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Sustainable construction: the prefabrication opportunity

Humans have been constructing shelters for nearly six thousand years. With new and exciting developments in prefabrication, as well as global issues such as climate change impacting business, the construction industry is finally moving into the digital era. Today the construction industry is one of the sectors which takes the greatest toll on the environment. It is possibly the largest contributor alongside the food sector, to climate change with this situation expected to deteriorate further in the next decade. Moreover, it is one of the few industries which has failed to significantly improve its labor productivity in recent decades.

At Ambienta, we believe construction has the potential to be part of the wider solution to climate change. The built environment has evolved based on the local availability of materials, the procurement of tools and skilled labor. With growing demands to improve the environmental impact of materials, a shortage of skills and an ageing work-

force, the industry must now adapt to become more sustainable in itself, productive and resilient to the effects of climate change and extreme weather events.

Prefabrication can play a central role in this evolution. Used as a catch-all term for assembling all or part of a building in a factory, and then transporting it to a construction site where the building is to be located, prefabrication has not always had the best of reputations. However, when employed effectively, prefabrication has the potential to reduce the frequency of design changes, increase productivity and improve final product quality which can help significantly improve the environmental impact of the construction industry.

In this "Ambienta Sustainability Lens" newsletter, we consider the evolution of the construction industry, current industry practices and how prefabricated construction methods, materials and approaches will bring this slow-moving giant of the global economy into the digital era.



The construction industry: a slow moving giant

For centuries, innovation in construction has followed a path of better tools leading to access to stronger or cheaper materials. In the Bronze Age, the availability of metals to construct effective tools alongside a larger workforce, often consisting of slaves, has enabled civilizations to build a variety of structures from small houses like the Knap of Howar, the oldest known stone house in the world, to landmarks such as the Egyptian pyramids.

Major Époques have been marked by their innovations in construction from the introduction of iron tools to cut stone, to the Romans' usage of concrete through to the mass production of steel which enabled the first Industrial Revolution. Key developments such as the introduction of cranes and lifts, the progressive use of concrete and the deployment of structural steel have enabled construction never previously imagined - from the first so called "Skyscraper",

the 10-story Home Insurance Building in 1884 in Chicago, to the astonishing Burj Khalifa with a total height of 830 meters.

For many, the skyscraper represents the pinnacle in human construction. Skyscrapers simultaneously emphasize our capabilities and embody urbanization that grew from less than 10% in 1800 to more than 55% today (4.1 billion people living in cities). Yet, from the stone hut to the skyscraper, the commissioning of buildings have a single common goal: a structure which can survive in the long-term and provide comfortable shelter to people.

As humans we have become more aware of our impact on the planet. The construction industry needs to be challenged to ensure it does more: it must play its part to promote an environmentally sustainable future for all of us.



Knap of Howar, the oldest known stone house in Orkney, Scotland; 3700BC



The construction of Burj Khalifa, 2007, Dubai

Construction: environmental and productivity issues

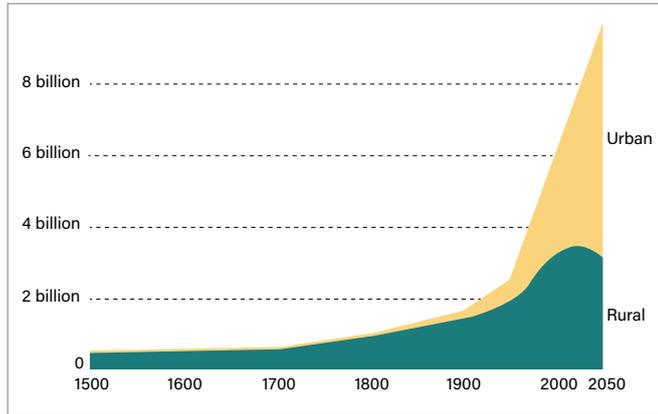
Today the construction industry represents around 13% of global GDP and accounts for 7% of the global workforce. It plays an important role in the value creation of other industries, enabling them to innovate and thrive, and it profoundly affects the quality of people's lives. The construction industry is impacted by many different trends: an ageing population, skills shortage, regulatory changes, growing project complexity, climate change, and urbanization.

