Driving sustainable outcomes across the AEC industry

How architects, engineers and the construction sector can create new business opportunities through sustainability

AUTODESK

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“

...businesses that don’t take action may start to see a decreased demand for their products and services, in conjunction with a rise in CO_2 emissions costs. As such, these businesses will have lower margins, and could see up to 50 percent of their profits put at risk.”

Yvonne Ruf
Partner, Member of Supervisory Board, Roland Berger

A large part of today’s sustainability agenda centers on achieving ‘net zero’ to minimize the impacts of climate change. We reach net zero when human-caused greenhouse gas (GHG) emissions are reduced as much as possible, with those that remain being balanced out by the removal of greenhouse gas emissions from the atmosphere.

Net zero is at the top of corporate agendas, in the front of consumers’ minds and a consistent theme of legislation, regulations, and government funding around the globe. The architecture, engineering and construction (AEC) industry and its customers have a huge impact on emissions of carbon dioxide (CO_2), one of the most important GHGs. It accounts for about 50% of the total global use of raw materials and 36% of final energy use.[1] Looked at like that, few industries are feeling the pressure to reduce carbon emissions like AEC.

Governments are driving the transition to net-zero greenhouse gas emissions. More than 70 countries, including the biggest emitters—China, the United States, and the European Union bloc—have now set net zero targets, covering about 76% of global emissions.[2] They are adopting a mix of encouragement and funding—such as the European Green Deal and Singapore’s Green Plan—and, increasingly, regulation. In Europe, the EU is imposing increasingly hard-hitting legislative frameworks. In the USA, new building energy code determinations[3] aim to reduce the climate change impacts of America’s building sector, avoiding 900 million tonnes of CO_2 emissions.

In business, most large corporations now shape and cross-check their business strategies against the UN Sustainable Development Goals (SDGs), which put carbon reduction in a central role. Environmental, social and governance (ESG) policies resulting from this work are now driving investment decisions. At the COP26 climate change conference, more than 450 of the world’s biggest banks and pension funds, with total assets worth US$130 trillion, committed themselves to helping limit greenhouse gas emissions.[4]

Some remain skeptical about ESG initiatives, but according to consultants Roland Berger, “... businesses that don’t take action may start to see a decreased demand for their products and services, in conjunction with a rise in CO_2 emissions costs. As such, these businesses will have lower margins, and could see up to 50 percent of their profits put at risk.”[5]

This e-book identifies the drivers, gaps, and opportunities for AEC to achieve more sustainable outcomes, with the ultimate goal of a more resilient, sustainable and equitable built environment in the future.

Our view is that, if we look beyond the sticks of regulatory penalties and assess the carrots available to the industry, there are exciting prospects opening up for more differentiated offerings, greater delivery efficiency, and higher margins. Sustainability, we believe, is not solely a cost, but an opportunity.

Nicolas Mangon
Vice President,
AEC Industry Strategy at Autodesk

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CHAPTER 1

Going beyond net zero

Any built structure has carbon emissions associated with it, in both the building materials used—'embodied carbon'—and when the building is in daily use—'operational carbon.'

Operational carbon comes from heating, cooling, and lighting the building, and anything else that draws power. Embodied carbon is the sum total of emissions, including those in the supply chain, from extracting resources, refining them, manufacturing, and logistics. Embodied carbon can account for up to 70% of a building's lifetime carbon emissions, more than half of which can happen before it is even occupied. An office for 750 people could contribute 10,000 tonnes of embodied carbon, about the same as driving 30 million miles in a car.[6]

Over the last two decades, the industry has made great strides in understanding, managing, and addressing emissions associated with building operations. Total carbon management (TCM) is a reliable methodology to measure and minimize the sum of a building's operational and embodied carbon.

It is even possible to talk about going beyond net zero to create buildings that remove more GHGs than they produce over their lifetime. (see **Renewable energy and carbon sequestering**, below).

However, this is still a relatively new direction in AEC. Talking to research group Frost and Sullivan, Mattias Goldmann, formerly Head of Sustainability at Sweco Sweden, noted that the industry still has a long way to go on this path: "Regarding key construction materials, we don't have exact calculations of what's needed and so the easiest thing is to just add more reinforcement until everybody feels safe. That's incredible amounts of material just going to waste because we don't calculate well enough."

