry Segment:

Roofing materials

Brief Description:

Eco Blocks and Tiles manufactures tiles made of a recycled plastic-based composite material that represent an alternative to traditional clay or concrete tiles.

Maturity:

On the market

Multimedia:

https://youtu.be/XCQVEda9e6U?si=vRse4pr2QT3Jv5_R

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **KENYA**

OF EMPLOYEES: **2 – 10**

Website: https://ecoblocksandtiles.co.ke

TOTAL FUNDING: **$0.05M**

PRODUCT **OVERVIEW**

Technology Focus

- Eco Blocks and Tiles produces roofing tiles, made of polymers and a composite material, that is composed primarily of recycled plastics, making tiles fully recyclable at the end of life. The company products can replicate the appearance of traditional tiles.
- The roofing tiles are manufactured through a patented process that requires reaching temperatures of over 2,200 degrees, making the final product resistant to sunlight and suitable for different latitudes. Since the material is non-porous it reduces water adsorption to a minimum, preventing moulds and weeds growth.
- The company tiles are lighter and stronger than traditional clay and concrete ones. Colour fading is prevented by a UV treatment. The material is flame resistant.

Main competitive advantage

Eco Blocks and Tiles manufactures roofing tiles using polymers and a material derived from recycled plastic and glass. The products are environmentally sustainable since their production supports cleaning ecosystems. In addition, the company provides indirect employment opportunities in the context of plastic waste collection. Since the company roofing tiles are lighter than traditional ones, their transportation and installation is facilitated. They are suitable for both residential and commercial segments.

Value Proposition

- Eco Blocks and Tiles is committed to reduce construction industry carbon footprint by adopting as main input of eco-friendly building products plastic and glass waste.
- The company is also engaged in indirectly providing opportunities for income generating activities to fragile communities in the context of waste picking.

NEBESYS

COMPANY **OVERVIEW**

Industry Segment:

Roofing materials

Brief Description:

Nebesys has developed a roofing system indistinguishable from ordinary roofs but transparent from the inside,enabling underutilized attic spaces use.

Maturity:

On the market

Multimedia:

https://youtu.be/aAV8iux-YW8?si=dGf8P-VqxiesCRO4

COMPANY **STRUCTURE**

FOUNDED: **2022**

COUNTRY: **CZECH REPUBLIC**

OF EMPLOYEES: **11 – 50**

Website: https://nebesys.com/en

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- Nebesys has developed a roofing system that is transparent from the inside of the building but looks like an ordinary roof from the outside.
- The roofing system is composed of an external layer made of perforated aluminium or enamelled steel tiles that work as covering. This layer has mainly a shading function reducing solar radiation.
- A further layer made of transparent triple-glazed panes mounted on aluminium profiles provides thermal insulation properties to the roof. An additional layer ensures internal space ventilation via direct air systems and recuperation, heating and cooling.
- Nebesys system weight is comparable to the one of the original roof without thermal insulation.

Main competitive advantage

Nebesys builds and installs roofing systems that are translucent but not distinguishable from traditional roofs, ensuring both privacy and aesthetical consistency with the nearby area. The system enables the exploitation of non-utilized under-roof spaces also in the context of conservation areas. The light penetrating through Nebesys roofing system is delicate since direct sunlight is prevented. It ensures thermal comfort in both hot and cold seasons. The company offers a degree of personalization of the roofing system via different materials, shapes and colours.

Value Proposition

- Nebesys is committed to provide systems that enable underutilized attics exploitation as living spaces, reducing the need for further urbanization.
- The company intends to provide the building renovation market with a solution that allows consistency with surrounding buildings and environments.

SOLARSTONE

COMPANY **OVERVIEW**

Industry Segment:

Roofing materials

Brief Description:

Solarstone manufactures and installs solar roofing solutions that exploit solar tiles both as main roofing layer and renewable energy generation elements.

Maturity:

On the market

Multimedia:

https://youtu.be/5rS-oHGA-PE

COMPANY **STRUCTURE**

FOUNDED: **2015**

COUNTRY: **ESTONIA**

OF EMPLOYEES: **11 – 50**

Website: https://solarstone.com

TOTAL FUNDING: **$10.5M**

PRODUCT **OVERVIEW**

Technology Focus

- Solarstone has developed a solar roofing solution exploiting solar tiles made of monocrystalline silicone cell and aluminium for the frame. The system interlocks with most conventional concrete and clay tiles. Each Solarstone solar tile is expected to substitute about 5-6 ordinary tiles.
- The solution power is 150 W/m2. The solar roofing is connected to the house electrical system, and each Solarstone tile is accessible so that replacement is facilitated.
- The solar roofing system can be installed directly on wooden battens thus it does not require further mounting systems.