Here, we will explore three key factors from the point of view of a sustainability focused investor: 1) urbanization 2) skills shortage 3) climate change.

1) Urbanization is set to accelerate - the 4.1 billion people currently living in urban areas will grow to more than 7 billion in the next three decades. A tremendous amount of buildings, infrastructure and services will be needed to support these people's lives.

2) The lack of the right skills is increasingly a systemic issue for the construction industry, particularly in developed economies: an ageing population and a shortage of skills are exacerbating longstanding issues with productivity. Since the 1990s, construction has struggled to deliver significant productivity gains, especially when compared to other areas of the global economy. In two decades from 1995, the value added per hour grew just short of 20% versus almost 70% for the general economy. Despite amazing buildings being built all over the world with daring designs and shapes, new technologies and practices in construction are hard to spread through the sector as a whole. The workforce is generally untrained since there is no formal schooling to become a builder. They are often low paid immigrants, which get experience (not necessarily training) on the job. Craftsman techniques are therefore overlooked and general construction does not benefit widely from productivity improvement. An increasingly older workforce makes adoption of innovation and productivity gains even more difficult to achieve. In 2015 43% of the workforce in the US was 45 or older compared to just 27% in 1985. In a few years' time, the majority of the workforce will be in their 50s. This will create a further shortage of skilled workers in a sector with existing productivity challenges, posing a clear issue for both the effective delivery and quality control of buildings.

3) Climate change is an increasing threat to the built environment as a whole. Economic damage and loss of life from climate related events has



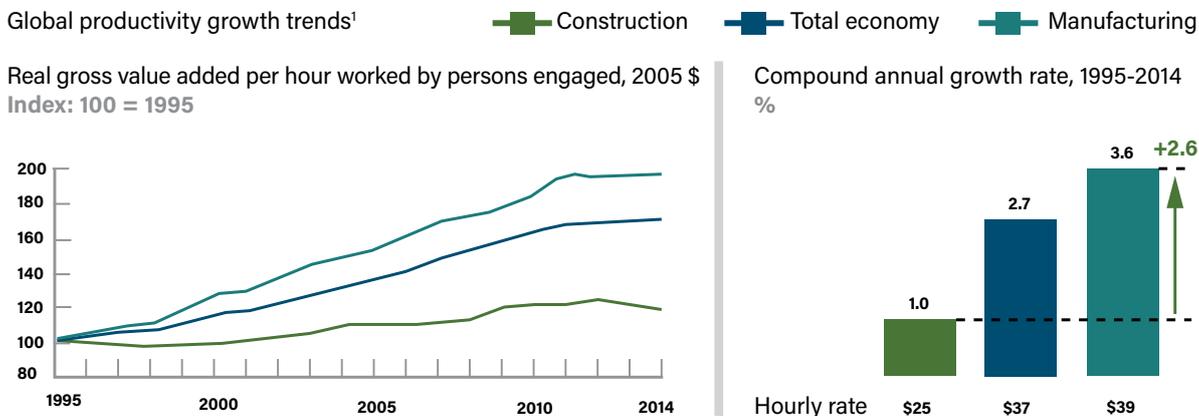
Urbanization rate: 7 billion people will live in cities by 2050, UN

doubled in the last few years. In low-middle income the negative effects of climate change costs \$18 billion a year through damage to power and transport infrastructure. This triggers wider disruptions for firms and households costing \$390 billion a year. Climate related insured losses tripled from the '80s, and the bankruptcy filed by PG&E, the largest utility in California, in early 2019 due to financial liabilities arising from wildfires, is just one recent powerful example. Unfortunately, this situation is set to get worse. Physical asset and infrastructure will be severely exposed to this risk and will need to endure it in the coming decades to protect people and goods. In coastal areas facing rising sea levels, the risk and impact will be even higher.