"Our sustainability commitments do not stop at our own business but ripple throughout our supply chain. We have a list of stringent requirements and expect our contractors in the construction field to follow them rigorously and pass them onto their partners. We don't just take their word for it; we audit it on our sites and persistently track progress on the ground."

Nils Rage
Sustainable Design and Innovation Manager at Landsec

6. www.theconversation.com/we-have-reusable-cups-bags-and-bottles-so-why-are-our-buildings-still-single-use-171345

ACTION AGENDA

Join the movement. 21% of the world's 2,000 largest public companies already have net-zero policies. That leaves 79% that do not—a proportion likely to be even higher outside of that top layer. Where does your organization fit here?

AEC's extensive impact on carbon emissions means it is going to be at the forefront of change—whether that is self-regulated or mandated by governments. The first step is to define your path to sustainability. Autodesk provides a tool to benchmark your current AEC sustainability strategy against global trailblazers. Armed with that insight you can start to audit existing policies, evaluate business model innovation based on a circular model, and set relevant KPIs.

Reducing operational carbon

Site analysis and optimization

To meet global housing demand, the AEC industry needs to build an average of 13,000 buildings every day through to 2050, particularly in China, Africa and southern parts of the globe.[7] Cities will need to build higher, denser, and faster than before to keep up with demand—but we also need to provide a high quality of living and create truly sustainable urban environments.

Architects and engineers can employ digital tools to help them make smart, sustainable choices from the earliest stages of design. Generative design and building simulation technology can provide detailed site layouts of the best possible options against a host of parameters. These solutions make it easier and faster for architects, urban planners and developers to evaluate the optimal choices around daylight, noise, views, wind, run-off and many more.

Early-stage site analysis can help mitigate the urban heat island effect. One of many concerns about urban heat islands is that the problem feeds itself, so hotter cities worsen heatwaves and vice versa. With technology, architects and developers can evaluate the thermal comfort of outdoor spaces, detect problematic areas, and simulate ideal solutions to implement more efficient and sustainable changes before major design decisions are locked in.

Many factors contribute to creating cities and spaces that people enjoy spending time in and improve their wellbeing. For instance, great cafés or lively sidewalks. “But there are also many invisible aspects involved here such as noise, wind and microclimate,”[8] explains Rob Grim, Head of Urban Planning at Mei architects and planners, Rotterdam, The Netherlands. “It’s challenging to show people the effect of sound but it’s an extremely important factor to consider when we design new neighborhoods. For example, people who live beside a train station want good public transport but also be able to sleep well at night.” Using early-stage site analysis tools helps architects and planners to visualize these factors and to talk about them.

