CONSTRUCTION,
CITIES & TERRITORIES

HOW VIRTUAL TWINS DRIVE MORE SUSTAINABLE AND HIGH-PERFORMANCE BUILDINGS

DASSAULT SYSTEMES

SUSTAINABLE TRANSFORMATION OF THE CONSTRUCTION INDUSTRY

Climate change is the defining challenge of our time that requires systemic change and global cooperation. The current generation needs to prepare for fast population growth to ensure a sustainable, energy-efficient world with a reduced global carbon footprint. Paradoxically, **sustainability is also one of the prime business drivers** as the industry strives to improve performance and efficiency while complying with restrictive international climate regulations and seizing new growth opportunities.

Sustainability is now an irreversible industrial trend that's accelerating fast, with global regulation pushing for a more circular economy in line with market expectations. Recent international commitments highlight how the sustainability agenda remains top of mind, impacting most industries:

- China announces that it will be carbon neutral by 2060;
- The EU sets a law to become climate-neutral by 2050 and achieve a collective, net greenhouse gas emissions reduction target of at least 50 percent by 2030 compared to 1990;
- The U.S. rejoins the Paris Climate Agreement under President Biden and committed to halve CO_2 emissions by 2030, in comparison with 2005 levels at the April 2021 Virtual Leaders Climate Summit;
- The transatlantic agenda that is under discussion starts with a joint commitment to achieve a green technology alliance, a global regulatory framework for sustainable finance and net-zero emissions by 2050 with measures to avoid carbon leakage;
- New Zealand becomes the first country to require the financial sector to report on climate risks.

With less than 10 years for countries to deliver on UN Sustainable Development Goals (SDGs), all stakeholders are conscious that it's time for radical and urgent action. The construction industry plays a significant role in a new era of technological breakthroughs, digitization and virtualization. What was technologically inconceivable even a few years ago is now feasible.

The construction industry is central to the world's sustainability ambitions because it:

Accounts for 13 percent of GDP, close to US$8 trillion, 7 percent of the world's working population and 25 to 30 percent of all waste generated in the EU. The industry impacts the world's sustainability agenda as it rethinks sustainability practices: More energy performance optimization, decarbonization, new bio-sourced materials and waste management practices;

Is a key source of demand for materials and resources, creating significant environmental and energy resource strain and, consequently, a need for more efficient use of resources;

Increases the spatial concentration of people and businesses, driving demand and supply challenges for urban systems such as water, energy and waste networks. This accelerates the need for affordable housing and safe infrastructure. But it also has potential upsides, making at-scale deployment of sustainable solutions much easier for new builds and retrofitting existing buildings;

Lags behind other industries in digitization and productivity growth for the past two decades because each project has bespoke requirements combined with standard components that limit repeatability and standardization. By rethinking traditional models and adopting a systems approach, embracing new materials and leveraging cloud and virtual twin technology, companies can achieve rapid innovations and offset the persistent cost and margin pressure;

Experiences major disruptions due to the Covid-19 pandemic from digitization, shortages in raw materials and substantial price increases in steel, timber and corrugated cardboard for packaging. For example, the wholesale price of a hot-rolled coil is 40 percent higher in 2021 than in July 2020. All of this adds to the margin pressure on building projects.

At the same time, public policymakers across the world are gearing up to renew economies. Extensive fiscal tools and green infrastructure spending in Europe and the U.S. provide opportunities for the construction industry to integrate shifts in market dynamics and drive competitiveness, energy efficiency and performance while adapting to new operating restrictions.

In the new norm today, the traditional linear take-make-dispose construction model is no longer relevant. The industry is preparing for a new model of how global buildings are planned, designed, built, renovated, operated, maintained, dismantled and disposed of. The new model integrates the circular economy, namely waste and pollution, keeping products and materials in use and regenerating natural systems. It can then extract greater value and efficiency and transform the industry's multiscale, fragmented ecosystems.

The pressure is on the entire ecosystem to move fast:

Across the world, governments and local authorities are standardizing strict regulations, financial penalties and big incentives to reduce the carbon footprint, save energy and enhance safety. For example, lifecycle assessment studies will soon be mandatory for building permits, encouraging design for maintenance, deconstruction and end-to-end business modeling. This implies shifting away from concrete and steel that account for 10 percent of the planet's gas emissions to wood and other more environmentally friendly, bio-sourced and recycled materials.