Main competitive advantage

Solarstone manufactures and installs solar tiled roofs for new or refurbished houses, providing solutions that combine roofing and energy generation functions in a uniform aesthetic. The company solar tiled roofs installation is less complex than the traditional solar panel installation and it saves costs. Solarstone solutions preserve the roof appearance and consequently the aesthetic consistency with the surrounding area. It is a weather-proof solution capable of resisting to cold weather, snow and hail. The company solar tiles are low maintenance, and Solarstone provides a 10 years' product warranty and a 25 years' power output warranty.

Value Proposition

- Solarstone is committed to promote sustainable living promotion and transition to renewable energy generation in the residential segment.
- The company intends to empower households with the possibility to contribute to a sustainable and resource-efficient future.

SUNSPEKER

COMPANY **OVERVIEW**

Industry Segment:

Roofing materials

Brief Description:

Sunspeker manufactures and installs a recyclable graphic cover that allows for the aesthetic customization of solar panels, while maintaining high solar efficiency.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=E8AGGnHJxfs

COMPANY **STRUCTURE**

FOUNDED: **2022**

COUNTRY: **ITALY**

OF EMPLOYEES: **2 – 10**

Website: https://sunspeker.com

TOTAL FUNDING: **€0.17M**

PRODUCT **OVERVIEW**

Technology Focus

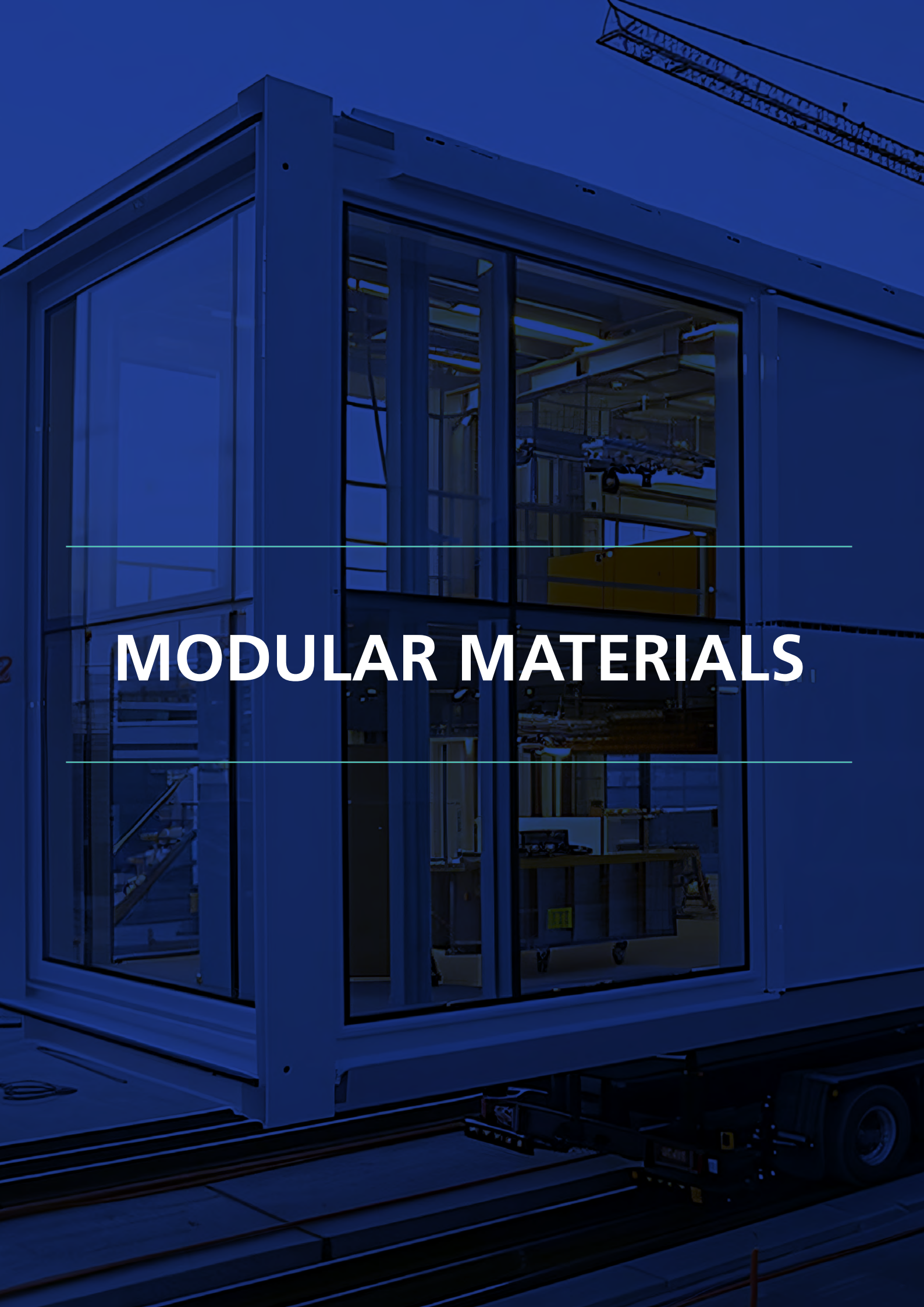
- Sunspeker's patented technology enables the creation of a graphic cover that is highly permeable to sunlight, allowing for the aesthetic customization of the solar panel without causing any hotspot issues.
- The company's graphic cover offers a highly flexible and customizable solution that can be applied to the majority of solar panels currently available on the market.
- The graphic cover is made from a fully recyclable material with strong resistance to weather conditions, maintaining its functional properties for over 10 years.