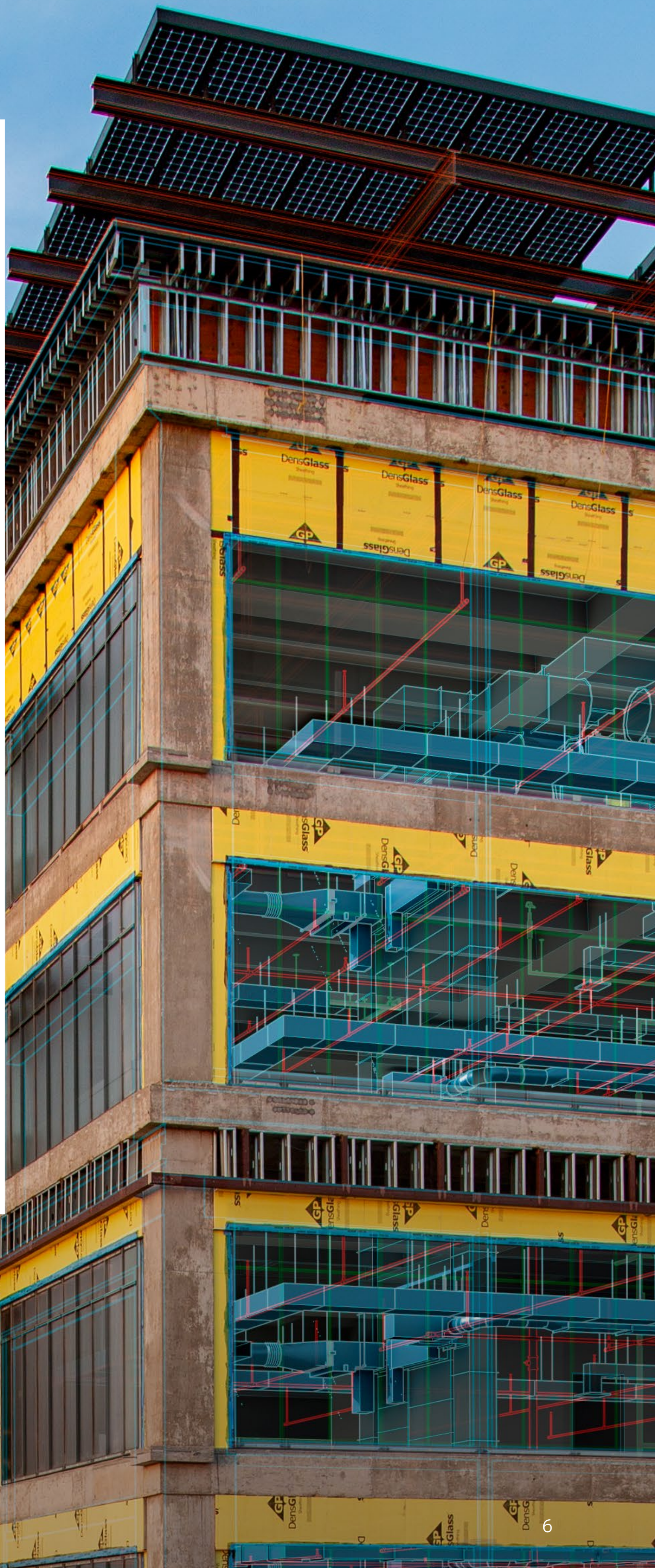
SAWA, “the healthiest building in The Netherlands” and Rotterdam’s first wooden residential high-rise - designed by Mei - makes extensive use of cross-laminated timber (CLT). Image courtesy of Mei

Early-stage energy analysis

Technology also allows building design and engineering teams to have decisive impacts on building energy consumption. Equipped with energy analysis tools, they can model the predicted energy use of building designs from the earliest stages of conceptual massing through to hand-off.

This enables them to visualize and interact with key performance indicators like predicted energy use and operating costs with real-time cause and effect feedback. For example, the window-to-wall ratio of a building's design has a significant impact on the amount of solar radiation entering the building. Using a simplified example, an insulated two-story all-concrete building in a warm climate with one small window will not allow in significant heat but it will require significant artificial lighting. Conversely, an almost all-glass two-story building in that same warm climate will heat up rapidly (much like a greenhouse) and will require significant air conditioning to maintain a comfortable indoor temperature but will not require significant lighting.

Understanding the energy impacts of increasing or decreasing this window-to-wall ratio (and a host of other parameters) throughout the design of a building equips building design teams to make informed decisions around the energy use (and cost) requirements of their designs.



The Jie Fang Nan Lu Community Culture and Sports Center, China

Working for the Jie Fang Nan Lu Community Culture and Sports Center in China, the Tianjin Architecture Design Institute team set out to design a building suitable for the area's climate, location, and function. It was aiming for a low-impact development incorporating an innovative mechanical, electrical and plumbing system to reduce energy consumption.[9]

The team started with four different designs. Based on the evaluation of lighting, wind, heat, topography, and more, it chose the ideal design along with the use of renewable energy sources such as solar and geothermal energy. All stakeholders were provided with direct updates to the model, including any analysis data from each specialty, in real time.

The design team leveraged simulations and analysis to improve the design, and field simulation and analysis of light to guide the climate response design. It also analyzed interior functions and indoor lighting to optimize the window openings, and shading and lighting uniformity determined the elevation. By calculating and optimizing the window-to-wall ratio, it was possible to reduce energy consumption. Through simulation of wind outside the building, the team designed the atrium to create its own microclimate, with air brought in from outside to support the temperature of other rooms. Solar photovoltaic power generation data enabled a detailed analysis model for a 15-degree sloping roof, along with the total monthly electricity output in a year calculated according to the local climate conditions.