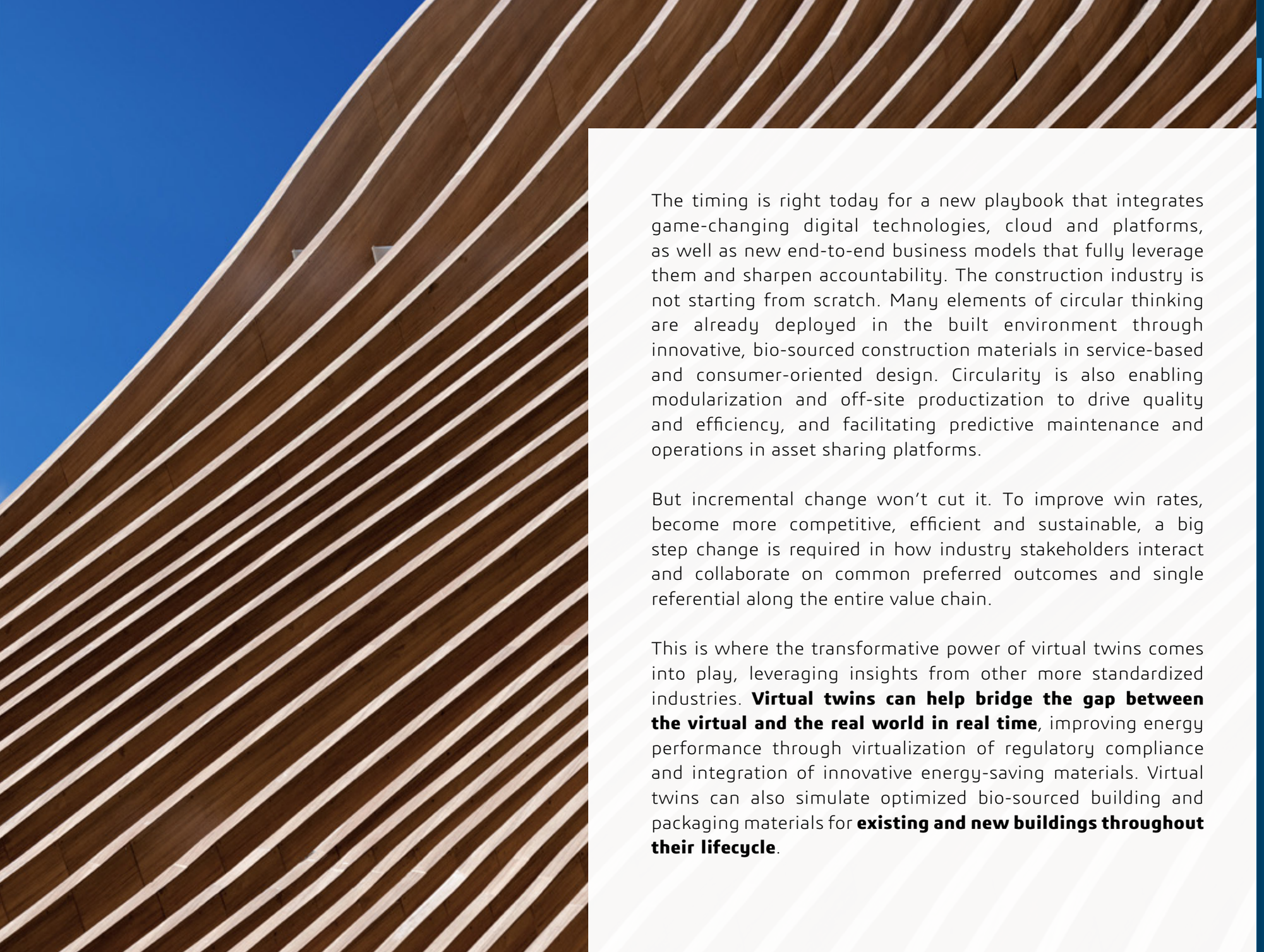
Sustainability is higher on the agenda of financial investors focused on risk mitigation and improving the brand perception of buildings.