Main competitive advantage

Sunspeker has developed a recyclable graphic cover that allows for the aesthetic customization of solar panels. The patented technology allows the covered solar panel to maintain between 80% and 90% of its electrical generation capacity. With Sunspeker's cover, a traditional solar panel can generate more energy than a colored glass solar panel of the same size, while also offering superior aesthetic integration.

Value Proposition

- Sunspeker's graphic cover allows solar panels to be aesthetically integrated into their surrounding environment, minimizing visual impact and ensuring compliance with regulatory constraints in protected areas.
- The graphic cover can be applied using the wrapping technique, commonly used for car bodies, a skill that is easily accessible and widely available across the territory.
- The graphic cover allows to transform the solar panel into a space that can both generate energy and convey an advertising message, such as a brand, slogan, or company logo.



MODULAR MATERIALS

Modular materials are another application area and is growing rapidly due to the impact of new technologies and the shift towards sustainability

Modular construction is a type of construction where building units are prefabricated off-site in a controlled manufacturing plant and then transported and assembled on-site. This process reduces construction time, produces less waste, and is more cost-effective than conventional construction methods.

This method is known for its efficiency, cost-effectiveness, and flexibility. The materials used in modular construction are similar to those used in traditional construction. Each of these materials offers distinct advantages and is chosen based on the specific requirements of the project.

The focus here is on modular materials, which refers to materials that are required for modular construction, segmented as wood; cement (concrete); steel; plastics, composites, and insulation materials; and others.

This market was valued at $40.2b globally in 2022 and is forecast to reach $58.8b in 2029 with a 4.2% CAGR in the forecast period.

The approach itself brings environmental benefits, reducing waste by 85% and cutting greenhouse gas emissions by 3% …

Globally, there is a growing need for housing and, as a consequence, an increase in demand for sustainable solutions. Indeed, the world's population will likely grow by two billion in the next 30 years. By 2050, more than double the current urban population will live in cities. As a result, global construction activities will register continuous growth to cater to the rising population and rapid urbanization trends.

However, skyrocketing construction materials prices and supply chain disruptions due to geopolitical chaos have led to a crisis in the affordable housing sector. In Canada, for example, Ontario, Alberta and Manitoba are the provinces facing the largest housing shortages. Over 650,000, 138,000 and 23,000 additional units will be needed to meet the national average of homes per capita in these areas respectively.

Prefabricated buildings can form part of the response, speeding up the construction process by 20% to 50% and yielding construction cost savings of about 20%. Along with improved quality control that results from manufacturing components in a controlled environment, modular construction can also provide environmental benefits, such as reducing material waste by 85%, increasing energy savings by 5% and cutting GHG emissions by 3%.