Image courtesy of BIM Design Centre, Tianjin Architecture Design Institute

Renewable energy and carbon sequestering

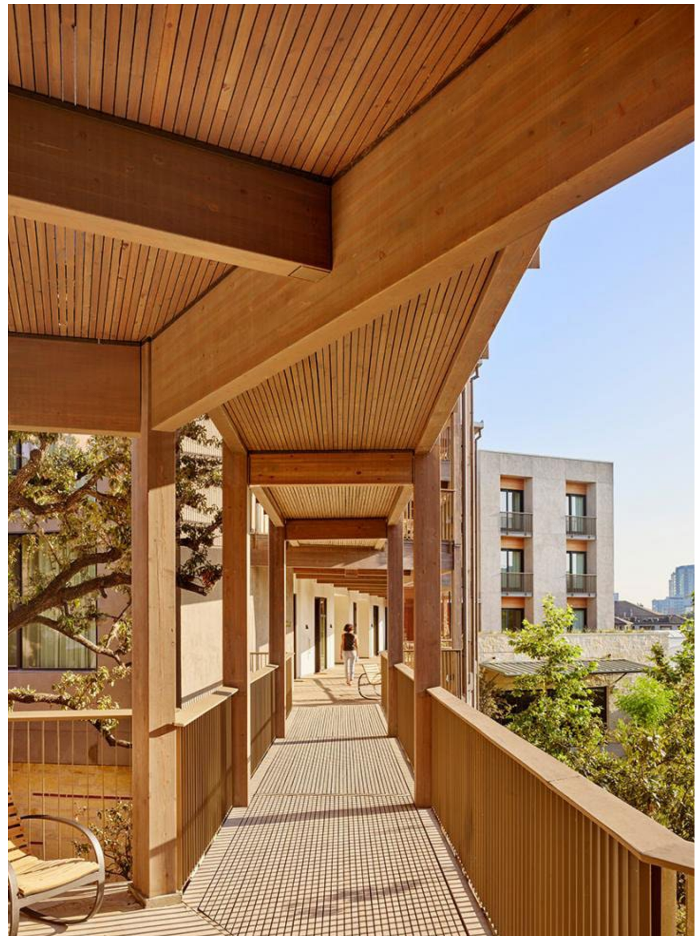
Ways to reach and exceed net zero include the ability of a building to supply its own energy over the course of a year by using renewables—often in the form of photovoltaics. With the increased affordability of photovoltaics and on-site energy storage technologies, buildings are more likely to be able to go beyond net zero.

A host of factors influence a building's photovoltaic potential, from geographical location and associated climate, roof size and slope to shading from surrounding buildings. Understanding these impacts is key to making informed design decisions.

By using predictive analytics, designers can visualize the photovoltaic potential of design options and understand the impacts of design changes (building rotation, size, height gradient, for example) on solar radiation load, as well as potential for generating energy through photovoltaic panels (see **Jie Fang Nan Lu Community Culture and Sports Center,** above).

New materials can also result in large reductions in total carbon. A cubic meter of conventional bricks has embodied CO_2 emissions of 357kg, while the same volume of concrete has around 3,507kg, about ten times as high. Hempcrete, a mix of hemp and lime, has negative embodied emissions of -108kg CO_2 per cubic meter[10] because the hemp crop absorbs—or sequesters—more CO_2 as it grows than is released while processing it into hempcrete.

As well as hempcrete, the principle of carbon sequestration and lower embodied emissions also applies to many other materials, such as the engineered wooden product CLT (cross-laminated timber). CLT has a very low carbon-embodied footprint because the material locks away the carbon absorbed during growth. Lake|Flato's Hotel Magdalena[11] in downtown Austin, Texas in the United States, for example, is the first mass-timber boutique hotel constructed in North America. Results indicate that switching to a mass timber structural system can provide an embodied carbon reduction ranging from 38% to 58%, depending on how much mass timber is replacing concrete or steel.



Hotel Magdalena. Image courtesy of Casey Dunn

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ACTION AGENDA

Many companies are already quite good at calculating operational carbon. Where the AEC sector can have a profound impact is on embodied carbon—and most companies don't look at that closely yet.

Digital tools exist that can automate some of this complex task, allowing design teams to create and test solutions that can boost successful responses to clients' briefs. As a starting point, investigate the Embodied Carbon in Construction Calculator, or EC3, which provides designers everywhere with a free, open-source tool that provides transparency about the impact of design and material procurement.