People worldwide want better, more inclusive outcomes and experiences where they live, work and play. This affects urban planning and construction.

Evolving requirements from increasingly sophisticated customers who demand more safety, better user experience, more sustainability are intensifying pressure to provide greater efficiency and flexibility while reducing total cost of ownership (TCO).

Large-scale inefficiencies across the construction value chain continue to negatively impact margins, energy efficiency and CO_2 emissions — 35 percent of building projects are over the budget, resulting in delays and failed objectives. This means that simply integrating lean processes will not be enough — companies need a more disruptive approach that rethinks the ecosystem.

Project complexity is increasing, integrating these evolving consumer demands as well as pressure for more affordable housing, tighter public budgets, shortage of skilled labor and stringent climate regulation.



The timing is right today for a new playbook that integrates game-changing digital technologies, cloud and platforms, as well as new end-to-end business models that fully leverage them and sharpen accountability. The construction industry is not starting from scratch. Many elements of circular thinking are already deployed in the built environment through innovative, bio-sourced construction materials in service-based and consumer-oriented design. Circularity is also enabling modularization and off-site productization to drive quality and efficiency, and facilitating predictive maintenance and operations in asset sharing platforms.

But incremental change won't cut it. To improve win rates, become more competitive, efficient and sustainable, a big step change is required in how industry stakeholders interact and collaborate on common preferred outcomes and single referential along the entire value chain.

This is where the transformative power of virtual twins comes into play, leveraging insights from other more standardized industries. **Virtual twins can help bridge the gap between the virtual and the real world in real time**, improving energy performance through virtualization of regulatory compliance and integration of innovative energy-saving materials. Virtual twins can also simulate optimized bio-sourced building and packaging materials for **existing and new buildings throughout their lifecycle**.

So far, the virtual twin opportunity is largely untapped primarily due to the fragmented and complex nature of the industry — with only 10 percent adoption globally. Its full potential to improve building lifecycle management has yet to be unleashed. In 2020, the global virtual twin market was worth an estimated US$5.4 billion and projected to grow at 36 percent CAGR over the next five years. Only five percent of companies and less than one percent of assets have started implementing digital twins.

First movers and bold decision-makers will gain market share and competitiveness for sustainable business success.

Dassault Systèmes, the **3D**EXPERIENCE® Company, provides virtual universes to imagine sustainable businesses and helps clients push the boundaries of innovation, learning and production. Virtual twins accelerate the sustainable transformation of the construction industry towards more circular, productive and competitive project engagements.

ENTERING A NEW ERA OF VIRTUAL TWINS

The era of virtual twins is here. Designed to help the industry cope with increased operational and regulatory challenges, virtual twins favor a systemic, circular and modular approach that is **lifecycle-focused and asset-driven**. In this era, construction virtualization is a reality where different scenarios can be simulated to enhance the smallest field execution details.

It doesn't stop there. Virtual twins **also address major skill shortages and, most importantly simplifies and streamlines collaboration** between teams on a single digital **3D**EXPERIENCE platform. With a prime focus on waste reduction and energy efficiency, virtual twins ensure **compliance to extensive sustainability regulation, more continuity throughout each construction phase and scaled-up sustainable innovation at every step**.

In this white paper, we will explore and provide examples of how virtual twins contribute to resetting two of the key phases of building life cycle management to drive greater value and sustainability and prepare the industry for success in the new norm:

1. The new governance of building planning with more cohesive accountability
2. Accelerate the transformation of design, manufacturing and construction, ensuring coherence and aligning incentives across the value chain

The critical role of the less visible building operations, maintenance and waste management and how economically significant it is, impacting the use of natural resources from energy to water to security, will be covered in a subsequent paper.

HOW VIRTUAL TWINS CAN HELP RESHAPE PLANNING

Commercial and residential buildings account for 50 percent of global emissions, 40 percent of global energy demand, 60 percent of global electricity use, 25 percent of global water usage and a third of global greenhouse gas (GHG) emissions. This highlights how important it is for the construction industry to become more efficient and circular, mirroring the natural world. There is no waste, outputs from one part of the ecosystem are simply inputs into another. With technological breakthroughs such as virtual twins, the transition is gathering pace.