The challenges faced by the industry will have to endure further long lasting strains from climate

Construction lags in productivity globally

Global productivity growth trends¹

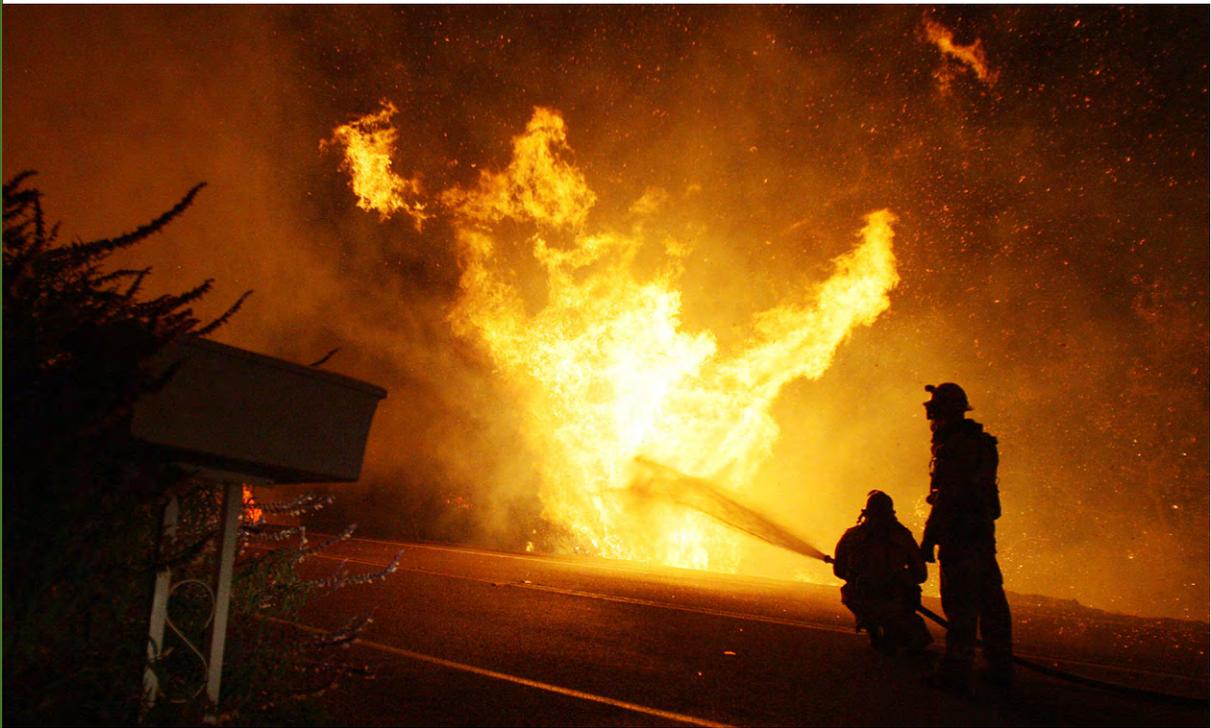


¹ Based on a sample of 41 countries that generate 96% of global GDP.

Source: OECD, WIOD, GGcd10, World Bank; BEA, BLS, National Statistical Agency of Turkey, Malaysia and Singapore, Rosstat, McKinsey Global Institute Analysis

Productivity in the construction industry has always been low and laggard with respect to other segments





PG&E bankruptcy resulted from wildfires after a prolonged period of drought and heat , 2019, California

change. The risk from the disruption caused by climate change related events will need to be increasingly priced in for any real estate property and building design and construction techniques will need to evolve accordingly.

The bigger issue perhaps is that the construction sector is not only likely to be hardily hit by climate change, but also bears significant responsibility in adversely contributing to its problem.

The construction sector leaves a substantial environmental footprint from its design and construction phase, throughout its lifetime until its end-of-life. Depending on the stage of life, impact unfolds differently. During the construction phase the main issues are the usage of natural resources and related greenhouse gases emissions from the production of materials. During lifetime and building management, energy consumption is most relevant, also in terms of its related emissions. At its end-of-life the disposal of the natural resources resulting from destruction is critical.