Countries around the world have started adopting modular construction techniques over traditional approaches to quickly and sustainably plug the demand and supply gap. Frost & Sullivan therefore expects the market to continue its upward trajectory and, in turn, to drive the associated demand for dedicated materials.

Source: Frost & Sullivan

… and is increasingly being supported by the introduction of more sustainable materials particularly across the main areas of concrete and steel

As with the overall market, materials for modular construction consist of **cement** (concrete), a mixture of cement, sand and water, that has various applications in wall panels and foundations and **steel** which is used as a framework or as a reinforcement in concrete.

Other materials include **wood**, which is used in lumber or engineered wood products in modular construction, as well as **plastics** and **composites**, which find many applications in construction and can also be used as structural materials, and **insulation** materials which are essential for maintaining energy efficiency and safety in modular buildings.

Concrete modular systems provide excellent thermal and sound insulation and are widely used in residential buildings

For modular construction, *concrete* breaks out into;

- **Normal strength concrete**, which is a basic concrete type obtained by mixing cement, water and aggregates with strength that varies from 10 MPa (megapascal) to 40 MPa; applications include flooring and slab applications
- **Precast concrete** which is manufactured according to building design specifications and is used as concrete blocks and staircase units
- **Reinforced concrete** which includes materials such as steel and fibers to bear a building's tensile strength and is used to make concrete frames

Here, the focus is on lightweighting and recycling

For **lightweighting**, manufacturers worldwide are investing heavily to tackle the main challenge of transporting prefabricated concrete elements and modules. For **recycling** aggregates and concrete, the need to reduce CO_2 emissions will highly impact the concrete industry. Since prefabrication provides the flexibility of a controlled production environment, there is a disproportionately high opportunity to deploy recycled aggregates or concrete in the modular construction market than in the construction market overall. Manufacturing modules in advance provides an opportunity for stakeholders to invest time and money in innovation and to work to achieving similar properties in recycled to conventional concrete.

In 2020, Holcim invested in CPC, a Swiss start-up which invented carbon-prestressed concrete which allows a 75% decrease in CO2 emissions

Carbon-prestressed concrete (CPC) slabs are made up of concrete reinforced with prestressed carbon fibers and have the same load-bearing capacity as traditional reinforced concrete slabs while being up to five times thinner and lighter. For instance, if builders built the Eulach footbridge in Winterthur, Switzerland, with traditional reinforced concrete, it would weigh 56 tons or 26 tons if built with timber. With CPC, it weighs 14 tons.

CPC slabs are expected to open the doors to using concrete in modular construction as they overcome the two major challenges of its conventional equivalent's heavy weight and carbon emissions. The penetration of CPC is already quite high in Europe and other mature markets. Germany, for example, has certified carbon-prestressed concrete and over 170 projects in Switzerland have used it to date.

In quantitative terms, the solution has the potential to lower material use by up to 80% and decrease CO_2 emissions by up to 75%. CPC is also completely recyclable.

BubbleDeck (Denmark) has developed a solution which reduces the concrete used in a building by 50% and replaces it with recycled plastic balls

BubbleDeck has invented a construction method that eliminates non-performing concrete from the neutral axis of a concrete floor slab. The technology can reduce the volume of concrete required in a building by up to half, replacing it with recycled plastic balls with a diameter of about 80% of a deck's thickness which are placed between welded reinforcement meshes and maintain the same strength as a conventional concrete slab.

BubbleDeck complies with all main building standards globally, provides design flexibility and is seismic and explosive resistant. It is available in cast in-situ and precast panel versions.

Although the company launched the product a few years ago, it has not yet registered high adoption globally. However, with advances in modular construction technology and the role that concrete plays in this market, Frost & Sullivan expects such technologies to be increasingly adopted by prefabricated building companies in the long term.

In quantitative terms, every 5,000 m^2 of the *BubbleDeck* floor slab can save up to 1,000 m^3 of site concrete, 166 ready-mix lorry trips, 1,798 tons of foundation loads, 416 million Kcal of energy used in concrete production and haulage, and about 278 tons of CO_2 emissions.