If we look back, the scientific revolution made it possible to reproduce drawings as blueprints; the industrial revolution introduced the assembly line for mass-producing pre-fabricated materials and the digital revolution provided 3D CAD, cloud-based collaboration, and more.

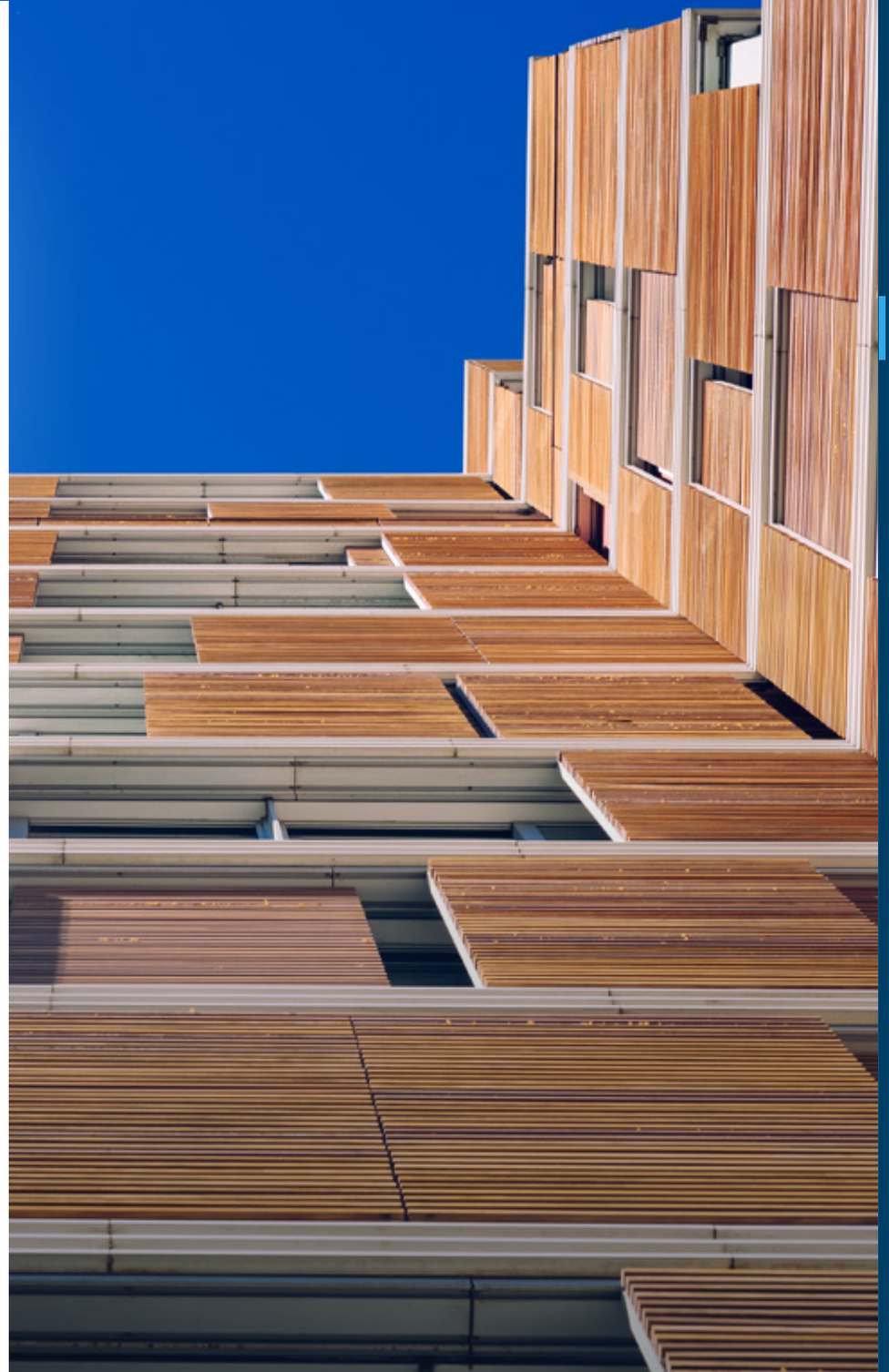
Critical to the future is the widespread sourcing, adoption and traceability of less carbon and energy-intensive materials. **Lifecycle assessment and project alignment with the Paris Climate Agreement, adopting sustainable materials and low carbon transition will soon be essential** to get a permit and help anticipate long-term operations and maintenance performance.