The construction of buildings requires a huge amount of natural resources: the industry consumes twice as many materials compared to the entire fossil fuels sector. It is also not widely known that this industry makes a significant contribution to global greenhouse emissions. The production of steel and cement alone accounts for about 13% of global greenhouse gases emissions. This is more than the annual emissions of the

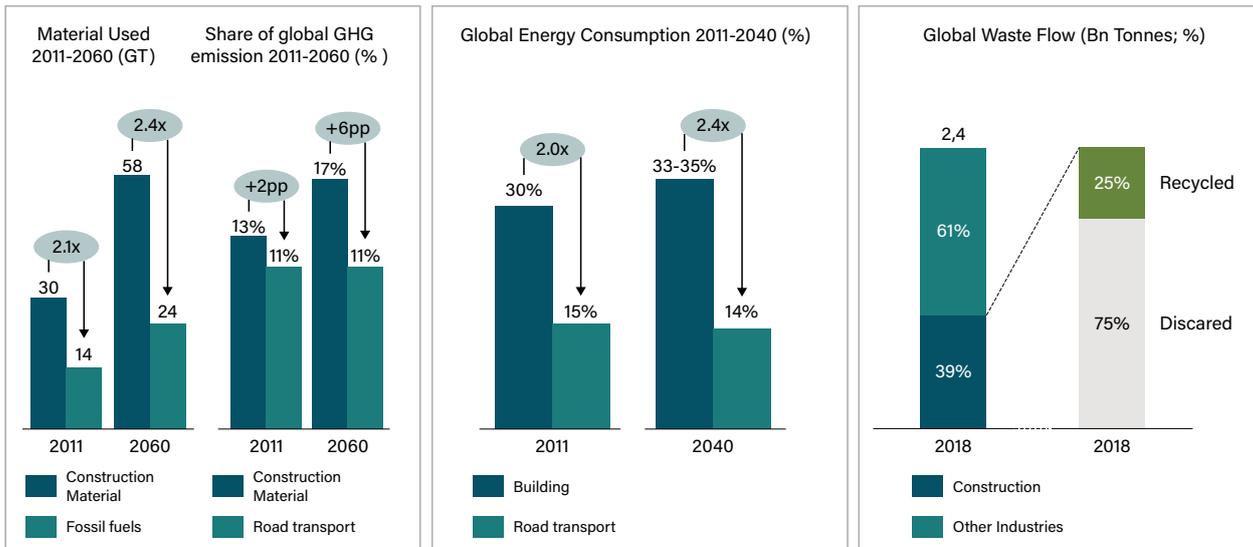
global road transport sector, one of the industries which is most often held responsible. Furthermore, unlike road transport which is transitioning to more efficient and cleaner solutions, this trend in construction is not set to slow down: because of population growth and urbanization a growing amount of materials will be required and emissions from construction materials production will increase from 13% to 17% of global emissions. Techniques such as high temperature processes used to produce cement and steel have limited viable technological alternatives today to reduce their footprint. There are ongoing efforts to make these materials "greener" but they are still far from tackling this issue at scale.

Building management accounts for about 30% of global energy consumption, which makes it the largest single user of energy. This energy obviously causes large greenhouse gases emissions which, combined with raw materials' emissions, makes construction the largest emitter of about 40% of total annual emissions. It is three times more impactful than road transport and unfortunately, its footprint is still growing. Population growth, urbanization and rising living standards are trends that energy efficiency gains have not yet widely overcome. For instance, the increased adoption of air conditioning, which is growing quickly in less penetrated developing markets, is going to offset many gains in the coming decades. In USA, as well, air conditioning energy demand continue to

Construction

Building Management

End of life



Overview of construction industry environmental footprint through its life cycle.

raise even if it already requires today almost as much electricity as the entire African continent.

The end-of-life phase of a building is also important to consider. Buildings and construction have always been designed to last, but construction produces almost 40% of total global waste, of which 75% is fully landfilled. It is made of low value inert materials often mixed with other materials which makes the waste stream contaminated and hard to recycle in an economically viable way.

In a nutshell, the construction sector is one of most damaging sectors for the environment and it is often overlooked. It is a large contributor to climate change and it is set to get worse in the next decade. This is most concerning because the industry lacks large scale solutions to its environmental issues, such as construction materials emissions in production. For these reasons, the industry will need to look for new solutions to make it more sustainable, productive and resilient to climate change.

Investing in the transformation: is prefabrication the answer?