CHAPTER 2

The transition from a linear to a circular economy

> ***"Circularity is emerging as a new way of thinking. Success requires a shift in mindset of the construction industry enabled by technology. The main objective is to help our customers achieve their sustainability goals by driving circularity."***
>
> **Janicke Poulsen Garmann**
> EVP for Norway, Norconsult

Circular economics is emerging as a leading contender to take on the massive task ahead of driving greater sustainability. This approach questions the very principles of our current consumption model. These are still largely based on a linear, throwaway economy in which resources are extracted, processed, consumed and discarded. A circular model eliminates waste, circulates resources, and regenerates nature.

It is an approach that is gaining ground rapidly. With the annual Circularity Gap Report revealing that the world is currently only 9% circular,[12] governments are getting behind the transition. In Europe, the EU has launched a Circular Economy Action Plan[13] and the Dutch government has set a target to be 100% circular by 2050 with an interim 50% target by 2030. China recently released a new multi-year plan to develop the country's circular economy, with the hopes of increasing resource efficiency, spurring innovation, and meeting climate commitments.[14]

In the built environment, a truly circular approach requires robust planning and data collection to ensure all components of a building are accounted for. Digitalization of projects from the earliest stages of conceptual design through to construction and ultimately operations is the first important step the industry is taking to deliver on the promise of a circular built environment.

How circularity played an important role in the 2021 Tokyo Olympics

Showing the potential of an integrated, circular approach, the Tokyo Olympics 2021 set a goal of reusing or recycling 99% of goods procured and 65% of waste generated.[15] Reuse and design-for-disassembly principles were adopted right across the Games, including the competition venues, and only eight of the 43 were built from scratch. Materials, like the wood for the Olympic Village Plaza, were donated by local government and returned or used in other public infrastructure projects afterwards.

Reuse was also part of Tokyo's procurement strategy, with the majority of goods leased or purchased as part of buy-back agreements with producers. Where items could not be rented, organizers developed resale systems to ensure a second life after the Games.

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Waste in construction

Circularity is often defined in terms of the 3Rs—reduce, reuse and recycle. The idea is to focus on reducing the impact of human activities by shutting off waste, pollution and resource demand. There is also a second set of 3Rs—remediation, restoration and regeneration—which aims to reverse damaged ecosystems.

As the planet's primary consumer of raw materials, how AEC maximizes use of those materials will be a significant driver in whether the world can achieve net zero. However, according to the Ellen MacArthur Foundation, one of the leading voices in circular economics, most built structures are simply demolished when they come to the end of their lifespan and only 20-30% of this construction and demolition waste (CDW) is currently recycled or reused globally.

The global picture varies widely. Thanks to the EU's Waste Framework Directive (WFD), which mandated a 70% CDW recycling rate by 2020, recycling rates across the continent have been consistently high—exceeding the target since 2016. In China, where another 323 billion tonnes of building stock will have been built by 2050, CDW recycling rates average about 5%.[16] And in Japan, where the average lifespan of a residential building is only 25 years before being demolished or abandoned, CDW recycling rates are among the highest in the world at 97%, alongside those in South Korea.[17] The circular economy is well established in Japan due to its lack of natural resources. Policies to reduce oil dependency, waste and environmental impacts, and to promote public awareness and education have long been the norm.

"At TATA Projects, digitalization in construction monitoring is a sustainability KPI aligned to the SDGs. We also have service offerings integrated with digital technologies and we use many IoT-based applications; for example, we have IoT-based technology solutions to measure consumption of water, energy, and air quality."

Sashidhar Karamballi
Head-Project Services (Services SBG),
Tata Projects Limited

The role of technology in increasing circularity

Technology can create considerable savings in the amount of materials needed to complete projects. "Circular design is critical to this," says Marius Jablonskis, Technology Manager at Norconsult, "and we're increasingly looking at how we use data and processes like machine learning to work smarter and reduce material waste. For example, by working from a 3D model rather than a drawing, we can rely on data in 3D models that the amount of concrete we need is just right—so can limit waste."

An academic study[18] identifies ten enabling digital technologies to facilitate a circular economy in the built environment: additive/robotic manufacturing, artificial intelligence, big data and analytics, blockchain technology, Building Information Modeling (BIM), digital platforms/marketplaces, digital twins, geographical information systems, materials passports/databanks, and the Internet of Things (IoT).