For example, emerging lighter-weight, recyclable materials, such as light-gauge steel frames and cross-laminated timber, can enable simpler factory production of modules. They will also change the logistics equation and allow easier longer-haul transport of materials and greater centralization. It then remains to ensure that the packaging of these materials is equally sustainable.

Replacing concrete or steel with massive timber is already gaining traction. Countries such as Norway are leading the way with the world's tallest pre-fabricated timber building, Mjøstårnet, in eastern Norway. The new North Pier at Oslo Airport Gardermoen is another example of the innovative use of materials. The roof is made of wood, and the rest of the building primarily of recycled materials, climate-friendly insulation and concrete in which a share of the cement was replaced with reused waste. For all existing and new builds, virtual twins can simulate most sustainable and energy-efficient materials throughout the lifecycle.

Consumer demands are evolving, resulting in a clear shift to serving people and creating an experience rather than simply creating buildings:

- There is increasing pressure for affordable, sustainable housing.
- Multiple lockdowns are accelerating already visible consumer trends. People are reconsidering how they want to work and live, not just spaces but also their services and experience.
- Citizens will no longer tolerate traffic, noise, dust and light pollution, working nights and long building cycles that affect operations.



To leverage these evolving trends calls for a more holistic approach at the outset. The virtual twin allows a complete review of how your project is organized and what can be optimized by:

Visualizing, simulating and integrating innovative processes and scenarios across all stages, including end-of-life demolition before actual operations. **The virtual twin accelerates the transition from a paper-heavy industry to a digital design and process industry**, where digital prototyping becomes possible. This redefines, for example, how they communicate with stakeholders, creating the emotional connection consumers need as they visualize their future.

Fast-tracking the shift towards more data-driven decision-making. With the power of the **3D**EXPERIENCE platform, data from multiple stakeholders can be accessed, aggregated and analyzed to ensure everyone has access to the same data and accelerate the decision-making pace, lower the likelihood of rework on design and boost overall productivity. For example, they can add additional operating parameters like schedule and cost—early in the project rather than finishing design while construction is already underway. This will materially change risks and decision-making sequence in construction projects, challenging the more traditional EPC models.

Paving the way for a systemic, less siloed approach for all stakeholders to collaborate around a common referential to simulate the evolution of buildings. Companies can build virtually before they build physically, thereby reducing risk, waste, and enhancing safety and sustainability.