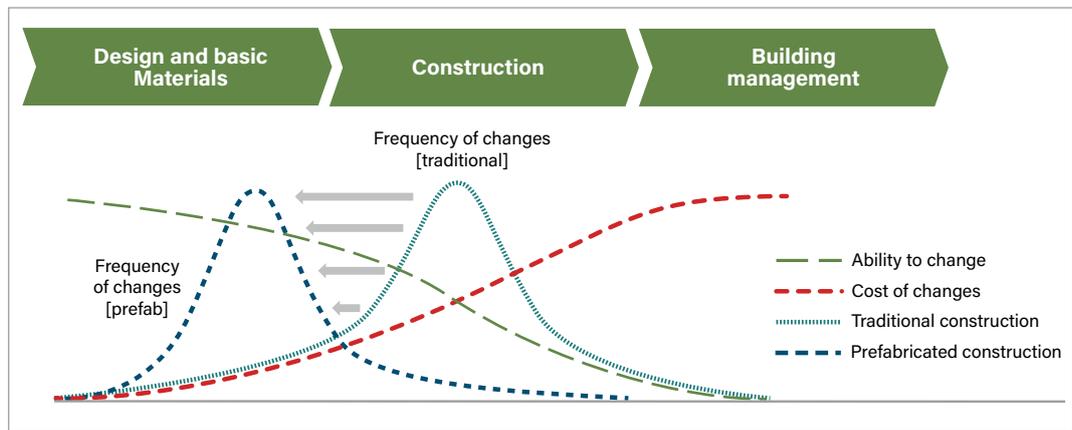
Reducing the environmental impact of the construction value chain and the built environment has to become a priority.

Over the years regulators and associations have tried to support this transition through policies, standards (i.e. the LEED rating system for green buildings) and certifications, but as stated before, they obtained only incremental gains and not any material impact. On the other hand, prefabrication can make a real impact. It should be considered not only as a construction technique but also as an approach to transforming a building's life cycle because it allows to carefully manage all issues in an integrated way from choice of materials, design, construction and end-of-life phase.

Prefabrication tightens the links throughout the life cycle steps. In parallel, prefabrication addresses key flaws in construction practices which negatively impact productivity, economics and the environment: 1) frequent design changes 2) lack of productivity 3) poor final product quality.

1) Frequent design changes: in contrast to traditional construction techniques, prefabrication drives, through modern software tools and detailed advance planning, a reduction in the frequency of design changes, thus speeding up work and reducing the usage of materials.

2) Lack of productivity: prefabrication drives effectiveness through the whole cycle from



materials usage, through to labour productivity and reworks. Off-site prefabrication of components into dedicated factories brings industrial productivity potential into an industry which had limited if any productivity upside.

3) Poor final product quality: prefabrication enables greater quality control throughout the production and installation phase, driving a replicable and high-quality finished product, whereas traditional techniques heavily rely on the individual craftsmanship to avoid such volatile results.

The impact of these gains is reflected in time, cost and environmental benefits. Prefabricated constructions use less material, are built faster and have fewer defects. This is embedded in the replicability and quality control of industrial approach and factory automation. The high quality of the finished construction even surprised us,

since there is a certain a pre-existing bias that pre-fabricated houses are low cost and low quality products. Because prefabrication requires far less need for rework or on-site decision making to accommodate last minute changes or unexpected issues, prefabricated construction produces far less waste (up to 90%) and reduces energy consumption of tools and equipment. Energy efficiency leadership is even more remarkable in the lifetime of the building, which can be up to 55% more energy efficient due to its high quality design and finishing.

As a sustainability focused investor, we consider these features as sources of a sustainable long-term competitive advantage when compared to more traditional techniques. Despite these factors extending the adoption of prefabrication in recent years, its reach is still far too small.

Impact of Prefabrication approach		
Time		% Benefit
Reduction in construction time		35-55%
Fewer total number of man-hours worked		40%
Cost		% Benefit
Reduction in construction cost		15-30%
Growth in performance of materials and labour		50%
Reduction in defects upon completion		60%
Environmental		% Benefit
Construction	Reduction in CO ₂ emissions	35%
	Less construction waste	40-90%
	Reduction in energy consumption	50%
	More water efficient construction	30-50%
LCA ²	Reduction in use of raw material	40-50%
	More energy efficient building performance	50-55%

Within residential construction, prefabrication is mostly used for single family homes. It developed in cold regions where on-site fabrication had to be reduced to the minimum. Therefore, the prefabricated single house market represents 42% share in Scandinavia, about 20% in Germany and only few percentage points in Italy. Nonetheless, in a low growth residential construction market in Europe, prefabrication represents a fast growing high single digit niche within residential properties.