Geographic information systems (GIS), for example, are used with BIM for the identification, mapping and management of resources embedded in building stocks for future reuse or recycling. In a study in the city of Kitakyushu in Japan, GIS analysis identified vacant houses and their material stock in order to make informed decisions on the future use of resources.[19]

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ACTION AGENDA

How well could your organization respond to a brief to design and build based on circular principles today?

Technology and data can help advance sustainable outcomes. BIM is a key methodology for circular projects. It enables architects and engineers to document and trace each component in a structure. From the nuts and bolts to a complete HVAC system, it means construction companies can disassemble and reuse materials, rather than throwing away the old and creating anew.

Generative design employs artificial intelligence to enable better decision making about materials by identifying which parts of a structure can be disassembled and reused. Designers or engineers input design goals into the generative design software, along with parameters such as performance or spatial requirements, materials, manufacturing methods, and cost constraints. The software explores all the possible permutations of a solution, quickly generating design alternatives. It tests and learns from each iteration what works and what doesn't.

In this approach, every building can become a "materials bank," (see **Adaptive reuse**, below) a place that stores valuable materials and components that can be withdrawn and reapplied at a later date or when the building is no longer viable.

Adaptive reuse

Alongside greater use of recycled CDW, AEC leaders are also turning to circularity's second R—reuse. The idea is—rather than reach for a new-build solution in every case—architects, engineers and construction companies should first assess whether structures or buildings that already exist can be remodeled to meet the client's brief, and second, consider ways of reusing and repurposing existing building materials.

It's a recipe for winning major contracts, with huge reductions in terms of virgin materials usage and environmental impact, alongside massive savings for the client.

During the bid for the Queensferry Crossing replacement of the 50-year-old Forth Road Bridge in Scotland, consultants Arup and partner Jacobs Engineering challenged the need for a new bridge to handle all traffic and proposed retaining the old bridge for light traffic. This resulted in a smaller new bridge, massive materials savings and an extraordinary two-thirds total project budget reduction, from £4.2bn to £1.4bn.[20]

Likewise, in France, when management and accounting association CDER wanted to expand its offices in Épernay—the "capital of Champagne"—it initially planned to replace a 1960's building, infamous in the area as an eyesore.[21] However, Paris-based architects OUYOUT, seeing the old building with an outsider's eye, noted its efficient use of space, and pitched a green renovation—a less costly alternative that could also bring the unloved structure into harmony with its surroundings.

In some adaptive reuse projects, 90% of the original building materials are reused or remain on-site.[22] Materials passports are a key innovation that help achieve such high levels of reuse. These are digital documents consisting of all the materials included in a product or construction, and data about what gives those materials value for recovery, recycling and reuse. An innovation led by Dutch non-profit Madaster Foundation, materials passports enable mapping of the resources used in buildings, assist during building demolition with greater visibility of reusable resources, and enable higher recycling rates.

By tagging and creating a detailed account of all materials going into a building, it enables buildings to be viewed as 'materials banks.' When buildings are slated to be adapted for a different use (converting a former prison to affordable housing, for example, or a hotel to an office building), all building components can be evaluated and plans put in place for adaptive reuse. Alternatively, if a building is determined to have served its useful life, it can be disassembled instead of demolished and materials within the building can be repurposed for other buildings.

When it comes to materials banks and materials passports, these increasingly vital resources can only be maintained efficiently through the use of technology, such as BIM and GIS for the identification, cataloging and extraction of materials for reuse. These approaches also form the basis of new value creation, as at Schiphol Airport, Amsterdam, where Cargo Building 18 was sold to a local business, dismantled and moved to a new location based on data supplied in a materials passport, with a reduction of over 3 million kg in CO_2 emissions.[23]

A rendering of renovations for the CDER building in Champagne, France, featuring a green double facade. Courtesy of OUYOUT Architects

Reusing salvaged materials at the Kendeda Building for Innovative Sustainable Design

In the USA, the project team behind the Kendeda Building for Innovative Sustainable Design,[24] located on the campus of the Georgia Institute of Technology, is seeking certification by the Living Building Challenge, the world's most rigorous green-building standard. Salvaged materials were an important component to meet 90-100% recycling requirements. The project features a dozen salvaged materials in its structure and on its grounds. Materials even came from the campus itself, such as the original 1880s pine joists discarded after a tower renovation and reused in a stairway.