OPTIMIZING DESIGN, MANUFACTURING AND CONSTRUCTION

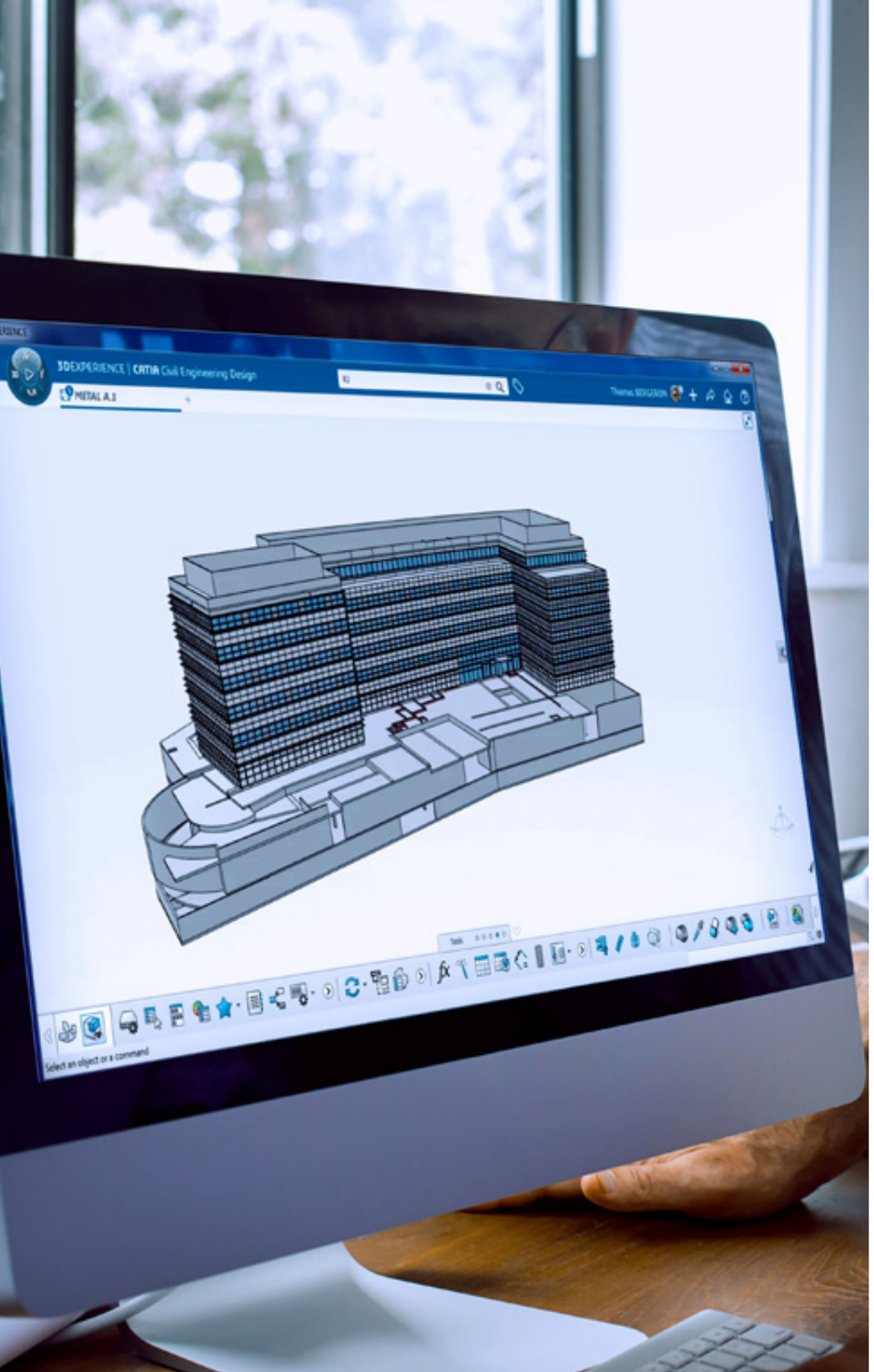
Digitalized and integrated aerospace and automotive industries are inspiring a reset in the construction industry, **with a new focus on circular design and bio-material sourcing, capital efficiency, resilience and risk management**. While these industries differ in their approach, today's project-based construction process is set to shift radically to a **product-based approach**, more standardized, efficient and integrated. This will improve customer satisfaction and offset the costs of conforming to evolving climate regulations.

The virtual twin can **facilitate circular design relating to product reuse, recycling and cascading**. Key areas to make circular design economically viable include material selection and procurement, standardized components and design for easy end-of-life sorting, such as Cradle to Cradle certified building materials.

Technological breakthroughs pave the way for the construction industry's renaissance. So far, deep implementation of industrialization practices has been slow because of project variability, managed by a heterogeneous ecosystem that includes planners, designers, material suppliers and builders. **Modularity integrates high variability into offers without standardizing the living experience**.

We see a real shift toward off-site productization. Though modularization, prefabrication and off-site manufacturing in safe and controlled environments are not new, the combination of lighter-weight materials that simplify traceability, material transportation, digital planning and automated production systems could foster new levels of quality and efficiency in products and operations. Instead of building uniquely designed structures on-site, companies will manufacture components and whole buildings off-site as transportable pieces. This approach improves quality as much as the work is completed in factory conditions, resulting in faster and efficient approval processes.

According to a 2018 McKinsey survey 40 percent of home builders in the UK and 45 percent in Scandinavia invested in manufacturing facilities or intended to do so soon.