Steel modular systems offer strength and durability which make it the most economical choice for most high-rise buildings

For modular construction, pre-engineered **steel** building (PEB) components break out into;

- **primary framing** which are the main load-carrying and support members (primary members). They include columns and other supporting elements. These members are designed as per the latest international codes and standards, such as those set out by the American Institute of Steel Construction, American Iron and Steel Institute and the Metal Building Manufacturers Association to meet all specifications
- **secondary framing** which are secondary structural members used to support the wall and roof panels. This includes Z-shaped roof purlins and wall grits which are lighter than C-shaped sections in conventional steel buildings
- Roof and wall panels which allow manufacturers to prepare galvanized roof panels with a multilayered coating to ensure durability and adhesion

In addition, steel joists and steel decks are also used in modular construction. Steel joists are primarily deployed to support a roof or floor deck and transfer the load imposed on the deck to the structural frames while steel decks are steel sheets supported by steel joists or beams. Both should confirm the American Society for Testing and Materials' standards and can be used to support concrete or insulating membranes of a roof.

Here, developments centre on improving versatility

While steel may pose challenges due to its weight and rigidity, it offers immense **versatility** in a controlled production environment, enabling manufacturers to shape it into almost any shape required for a specific modular project, even those with complex designs.

Tata Steel's (India) HabiNest solution is 100% recyclable and consumes 48% less fresh water than a conventional structure

Tata Steel's *Nest-In* platform is present in over 26 states in India today, offering various steel-based modular construction solutions for portable cabins, premium living, safe drinking water and sanitation purposes.

Within this, the company's *HabiNest* solution is a light gauge steel frame that uses less space and foundation. It can be constructed in almost one-third of the time compared to traditional buildings, weighs 70% less than traditional structures and withstands wind speeds up to 240 km/hour. Moreover, the steel used in HabiNest is 100% recyclable.

The HabiNest solution has significant positive environmental impact

It consumes 48% less fresh water, requires 65% less material and its GHG impact is 53% lesser than a conventional equivalent.

Other elements of Tata Steel's Nest-In platform include *Nestudio*, a low maintenance and sturdy construction solution that allows clients to create a working or premium living space, and *MobiNest*, an easy-to-install, steel-based customizable and portable cabin.

Ecosteel (US) has produced a solution with a urethane core between two pre-finished steel facing which improves insulation

California-based Ecosteel designs, engineers and supplies steel buildings. It exclusively works with pre-engineered steel components, enabling it to provide a strong BIM platform coupled with state-of-the-art engineering and construction technology.

From a product point of view, the company's unique clear-span curtain wall structure eliminates the requirement for load-bearing interior walls, optimizing space utilization and enabling innovative design solutions. Furthermore, its interior panels feature a urethane core injected between two pre-finished steel facings which provide optimal thermal efficiency. The solution's specially formed side joint also allows hidden sealant application within recessed grooves, creating a strong water and vapor seal for weather protection.

Since the company focuses on sustainability, all its products meet the requirements of building codes while contributing to Leadership in Energy and Environmental Design (LEED) credits.

Indeed, sustainability initiatives in the modular materials market more generally have targeted *insulation* with US-based Plant Prefab using cellulose …

Plant Prefab is a sustainability-focused prefabricated design and construction company that provides premium, eco-friendly homes. It utilizes sustainable materials and processes such as cellulose and recycled paper for insulation to ensure that the homes which the company builds are as environmentally friendly as possible.

With its patented ***Plant Building System***, Plant Prefab offers a wooden hybrid solution incorporating a new panel and specialized modules to deliver personalized buildings. Its system represents an upgrade on existing panelized products, incorporating framing, insulation and even plumbing, electrical and finish materials.

The emergence of modular construction presents a very valuable opportunity for companies such as Plant Prefab which prioritize enhancing client satisfaction by delivering personalized modular homes.

The company's ***Plant Building System*** offers significant time savings over conventional construction techniques as up to 90% of the finished work can be completed in the factory. It also provides efficiencies by reducing the barrier to traditional modular construction which is transportation. With flexibility in building component size and shape, it is more feasible for Plant Prefab to deliver projects on sites. Another advantage is design flexibility, since the Plant Building System offers the freedom to build in any architectural style and to provide different dimension houses (from single family to multifamily homes) or commercial premises.

… and Knauf Insulation's (Germany) Supafil made up of 80% recycled glass and ideally suited for prefab manufacturers as it requires no manual cutting

Knauf Insulation is a manufacturer with over four decades of experience in North American and European markets. It offers sustainable insulation solutions for prefabricated buildings under its "innovative solution" product segment.

The company has notably developed a system called ***Supafil MAX*** Frame to automate the installation of blown glass wool in the prefab manufacturing process. This cutting-edge technology reduces costs and saves time by efficiently fitting compressed blowing wool into prefab frame elements while minimizing waste.