The project also produces more energy than it consumes and conserves more water than it uses with sustainable elements such as composting toilets, solar roof panels, and wetlands to naturally treat runoff.

Design for manufacturing assembly and disassembly, and industrialized construction

The fact remains, however, that the urban built environment needs to grow 60% by 2050, according to the Circularity Gap Reporting Initiative.[25]

The ideal to meet this challenging target is to design and construct buildings in a way that they can be set up for adaptive reuse, or disassembly and reuse, rather than recycling, which is a more energy-intensive and environmentally disruptive process.

The search is on for business model innovation that can meet the challenge, with industrialized construction already playing a significant role here. Industrialized construction is the application of manufacturing techniques to the built environment, with a shift of a significant part of the value chain to prefabrication. "Without a commitment to industrialized construction including prefabrication," says Amy Marks, VP Industrialized Construction Strategy at Autodesk, "I don't think we'll be able to meet our world's future infrastructure needs."

Industrialized construction also has a major impact on waste. When large portions of a structure are standardized 'products' that can be fabricated off-site and assembled on-site, efficiency of materials use is massively improved, with far less waste.

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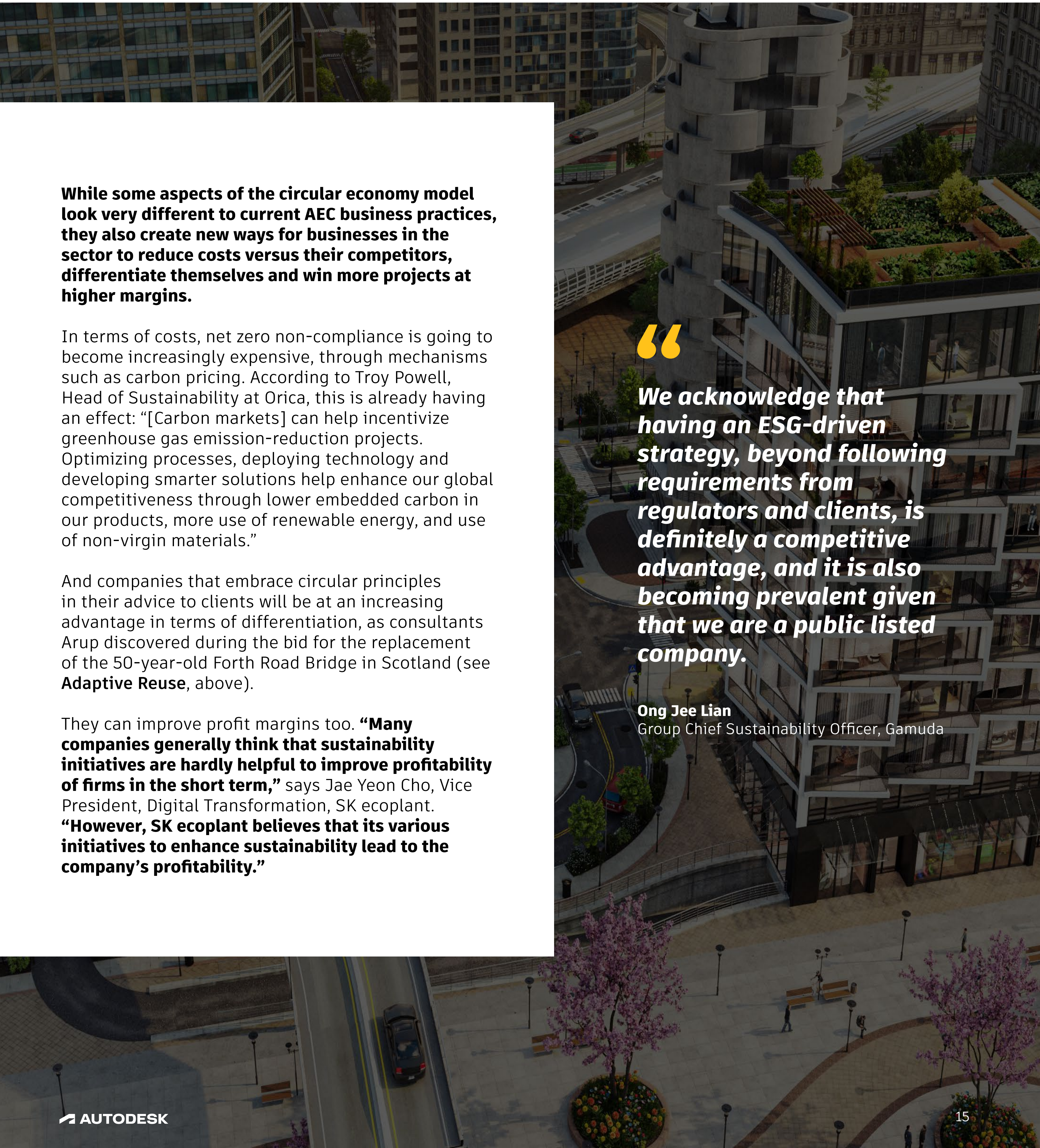
CHAPTER 3