Energy optimization is another key objective today. By integrating this early into the design process using virtual twins, **energy consumption in buildings can be reduced by 30 to 80 percent**, providing a real market advantage. And some of these energy solutions can be retrofitted to existing buildings which is key as many older buildings, for example, were not designed for energy efficiency.

We are also seeing the impact of technology, for example, at Leko Labs that increases liveable space up to 10 percent with the same footprint as a conventional property and substantially cuts build times, allowing developers to provide more accommodation and see a faster return on their investments.

A big barrier to more efficient sustainable solutions in the construction industry has been siloed working and lack of coherence and alignment along the value chain from various teams. **The virtual twin tackles siloed working, enabling better collaboration, better control of the value chain, contractual coherence and data-driven decision making**.

SPOTLIGHT:

BOUYGUES CONSTRUCTION

Highlights from a recent conversation about the future of the construction industry with Fabrice Bonnifet, Director of Sustainable Development & QSE at Bouygues Construction:

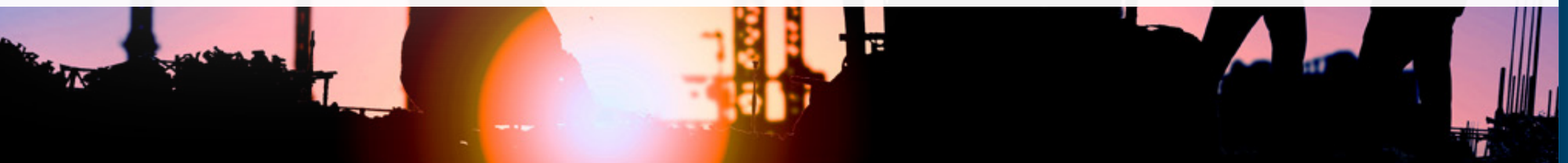
One of the leading global construction businesses involved in major projects across the world, Bouygues Construction has an ambitious climate strategy underway to reduce its carbon footprint by up to 50 percent this decade. How? Through a combination of innovations, including a 40 percent reduction in the carbon intensity of concrete, 30 percent of all European buildings in sustainable wood, and 90 percent green vehicles by 2030.

Bouygues Construction is developing low carbon concrete alternatives that divide their carbon footprint by two or three and also rapidly increasing wood construction for social housing to 25 percent in four years because it stores rather than emits carbon. They are also cutting waste by reusing building components after their first life, improving quality, and making construction processes safer and more efficient.

Beyond carbon taxes, other regulations and agreements are driving environmentally positive changes in building management, including intensifying and diversifying usage through sharing office space and resources such as space, energy, water and car parking with wider communities. This leads to greater asset usage, fewer buildings being required, and enhanced social, environmental and economic benefits.

With new taxes, regulations and penalties, construction companies will only be able to generate significant profit if they reduce the use of natural resources and lower their carbon emissions as well as those of the buildings and infrastructure that they create. It calls for reinventing many jobs with increased use of AI, robots and virtual twins.

Bouygues Construction and Dassault Systèmes have recently renewed their partnership to reinvent.



SPOTLIGHT:

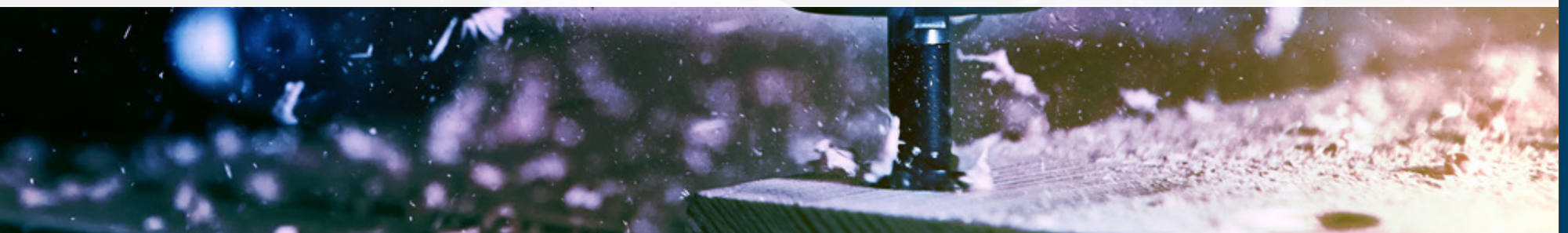
LEKO LABS

Luxembourg-based Leko Labs creates cross-machined wooden modules that can be assembled and then disassembled, allowing houses to be expanded, reconfigured or rebuilt into something else. The digital platform that coordinates and drives all of its processes ensures harmony from start to finish. Here's an excerpt from a Compass magazine interview with François Cordiner, CEO of Leko Labs.