The rate of adoption of pre-fabrication is now likely to expand in the next few years beyond the single house market. For a long time, several barriers restricted it to predominately low rise buildings given its link to a value chain most accustomed to using concrete and its associated techniques. On the other hand, wood, the preferred material for prefabrication, and its technologies had both mechanical limits and less advantages when applied to taller buildings. Recently, the increased availability of cranes, confidence in construction techniques, integrated design software such as Building Information Modelling and innovations in wood preparation have started to shift the case.

Cross laminated timber, a wood panel made of cross oriented boards, demonstrated improved mechanical properties that make it suitable for high rise buildings in excess of six floors.

These technological progresses arrive at a time when wood's renewable nature can prove as an additional advantage. Wood absorbs roughly 1 Ton of carbon dioxide per kilogram of weight, while standard Portland cement emits about 1. These 2 tons of net gain in terms of carbon footprint increase further since wood requires less weight in specific applications where it is being used to replace cement. This will ensure wood becomes a preferable material to use to improve the overall sustainability characteristics of buildings. Wood is not suitable for all applications, but it is now considered more widely and it has started a new phase of development. The future challenge for construction will be to take the best of prefabrication, wood and concrete (which is going to be greener as well, but that's another story) characteristics and unlock unexplored potential to build more sustainable, resilient and innovative buildings.

Historically construction has proven to be a complicated sector where to invest and that offers fewer investment opportunities than other sectors as food or healthcare. Nonetheless, the size of the sector and its enormous environmental issues, requires the attention of a sustainability focused investor for prefabrication and other trends which



World tallest prefabricated wooden building, 2019, Brumunddal, Oslo

can create new opportunities. At the time of finalizing this release of Ambienta Lens, The Times of London has reported that France is considering mandating that all new public buildings are made of at least 50% wood. Whether compulsory or not, wood and prefabrication represent a perfect match. Within ongoing efforts to reduce the environmental footprint of the construction value chain we see several interesting opportunities:

▪ **Prefabricated house developers:** the single house prefabricated market is set to grow across the world. Depending on specific markets and segments, from highly customized luxury houses to large scale development programmes encompassing more standardised living solutions, its key success factors are slightly different but always create opportunities for well managed businesses in the space.

▪ **Materials, solutions and modules for multi-storey buildings:** prefabricated multi-storey buildings for residential buildings will rely on specific construction techniques or modules. Pre-fabricated kitchen or bathrooms or ducted air conditioning are growing in importance to improve the productivity of projects alongside dedicated construction materials, specifically wood based.





Toronto's \$1.3bn waterfront renovation project will extensively use wood and prefabrication

- **Supporting software solutions:** software is now being extensively used by the construction industry connecting pure design to procurement and project management. Building Information Modelling software platforms have been around for a long time but now the market seems more willing to embrace them. The recent acquisition by Schneider Electric of Rib-Software for \$1.4bn to enhance its leadership in smart and carbon-free buildings highlights the interest in this area.
- **Machines and tool for wood working:** wood will take a larger share of construction materials. Woodworking machines from forestry to factory will grow in number and complexity to support the value chain transformation and should represent a reliable area where to look for growth.

Many other interesting niches exist which are driven by prefabrication and are suitable for different types of investors, even if construction is not traditionally the easiest of sectors to invest in. Even venture capital, a segment of the asset management industry not particularly attracted by the construction sector, has started to look

into it. Kattera represents one of the clearest example of this. Kattera is a vertically integrated prefabrication construction company aiming to disrupt the slow moving construction industry through its usage of prefabrication and modern technologies. Over four years it raised more than \$1 billion in capital and only time will tell if they will succeed. More generally, disruption and change across the wider value chain will always create interesting investment opportunities that we should actively seek out.

At this point in time, we expect the construction industry to enter a new phase of transformation and change, and one of the main drivers will be sustainability consideration. The whole industry can enter a new, flourishing era through the adoption of resource-efficient construction techniques, new software solutions and carefully selected materials. Prefabrication and wood, which would merit a dedicated Ambianta Lens by itself, might have a critical role in enabling a smooth transition into a low carbon construction sector.




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