A win-win for AEC and the planet



While some aspects of the circular economy model look very different to current AEC business practices, they also create new ways for businesses in the sector to reduce costs versus their competitors, differentiate themselves and win more projects at higher margins.

In terms of costs, net zero non-compliance is going to become increasingly expensive, through mechanisms such as carbon pricing. According to Troy Powell, Head of Sustainability at Orica, this is already having an effect: “[Carbon markets] can help incentivize greenhouse gas emission-reduction projects. Optimizing processes, deploying technology and developing smarter solutions help enhance our global competitiveness through lower embedded carbon in our products, more use of renewable energy, and use of non-virgin materials.”

And companies that embrace circular principles in their advice to clients will be at an increasing advantage in terms of differentiation, as consultants Arup discovered during the bid for the replacement of the 50-year-old Forth Road Bridge in Scotland (see **Adaptive Reuse**, above).

They can improve profit margins too. **“Many companies generally think that sustainability initiatives are hardly helpful to improve profitability of firms in the short term,”** says Jae Yeon Cho, Vice President, Digital Transformation, SK ecoplant. **“However, SK ecoplant believes that its various initiatives to enhance sustainability lead to the company’s profitability.”**

> ***“We acknowledge that having an ESG-driven strategy, beyond following requirements from regulators and clients, is definitely a competitive advantage, and it is also becoming prevalent given that we are a public listed company.***
>
> **Ong Jee Lian**
> Group Chief Sustainability Officer, Gamuda

This report has identified a number of other ways in which net zero and circularity create opportunities for the AEC sector to reinvent itself and meet its ESG commitments. Autodesk believes that data and insights help organizations make better decisions and optimize design and processes, helping to achieve more sustainable outcomes.

The complexity involved is beyond manual processes—digital solutions are essential within a systems-thinking approach to how resources are consumed and retained in a closed loop economy. A report by consultants Roland Berger, "How circular economy can drive greater sustainability and new business opportunities in construction,"[26] concluded: "The rapid adoption of digital technology will fuel significant growth for new and innovative circular business models.

We expect those in the planning and design phase to show 20% CAGR between 2020 and 2025. Models linked to operations will grow by 13% globally and 18% in the EU across the same timeframe. Hitherto largely undeveloped, the end-of-life phase will show the largest CAGR over the next four years: 33% in Europe and 27% worldwide."

The momentum towards net zero and a truly circular economy is unstoppable. As the examples and benefits covered in this report demonstrate, by exploring and adopting net-zero strategies and circular principles, the AEC sector can convert this inevitable change into a business opportunity, not a cost.

ACTION AGENDA

Do your projects incorporate full documentation of the materials used and their recyclability?

The intense use of raw materials in construction highlights the need for a common data environment as a single source of information used to collect, manage and share documentation, graphical models and non-graphical data for the whole project team. Initiatives such as BAMB (Buildings as Materials Banks)[27] are pursuing a systemic shift in sustainable building and promoting digital materials passports as a means to streamline the collection, sharing and leveraging of data about recyclable materials.

These approaches are increasingly based on systems-thinking about how resources are consumed and retained in a closed loop economy. Software applications enable design optimization that predicts structural system layouts and presents design alternatives to minimize the weight of components in building structures, for example. Digital tools and industrialized construction principles, such as off-site prefabrication of construction components, are heightening sustainability in construction by incorporating economic efficiency, energy and resource efficiency, and environmental performance in different stages of construction.

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