Can you briefly describe Leko Labs and its work?
François Cordier: We started five years ago to revolutionize the design, engineering, manufacturing and construction of sustainable housing by deploying technology that addresses the cost, time, risk and inefficiencies of building with traditional materials and methods. By manufacturing glue-free, cross-machined and ecologically treated timber components from renewable sources, our walls are lighter, stronger and 40 percent thinner. This increases the liveable space by up to 10 percent over conventional building methods.

How does the Leko Labs system reinvent the construction process?
François Cordier: A conventional house takes around 24 months to build. Currently, a Leko Labs house takes nine months to complete. With further advances in robotized component manufacture and assembly, this will soon be reduced to six months. And, with the introduction of modular rooms with pre-installed plumbing and electrics, we are working toward reducing the build time of a complete house to 24 hours.

What effect does this have on construction industry economics?
François Cordier: Because we can increase room spaces within the same footprint as a conventional property and substantially cut build times, developers can provide more accommodation and see a faster return on their investments. Architects may not always be required to design or coordinate projects, and subcontractors who have been more than 30 percent over budget will no longer be able to overcharge this way. Leko Labs' buildings are recyclable so, after 30 or 50 years of use, they can be disassembled and reused on an infinite loop.



What DfMA (design for manufacturing and assembly) technologies does Leko Labs deploy?

François Cordier: We are able to automatically turn any architect's plan into a Leko Labs design in 10 minutes. Using a single digital model throughout our processes increases productivity and avoids the potential mistakes and quality issues caused by misinterpretation. We deploy technology that automatically generates optimized scripts for dividing wall lattices, slats and posts as well as BOMs [bills of materials] and NC [numerical control] files. Designs that are verified for stress analysis are directly linked to robotized CNC [computerized numerical control] machines that manufacture building components. A simple on-screen "print" button initiates their manufacture.

How do you see the future for Leko Labs and the industry in general?

François Cordier: In addition to single family houses, we are developing the technology for high-rise buildings in which everything will be modularized and pre-fabricated. Building component factories will be decentralized, moving into cities to reduce transportation. Mass customization will become the norm and families will configure their home online the same way as they currently specify their car. Labor shortages in construction will continue, but digitalization and automation of the industry will help achieve commercial and environmental sustainability, enabling more cost-effective housing for generations to come.

CONCLUSION

After decades of relatively slow evolution, an at-scale shift to digitization and modularization is positively disrupting the construction ecosystem. The virtual twin has changed the game and created a new horizon for the whole construction ecosystem as it can simulate and optimize every phase of sustainable building development and operations in its minutest execution details. And yet, according to Accenture, it is still a substantially underused lever in operationalizing sustainability and the circular economy at speed and scale. The best is yet to come.

With the shift to productization and moving the bulk of construction off-site into controlled environments in factories and warehouses, the industry has the opportunity to address skill shortages, optimize procurement, traceability and costs and upscale the efficiency of energy, waste and CO_2 emissions management.

Virtual twins offer the construction ecosystem a unique opportunity to reset, reshape and improve their future by leveraging real-time planning simulation tools that drive data-driven decisions. Technology today is making it possible to simulate the impacts of recyclable materials on CO_2 emissions and energy consumption, fostering the transition from concrete to wood or other recyclable materials for existing and new buildings. By improving modular design efficiency, they can shorten processes and enhance maintenance operations, in particular by making them more predictive and reduce waste management.

Virtual twins are today's levers of sustainable competitiveness for construction companies to connect societal and regulatory demands with internal efficiency gains and growth opportunities, paving the way for a more sustainable and human-centric future.

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