The main advantages of ***Supafil Blowing*** Wool are its excellent acoustic and thermal insulation. It is non-combustible and highly sustainable since it is made up of up to 80% recycled glass. Supafil also has the potential to achieve 72% compression so occupies minimum space compared to plastic-based insulants. In addition, it saves prefab manufacturers time as it requires no manual cutting.

It is also Eurofins Gold certified for indoor air quality.

Knauf Insulation believes strongly in the future of machine-applied mineral wool in insulation applications. Since speed and sustainability are key drivers of the overall modular construction market, Frost & Sullivan expects this and other similar product innovations to be well position to record growth now and in the future.

Source: Frost & Sullivan

PLAEX BUILDING SYSTEMS

COMPANY **OVERVIEW**

Industry Segment:

Modular Materials

Brief Description:

Plaex Building Systems has developed an interlocking building system that can easily be assembled and disassembled.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=xCEuGYvLd-U

COMPANY **STRUCTURE**

FOUNDED: **2020**

COUNTRY: **CANADA**

OF EMPLOYEES: **2 – 10**

Website: https://plaex.ca

TOTAL FUNDING: **$1.4M**

PRODUCT **OVERVIEW**

Technology Focus

- Plaex Building Systems has developed a fully interlocking building system that is made mostly with waste materials. The system does not require mortar for construction, but each element has centre holes in which rebar and cement can be placed.
- The elements of the modular construction system are made of a concrete-like composite that makes them 35% lighter than concrete. They hold screws better than materials such as wood and concrete since they are less subject to cracking and chipping.
- Plaex Building Systems construction elements, being dense and durable, are more resistant to water and impacts than conventional bricks and concrete.

Main competitive advantage

Plaex Building Systems manufactures an interlocking building system that interlocks on all sides, simplifying the building process. The system is no-cut and it reduces the typical waste of construction sites coming from cutting and errors, reducing project costs. The simplicity of assembling and its mortar-less feature that does not require waiting for cure times reduce the construction time up to 80% when compared to the use of concrete. Plaex Building Systems elements are manufactured using mostly waste materials and they are recyclable at the end of life. Since they are easily assembled and disassembled, they embody a circularity feature.

Value Proposition

- Plaex Building Systems intends to address the environmental problem caused by waste ending up in landfills and oceans by using waste as primary input of its construction system.
- The company is also committed to address the issue of labour shortage and workers ageing affecting the construction sector via the provision of a simple and fast construction system.

MIGHTY BUILDINGS

COMPANY **OVERVIEW**

Industry Segment:

Modular Materials

Brief Description:

Mighty Buildings has developed a 3D-printed composite panels-based solution that is ready for installation on construction sites.

Maturity:

On the market

Multimedia:

https://youtu.be/LurKyQIDh7I

COMPANY **STRUCTURE**

FOUNDED: **2017**

COUNTRY: **USA**

OF EMPLOYEES: **51 – 200**

Website: https://mightybuildings.com

TOTAL FUNDING: **$153.8M**

PRODUCT **OVERVIEW**

Technology Focus

- Mighty Buildings has developed a building platform that employs 3D-printed panels using automated robotic fabrication technologies. Panels are made of five layers of a patented composite stone material and they have a thickness of 8 inches. When delivered to the construction site, panels are ready to be installed.
- Epoxy primer and acrylic paint are used for coating, ensuring resistance to different weather conditions and not requiring vapor barrier of further finishing. Polyurethane foam is employed for insulation and panels are completed with steel frames.
- The composite material has fire self-extinguishing properties, it is mold and insect resistant.

Main competitive advantage

Mighty Buildings has developed a building platform based on 3D-printed composite panels that can be quickly installed on site. The exploitation of automation and robotic technologies reduces the manufacturing process and the construction time by up to 90%. The employment of the platform enables waste and scrap reduction compared to conventional methods. Buildings employing Mighty Buildings platform have an expected lifespan of over 50 years. The patented material used is made 60% of components that are sourced sustainably and recycled ones.

Value Proposition

- Mighty Buildings is committed to create carbon-neutral houses leveraging innovation in material science, robotics and automation technologies.
- The company is engaged in streamlining and optimizing houses construction processes while ensuring long dwelling lifespan.

SYSTEM 3E

COMPANY **OVERVIEW**

Industry Segment:

Modular Materials

Brief Description:

System 3E has developed a construction system based on elements that are self-interlocking, self-insulating and fully recyclable.

Maturity:

On the market

Multimedia:

https://www.youtube.com/watch?v=T3VnJ5BJMrU

COMPANY **STRUCTURE**

FOUNDED: **2018**

COUNTRY: **POLAND**

OF EMPLOYEES: **51 - 200**

Website: https://system3e.com

TOTAL FUNDING: **N.A.**

PRODUCT **OVERVIEW**

Technology Focus

- System 3E has developed a jointless construction system made of self-insulating elements that are self-interlocking thus preventing movement in any dimension.
- The elements are made 99% of a naturally occurring volcanic glass, perlite that is fully recyclable at the end of life. System 3E construction system is dry-stack so it does not require mortar, water and glue.
- The production process for the elements is highly advanced, with 90% of the operations being fully automated, ensuring greater efficiency and precision.

Main competitive advantage

System 3E manufactures and commercializes a construction system that is dry-stack and jointless. It is sustainable, self-insulating and composed almost exclusively from perlite, it is fully recyclable and has lower carbon footprint than conventional technologies. System 3E elements enable to make the building process up to three times faster than with traditional methods. In addition, the construction process is easier and waste typical of construction sites is reduced by 80%. The price per square meter of the system is comparable to the one associated with conventional methods. Labour cost cuts and not requiring the use of insulation, mortar, glue and other materials represent the key savings associated with using System 3E construction elements.

Value Proposition

- System 3E intends to support the transition of the construction industry towards sustainability while enabling efficient building processes that are suitable to multiple design.
- The company is committed to bring rapidity and modularity in the construction industry via its technology.

Source: Crunchbase, SYSTEM 3E

PRINCIPAL
ABBREVIATIONS

OSB	*Oriented strand board*
LVL	*Laminated veneer lumber*
CLT	*Cross-laminated timber*
AI	*Artificial intelligence*
UF	*Urea-formaldehyde*
MUF	*Melamine-urea formaldehyde*
EPI	*Emulsion polymer isocyanate*
PVC	*polyvinyl chloride*
ML	*Machine learning*
SDG	*Sustainable Development Goals*
R&D	*Research & Development*
B	*Billion*
NZEH	*Net zero energy homes*
ZEB	*Zero energy building*
PV	*Photovoltaic*
HVAC	*Heating, ventilation and air conditioning*
BIM	*Building information modelling*
AEC	*architecture, engineering and construction*
MDF	*Medium Density Fiberboard*
AAC	*Autoclaved aerated concrete*
PU	*Polyurethane*
PIR	*Polyisocyanurate*
GHG	*Greenhouse gases*
CVD	*Chemical vapor deposition*
NLT	*Nail-laminated timber*
GLT	*Glue-laminated timber*
LSL	*Laminated strand lumber*
ECC	*Engineered Cementitious Composite*
SDG	*Sustainable development goals*

BAMB	*Buildings as material banks*
OSB	*Oriented strand board*
EW	*Engineered wood*
EU	*European Union*
PF	*Phenol*
EVA	*ethylene vinyl acetate*
MDI	*Diphenylmethane diisocyanate*
O&M	*Operations and maintenance*
M&A	*Mergers & Acquisitions*
NRW	*Non-revenue water*
EPS	*Expanded PolyStyrene*
EoL	*End-of-life*
BIPV	*Building-integrated PV*
W	*Watt*
CAGR	*Compound Annual Growth Rate*
PEB	*Pre-Engineered Buildings*
Mm	*Millimetre*
K	*Kelvin*
LPF	*Lignin–phenol–formaldehyde*
PU	*Polyurethanes*
TPO	*Thermoplastic polyolefin*
UV	*Ultraviolet*
EPDM	*Ethylene propylene diene terpolymer*
CO_2	*Carbon Dioxide*
m^2	*Square metre*
m^3	*Cubic metre*
KG	*Kilogram*
PC	*Polycarbonate*

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research

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Published: September 2024

This study was funded by the European Union - NextGenerationEU, Mission 4, Component 2, in the framework of the GRINS -Growing Resilient, INclusive and Sustainable project (GRINS PE00000018 – CUP B13D21011870004). The views and opinions expressed are solely those of the authors and do not necessarily reflect those of the European Union, nor can the European Union be held responsible for them.